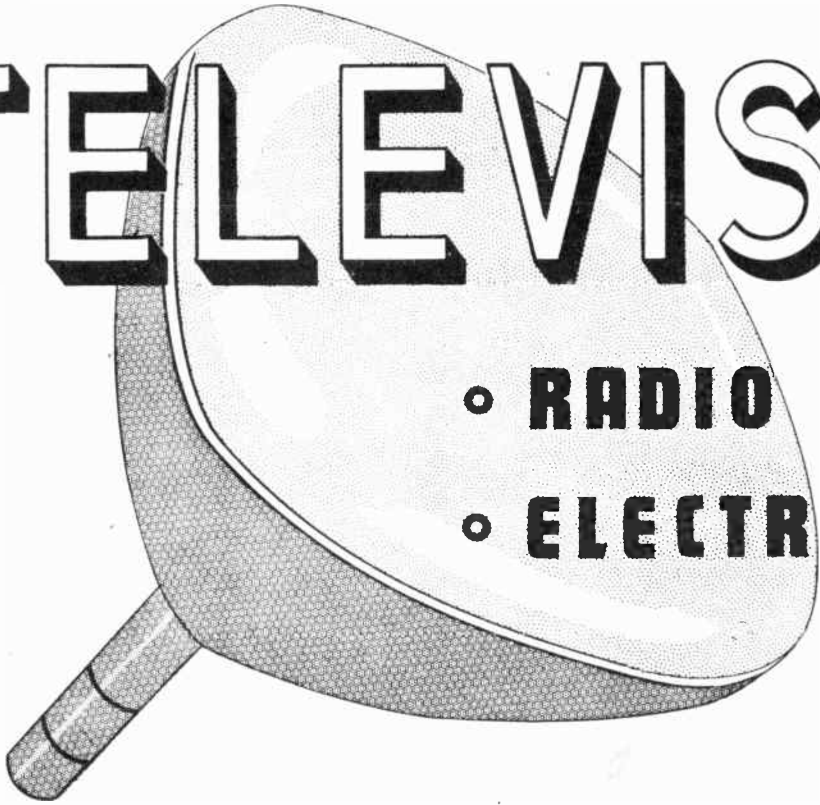
TELEVISION



- RADIO
- ELECTRONICS

LESSON 51 — SERVICE OSCILLOSCOPES

Coyne School

practical home training

Chicago, Illinois

World Radio History

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Lesson 51

SERVICE OSCILLOSCOPES

Were someone to ask, "What is an oscilloscope?" you could answer, according to the dictionary, "It is an instrument for showing visually the changes in a varying voltage." This doesn't sound too important from the standpoint of television servicing, it might mean that the oscilloscope is a variety of voltmeter.

But supposing you answered, "The oscilloscope is the only means for actually seeing the video signal and all its effects as they go through the sync, sweep, and deflection systems on the way to the picture tube." Or you might put it this way: "The oscilloscope is the only instrument which shows the effect of every adjustment during alignment of tuners, i-f amplifiers, and sound sections, and does so while the adjustment is varied." It would then be plain that the oscilloscope is capable of saving a great deal of time on difficult service operations.

Note that we say, "the oscilloscope is capable of saving time." Time will be saved in actual fact only when you use the scope correctly, and only when you learn to understand what the instrument is trying to tell you. The oscilloscope is the most complex service instrument, and is most difficult to use correctly. But it pays greatest dividends in both speed and accuracy of servicing.

The principal part in a service oscilloscope is a cathode-ray tube. This tube operates with an electron beam like that in a picture tube, but both deflection and focusing always are electrostatic, not magnetic. There is a screen like that in a picture tube, except that trace lines are green instead of white, and the face is smaller than in a picture tube.

The oscilloscope seems complicated because of so many adjustment on the front panel. Actually, there are not so many adjustments as on an ordinary television set. The apparent complexity is because none of the controls are hidden on the chassis. All are in plain view, and each is provided with an accessible knob, pointer, or switch.

Much of the difference between television and oscilloscope controls is on different names given to equivalent parts. In the scope there is a brightness control for varying grid bias in the cathode-ray tube. It is called the intensity control. There is an adjustment for height of observed traces, called a vertical gain control, and another for width, called a horizontal gain control. There are vertical and horizontal centering controls, usually called position controls. There are equivalents of horizontal frequency and hold controls, called range, vernier, and sync controls on the scope. About the only control having the same name on both scopes and receivers is the one for focusing.

Relations between the more important sections of an oscilloscope are shown by Fig. 2. Omitted, to simplify the diagram, is the d-c power supply which feeds all other sections. The horizontal sweep oscillator serves to repeatedly deflect the electron beam in the cathode-ray tube across the screen from left to right, and thus produce a luminous trace, as in a picture tube. Each trace is followed by a rapid retrace from right to left.

In the scope there is no vertical sweep oscillator such as causes vertical deflection in a television receiver. The oscilloscope beam is deflected vertically by any external alternating voltage, signal or otherwise, applied to the vertical input terminals. This applied voltage is controlled in strength and is amplified as may be required before going to the cathode-ray tube. There is amplification and control also for the output of the horizontal sweep oscillator.

With the horizontal oscillator operating, and no external voltage applied to the vertical input terminals, we have a trace such as shown at A in Fig. 3. The electron beam is sweeping repeatedly across the same horizontal line, which shows as a straight lum-

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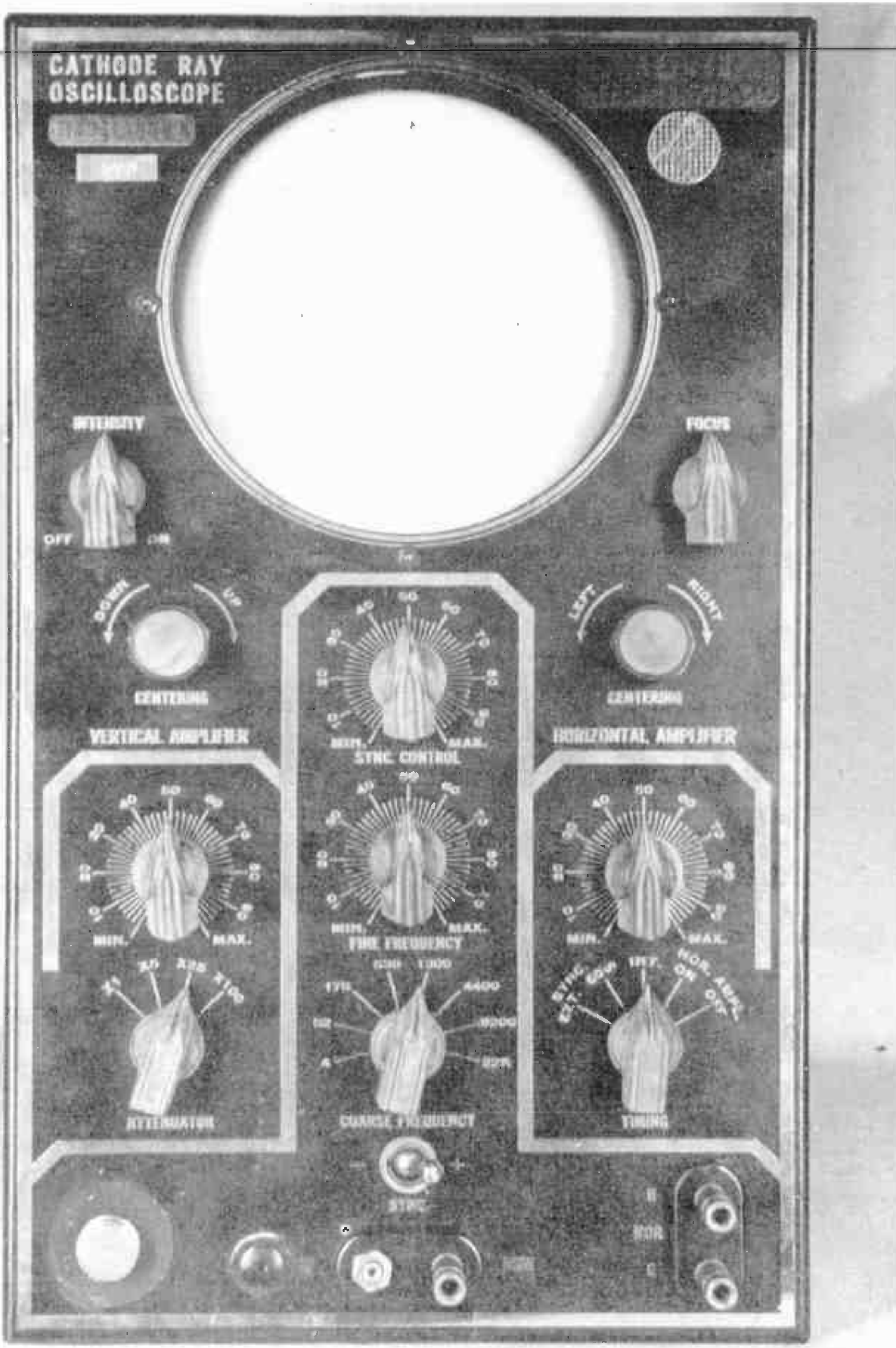

Fig. 1. There are many controls and terminals on the panel of a service oscilloscope.

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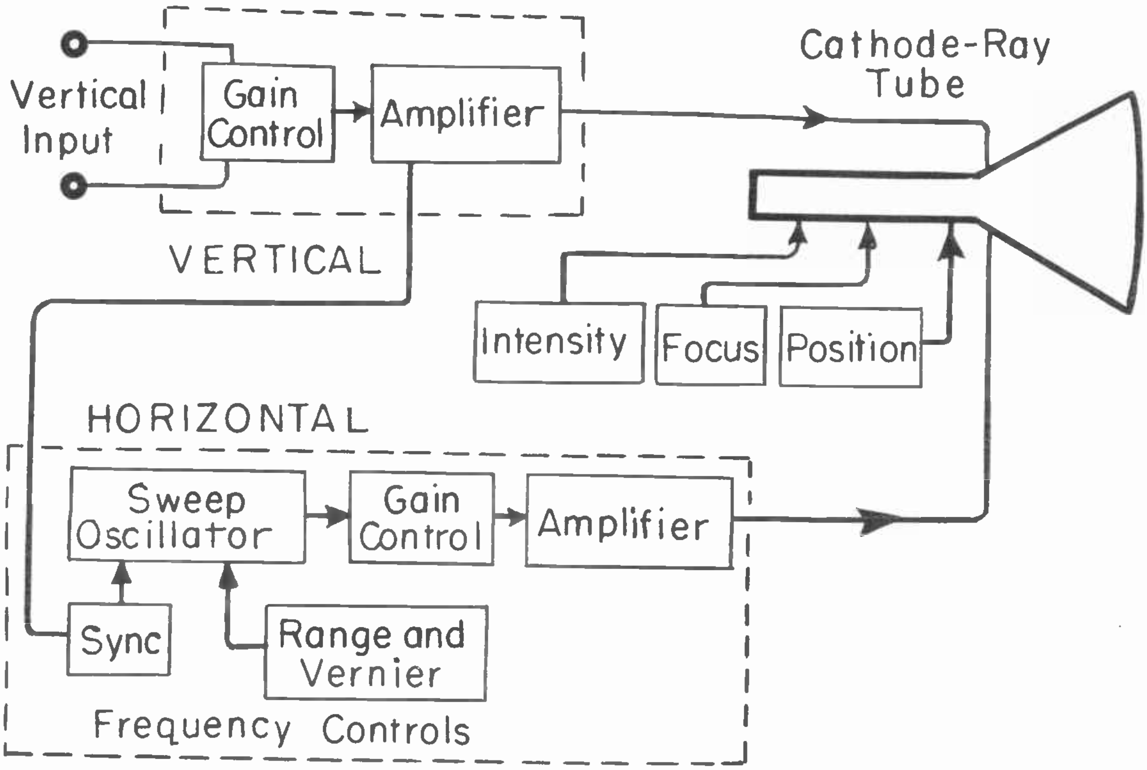

Fig. 2. The principal sections of an oscilloscope, and how they are related.

inous trace. If the vertical input terminals are connected to a source of sine-wave alternating voltage we have the trace at B. The electron beam is deflected upward when the a-c voltage goes positive, and downward when this voltage goes negative, while being swept horizontally at the same time.

The trace at B was made with the vertical input connected to a building power line carrying a 60-cycle frequency, giving one cycle every 1/60 second. The horizontal sweep rate in the scope was 30 per second, or one sweep every 1/30 second. During each 1/30-second horizontal sweep there was time for two of the 1/60-second cycles of observed voltage. Consequently, two of these cycles appear on the screen.

With the time per horizontal sweep made

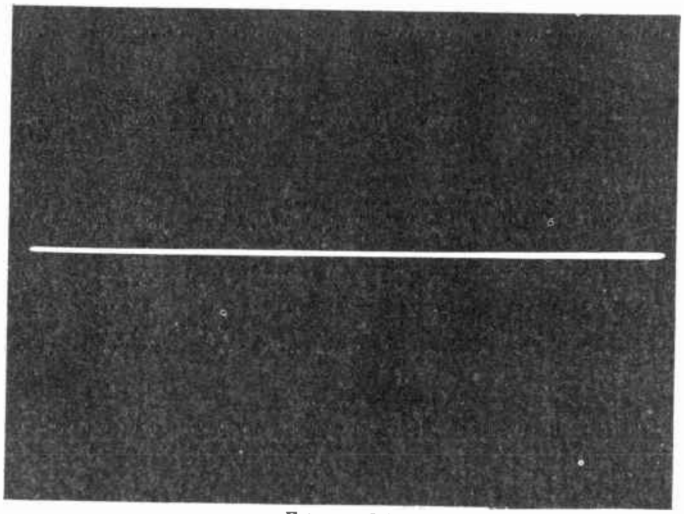

Fig. 3A.

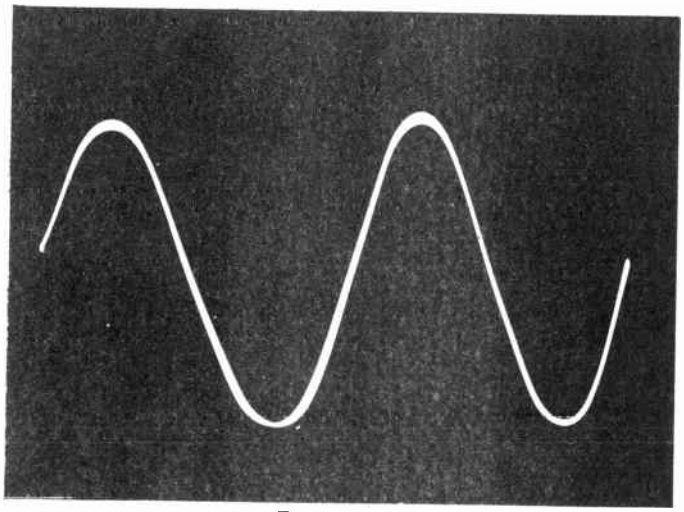

Fig. 3B.

Fig. 3. Simultaneous horizontal and vertical deflection of the electron beam traces the changes of an observed voltage.

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three times as long as the time for one cycle of observed voltage, three of the voltage cycles will appear on the screen, as at A in Fig. 4. By suitable timing of the horizontal sweep rate it is possible to look at any number of cycles of a voltage applied to the vertical input. The waveform of a voltage which deflects the beam vertically makes no difference to the oscilloscope. At B are shown three cycles of a decidedly irregular waveform.

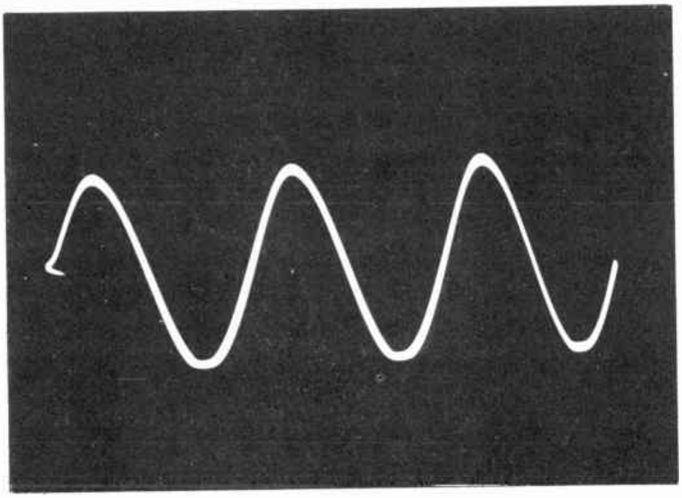

Fig. 4A.

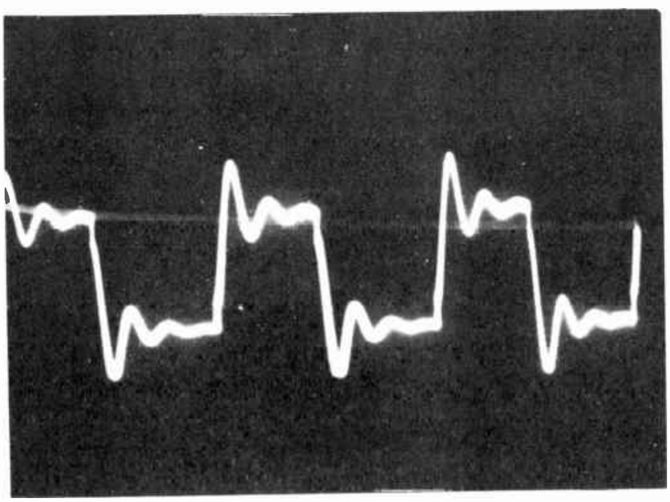

Fig. 4B.

Fig. 4. The number of cycles of an observed voltage seen at the same time depends on frequency of the horizontal sweep oscillator.

During service work you often will see the irregular or complex waveform at A in Fig. 5. It is the video signal voltage at the load of a video detector. The scope is pick-

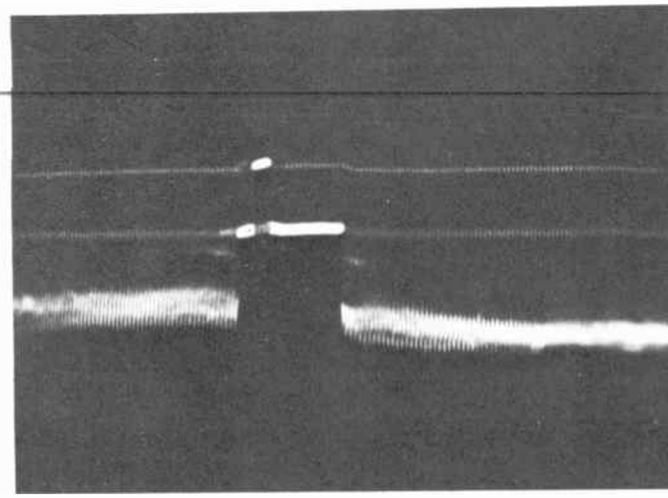

Fig. 5A.

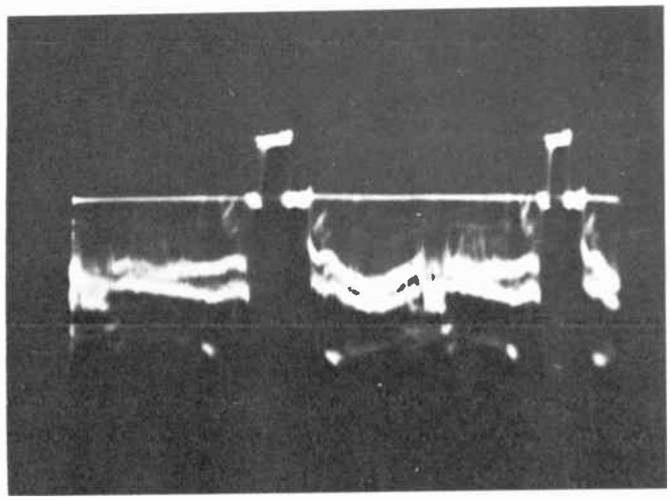

Fig. 5B.

Fig. 5. Adjusting the sweep frequency allows examination of either field periods or line periods of a video signal.

ing up the signal part way through one field. We see picture line voltages for the remainder of this field, then a vertical blanking interval followed by picture lines part way through the next field. During vertical blanking, while there are no picture lines, we see the vertical sync pulse preceded by equalizing pulses and followed by equalizing and horizontal sync pulses.

You might wish to look at the signal for one or more horizontal line periods. The horizontal line frequency is 15,750 per second. By adjusting the internal sweep of the scope to this frequency we could see what happens during one line period. To see what happens during two line periods the internal

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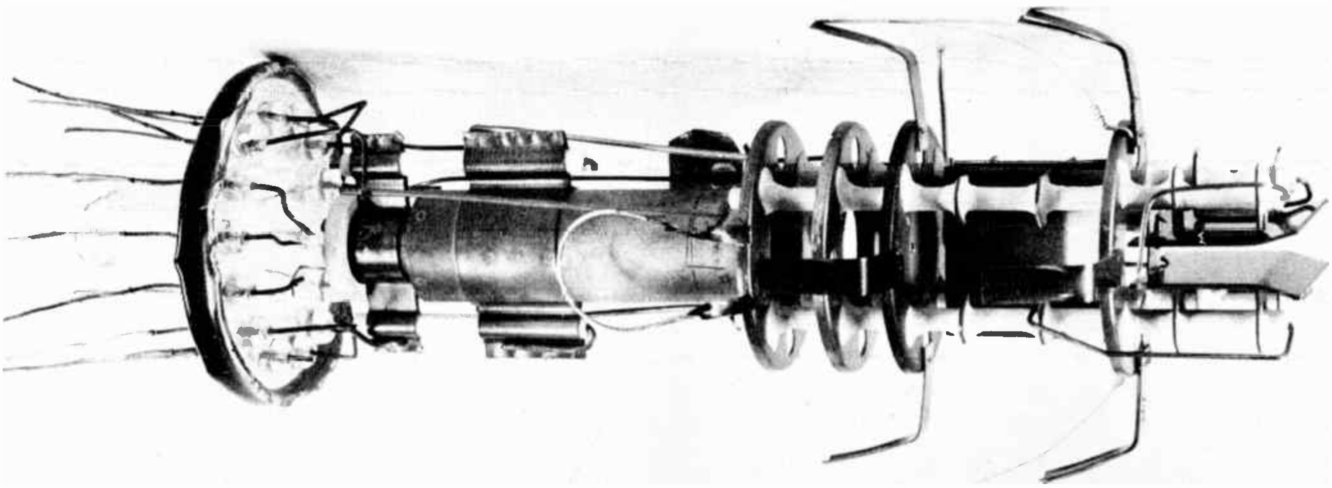

Fig. 6. The electron gun of a cathode-ray tube such as used in oscilloscopes.

sweep would be held at 7,875 traces per second. The time for each sweep then will be twice that of one line period in the video signal, and we see the trace at B of Fig. 5. The signal is picked up part way through one line, continues through the remainder of this line, all of the next line, and part of a third. There are two horizontal blanking intervals, in which are horizontal sync pulses with front and back porches of the pedestals.

To operate an oscilloscope to best advantage you should know how the instrument is constructed and how it works. To this end we shall commence by examining the cathode-ray tube, then take up other important components and sections.

CATHODE-RAY TUBES. The name of the cathode-ray tube is so long that often we abbreviate it to CRT. Fig. 6 is a picture of the electron gun from an oscilloscope tube. At the left is the glass press held by the base in a complete tube, also the wire leads which go from the elements to base pins. Then comes the control grid which encloses cathode and heater. Next is the element called either the second grid or the first anode, which, in tubes of this kind, is used for focusing. This element is followed by the gun portions of the second anode. The remainder of the second anode is a conductive coating inside the flare, as in all-glass picture tubes.

Beyond the second anode are the deflecting plates, whose arrangement is shown more

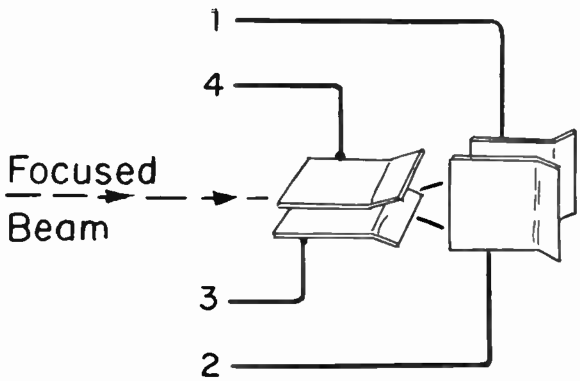

Fig. 7. How the deflecting plates are arranged in a cathode-ray tube.

clearly by Fig. 7. The plates of one pair, numbered 1 and 2, are toward the screen and face of the tube. The other pair, numbered 3 and 4, are toward the electron gun and base. The focused electron beam passes first through the space between plates 3 and 4. Electrons in the beam are negative. When plate 4 is made positive, and plate 3 negative at the same time, the negative electrons are attracted toward the positive plate and repelled from the negative plate. This deflects the beam vertically upward. Reversing the polarities of these two plates reverses the attraction and repulsion, to deflect the beam downward.

Then the beam passes through the space between plates 1 and 2, where it is deflected horizontally. Making plate 1 positive and plate 2 negative will deflect the beam hori-

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zontally away from you. Reversing the polarities of these two plates causes the beam to be deflected toward you.

Practically all service oscilloscopes have phosphor No. 1 in the screens of their CRT's. This phosphor produces a green trace of a hue to which the average human eye is most sensitive. This results in a decided contrast while either artificial light or daylight falls on the outside of the face, and traces are clearly visible.

The first numeral in the type designation of CRT's stands for the nominal face diameter in inches, as in the case of picture tubes. The following letter shows the order in which each particular variety of tube was registered. Then, for all tubes having phosphor No. 1, we find "P1". This may be followed by a hyphen and a final letter to indicate some special structural feature.

Most present service oscilloscopes are equipped with CRT's of either 7-inch or 5-inch nominal face diameter. A few special types and most earlier designs have 3-inch tubes. All these tubes have round faces and are of all-glass construction.

Among the widely used oscilloscope CRT's are types 7JP1 and 7VP1, with connections from elements to base pins as shown at A in Fig. 8. The base is a medium-shell diheptal with spaces for 14 pins, but with pins in only 12 positions. Positions 6 and 13 are vacant. On pins 4 and 12 are internal connections used only during manufacture. Type 5CP1-A has the same base connections, but there is an additional accelerating anode beyond the deflecting plates. This anode is connected to a recessed terminal on the glass flare, as in all-glass picture tubes.

Type 5UP1 has basing connections shown at B. The base is a small-shell duodecal, as used for picture tubes, but there are pins in all 12 positions. The heaters for all these CRT's operate at 6.3 volts a-c, and draw 0.6 ampere, as do the heaters of all picture tubes.

POWER CIRCUITS. Fig. 9 is a diagram of typical B-power and high-voltage circuits for an oscilloscope. There are two rectifier

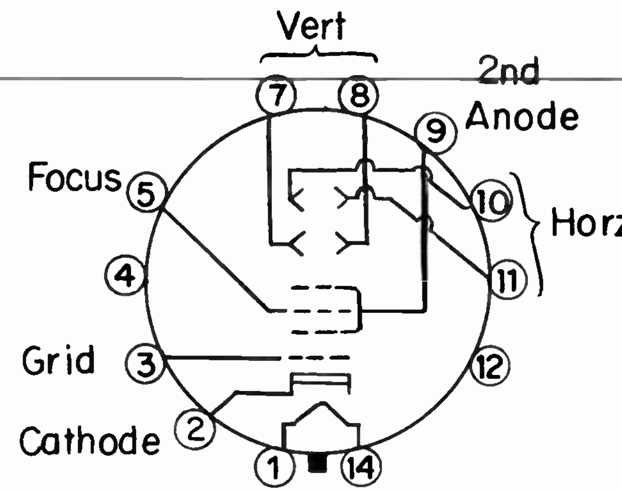

Fig. 8A.

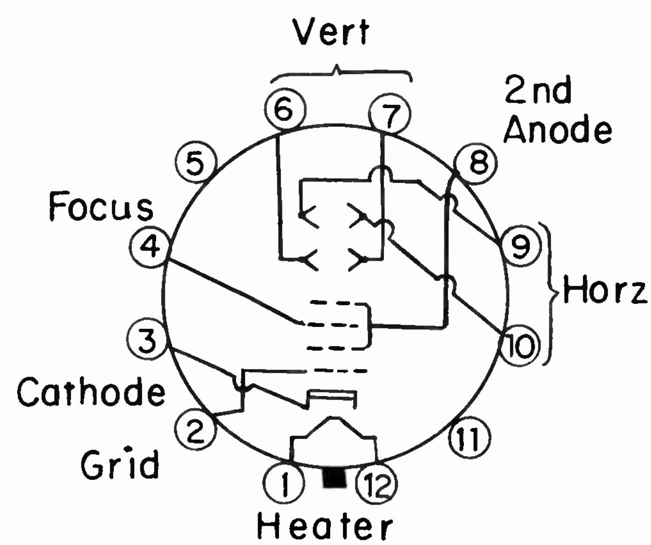

Fig. 8B.

Fig. 8. Connections between elements and base pins of cathode-ray tubes commonly used in oscilloscopes.

tubes. One is a half-wave high-voltage type used for most of the CRT elements. The other is a full-wave low-voltage type for plate and screen circuits of amplifiers and sweep oscillator. The secondary of the power transformer has one center-tapped section for the low-voltage rectifier, and an extended section of many turns and high step-up ratio for the high-voltage rectifier.

D-c output from the low-voltage rectifier is from its cathose, as usual, and is positive with reference to ground. D-c output from the high-voltage rectifier is from its plate,

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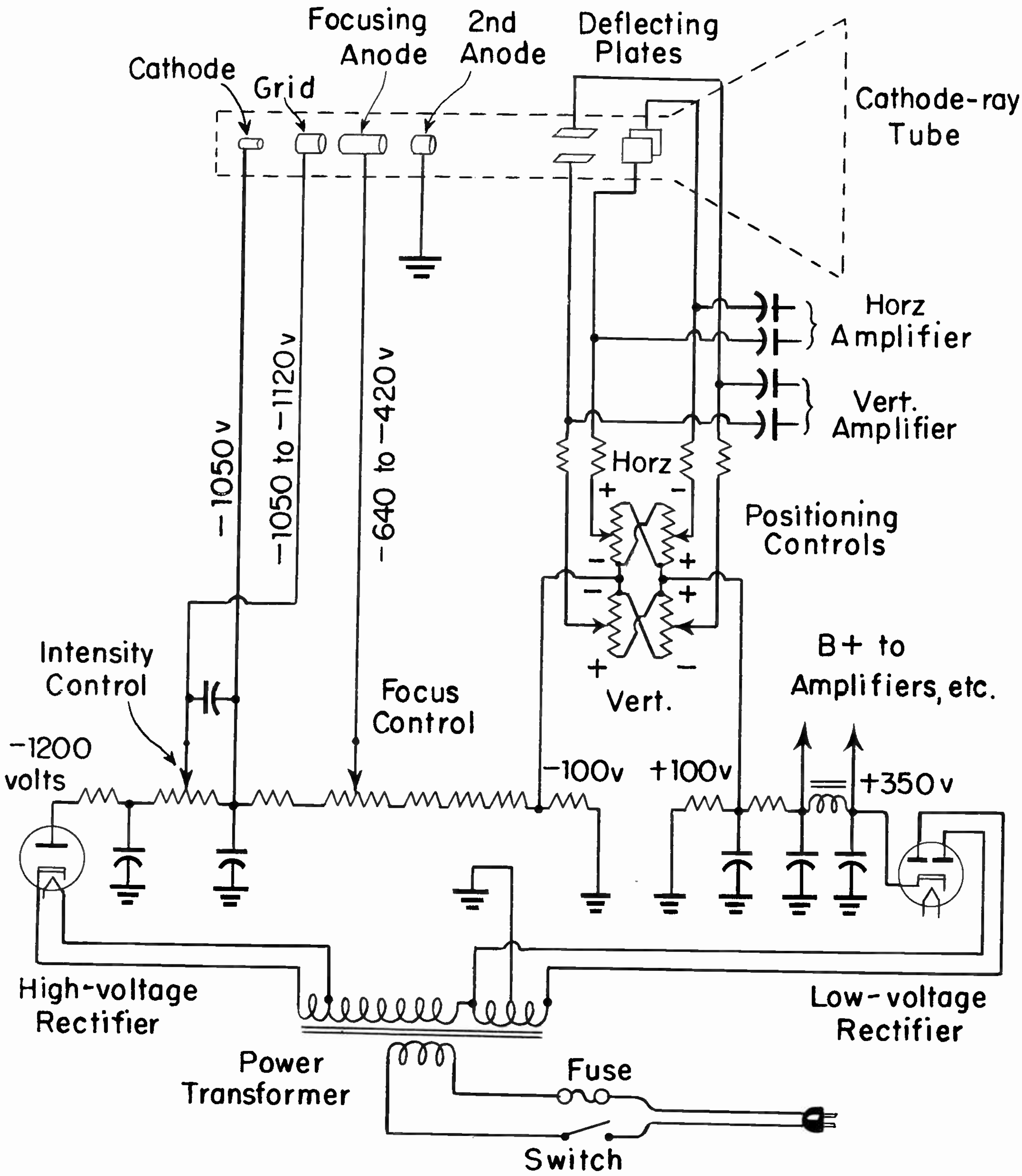

Fig. 9. Typical connections between power-supply circuits and the cathode-ray tube in oscilloscopes.

consequently is negative with reference to ground. The value of 1,200 negative volts marked at the plate of the high-voltage rectifier is merely illustrative, it might be almost anything from 800 to 2,000 volts or more, depending on the type of CRT and general de-

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sign of the scope. Other marked voltages are such as might be found when the high-voltage rectifier delivers 1,200 negative volts.

The voltage divider system between the plate of the high-voltage rectifier and ground consists of a number of resistors in which voltage gradually decreases from maximum negative to zero. Capacitors at some points along the divider string provide d-c filtering. Note that the second anode in the CRT is at ground potential, while the cathode is shown as 1,050 volts negative. This makes the second anode effectively 1,050 volts positive with reference to the cathode.

One of the resistors in the voltage divider is marked "Intensity Control". Its slider is connected to the grid of the CRT, and the end terminal which is less negative is connected to the cathode. Moving the slider varies the grid potential from -1050 to -1120 volts. Since the cathode remains at -1050 volts, the intensity control will vary the grid bias, with reference to the cathode, between zero and 70 volts negative. This regulates the rate of electron flow in the beam of the CRT, and varies the brilliance of traces on the screen.

Another potentiometer in the voltage divider system is marked "Focus Control". Its slider is connected to the focusing anode of the CRT. This potentiometer is at such a point along the divider that potentials at its end terminals are -640 and -420 volts. With reference to the -1050 volts on the CRT cathode, these focus control potentials are positive by 410 and 630 volts and the control will make the focusing anode from 410 to 630 volts positive with reference to the cathode. Principles of electrostatic focusing in the CRT are essentially the same as for this method of focusing in television picture tubes.

The horizontal deflecting plates of the CRT are connected through blocking capacitors to the output of the horizontal sweep amplifier. The vertical deflecting plates are similarly connected to the output of the vertical amplifier. Amplified deflecting voltages thus are applied to the plates.

The deflecting plates are connected also, through resistors, to two dual potentiometers which are positioning controls corresponding to centering controls for a picture tube. One end terminal of each potentiometer is connected to 100 volts negative, while the other end terminal is connected to 100 volts positive. Then the average potential on the deflecting plates is zero or ground, the same as on the second anode.

Moving the sliders of a dual potentiometer in one direction makes one of the connected deflecting plates more positive and at the same time makes the other plate of the same pair more negative. Thus the electron beam is shifted one way or the other on the screen of the CRT, and centers at this position while being deflected by alternating or sawtooth voltages from the vertical and horizontal amplifiers.

SWEEP OSCILLATORS. Changes of any voltage to be observed on the oscilloscope must be shown in relation to time. That is, we wish to see how such a voltage varies from one instant to another within some certain period of time. During this period the electron beam in the CRT must sweep at a uniform rate from left to right across the screen while being moved up or down by the voltage to be observed. At the end of the time period, whatever it may be, the beam must return very rapidly to the left-hand side of the screen, from where it begins another trace to the right.

To deflect the beam in this manner we apply voltages of sawtooth waveform to the horizontal deflecting plates, as shown by Fig. 10. These deflecting voltages are of oppos-

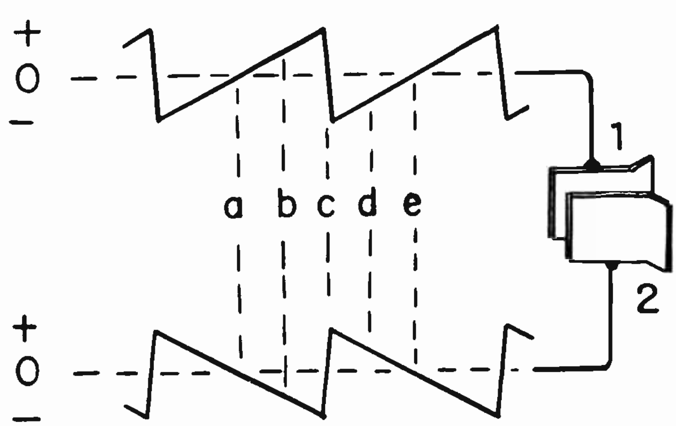

Fig. 10. Sawtooth voltages of opposite phase are applied to the two horizontal deflecting plates.

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ite phase. While one goes positive the other goes negative, and vice versa. The changes of voltage on each horizontal deflecting plate at five successive instants of time during a complete sweep cycle, as marked a to e on the diagram, are as in the accompaying tabulation.

Instant of Time	Deflecting Plate 1	Voltages Plate 2	Movement of Beam
a	Zero	Zero	Centered
b	More positive	More negative	Slowly toward plate 1
c	Suddenly negative	Suddenly positive	Rapidly toward plate 2
d	Less negative	Less positive	Slowly toward plate 1
e	Zero	Zero	Centered

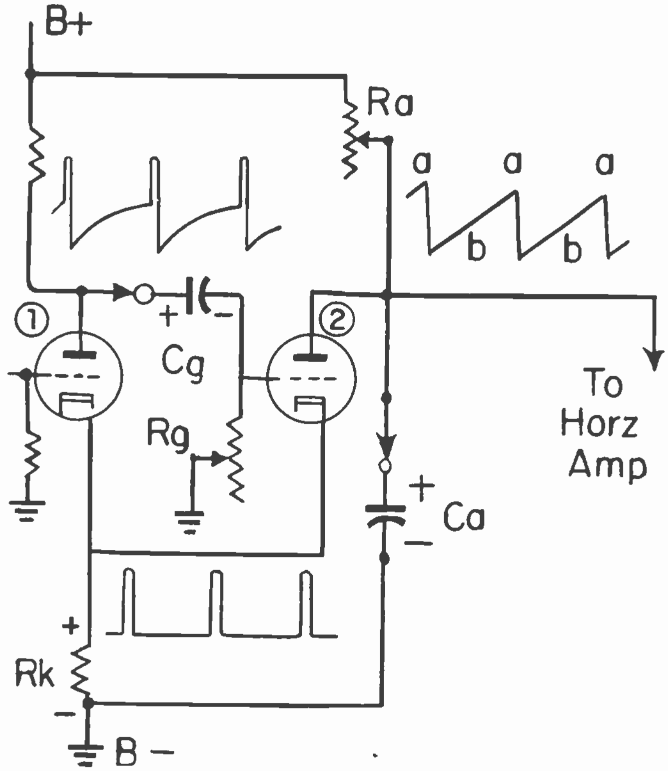

Fig. 11. The circuit of a multivibrator sweep oscillator.

Any of several types of sweep oscillators will provide a single sawtooth voltage. This single sawtooth is applied to a "push-pull" type of horizontal amplifier which produces an additional sawtooth voltage of opposite phase. The two sawtooth voltages are applied to the two horizontal deflecting plates as in Fig. 10.

<u>MULTIVIBRATOR SWEEP OSCILLATOR.</u> Among the types of horizontal sweep oscillators found in oscilloscopes the one called a multivibrator is especially interesting because it is used also for horizontal and vertical sweep oscillators in many television receivers. Fig. 11 is a simplified circuit diagram of a multivibrator. The tubes marked <u>1</u> and <u>2</u> ordinarily are the two sections of a twin triode.

When power is first turned on, plate current commences to flow and to increase in tube <u>1.</u> This current flows in cathode resistor <u>Rk,</u> which is common to both tubes. The increasing plate current causes an increasing voltage across <u>Rk</u> and an increasingly negative grid bias on both tubes. Because of rather low plate voltage on tube <u>2,</u> that tube is quickly biased to plate current cutoff and becomes non-conductive.

While tube <u>2</u> is non-conductive there is electron flow from ground or B-minus to B-plus by way of capacitor <u>Ca</u> and an adjustable high resistance at <u>Ra.</u> This flow gradually charges the capacitor in the polarity marked. The top of <u>Ca</u> is directly connected to the plate of tube <u>2,</u> making plate voltage always the same as capacitor voltage. The increasingly positive voltage at the top of capacitor <u>Ca</u> and at the plate of tube <u>2</u> brings plate voltage high enough to overcome the cutoff effect of grid bias, and this tube becomes conductive.

Capacitor <u>Ca</u> now discharges very rapidly through tube <u>2.</u> Discharge current flows as a pulse in cathode resistor <u>Rk,</u> making the grid biases for both tubes highly negative during the pulse time. This cuts off plate current in tube <u>2,</u> to stop the capacitor discharge, and momentarily cuts off plate current in tube <u>1.</u>

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Sudden stoppage of plate current in tube 1 allows its plate voltage to become suddenly more positive. The pulse of positive plate voltage charges capacitor Cg in the polarity marked. Capacitance at Cg and high resistance at Rg are the equivalent of a grid capacitor and grid resistor such as used for grid leak bias. Consequently, the grid of tube 2 is made strongly negative by the negative charge on the grid side of capacitor Cg. The grid remains negative and holds the tube at plate current cutoff until most of the charge from Cg has time to leak away through high resistance at Rg.

While all this has been going on, with tube 2 held at plate current cutoff, capacitor Ca has been recharged by electron flow from B-minus into the capacitor and out through resistor Ra to B-plus. This charging has increased the plate voltage on tube 2, while, at the same time, grid bias on this tube has become less negative as capacitor Cd loses its charge through resistor Rg. After a period depending on time constants of Ca and Ra, and of Cg and Rg, the rising plate voltage and decreasing negative bias on tube 2 reach values at which this tube becomes conductive. Then capacitor Ca again discharges through the tube. Just as before, the discharge causes a current pulse in resistor Rk, and the whole performance repeats over and over again.

The sawtooth waveform at the right in Fig. 11 shows the changes of voltage across capacitor Ca. Each sudden discharge of this capacitor causes a rapid drop of voltage as at a-a-a. Each relatively slow recharge of the capacitor causes the rises of voltage at b-b.

Each cycle of sawtooth voltage may be considered to begin with a capacitor discharge and drop of voltage, and to end at full recharge and maximum rise of voltage. Frequency of the sawtooth voltage is determined by time constants of Ca-Ra and of Cg-Rg. Because these two time constants must be kept approximately equal, resistors Ra and Rg are made as a dual potentiometer with a single control knob. Instead of single capacitors at Ca and Cg there are a number of capacitors of different values, any required combinations of which may be connected into the circuits by a suitable selector switch.

Frequency of a sawtooth voltage as determined by time constants of capacitor-resistor combinations is called the free-running frequency of the oscillator. It is the frequency at which the oscillator would operate when no additional external voltages are applied to the tubes or circuits in a way to alter the frequency.

GASEOUS TUBE OSCILLATOR. The type of sawtooth oscillator or sweep oscillator used longer than any other in oscilloscopes employs a kind of tube found in many industrial electronic applications. This tube, called a thyratron, is of the triode type, with cathode, control grid, and plate. But instead of a nearly perfect vacuum within the envelope there is a small quantity of gas. A thyratron made especially for oscilloscopes is pictured by Fig. 12. It appears much like some common styles of vacuum tubes.

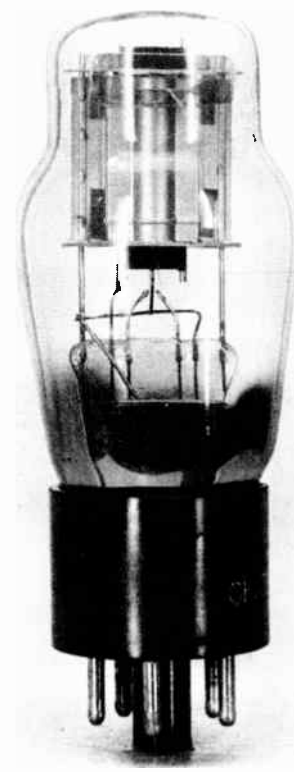

Fig. 12. A thyratron tube used as the horizontal sweep oscillator in many oscilloscopes.

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The peculiar properties of the thyratron are due to an action called ionization, which may be described as follows: When negative electrons travel from cathode toward plate at high velocity they collide with atoms of gas. Other electrons are knocked out of the atoms. These other electrons, along with those emitted from the cathode, go to the plate. Loss of one or more electrons leaves the gas atoms positive, they become positive ions. The positive ions move toward the negative cathode, pick up negative electrons from the space charge which is near the cathode, and thus neutralize or get rid of most of the space charge.

It is the negative space charge that retards electron emission from cathodes and causes the opposition to electron flow which we call plate resistance. With the space charge neutralized, plate resistance of the tube drops to something around five or ten ohms, and the tube becomes highly conductive.

When the grid is so negative with reference to the cathode as to cut off electron flow to the plate, the tube has very great plate resistance. As the grid is made less negative there will be a value of bias at which electrons commence to pass through the grid and ionize atoms of gas. For any given voltage on the plate there is some certain value of grid bias at which ionization commences. Or, we may say that for any particular value of grid voltage there is a plate voltage which pulls electrons through the grid and starts ionization.

Ionization drops the plate resistance to a negligible value within about 1/100,000 second. No matter how negative the grid voltage may remain, the grid has no further control of electron flow in the tube, because positive ions neutralize the negative charge of the grid as well as the negative space charge. Tube resistance remains negligible until plate voltage drops so low as to cause no further electron flow through the tube.

Although plate resistance goes from maximum to minimum in about 1/100,000 second, and current through the tube goes from zero to full value just as quickly, the current does not decrease to zero quite so quickly at the end of the flow. It takes at least 1/50,000 second and maybe slightly longer for all the remaining positive ions to pick up negative electrons and again become neutral atoms. Only then can the space charge and the negative grid regain control and increase the plate resistance to a value which completely stops electron flow. This part of the process is called de-ionization.

The circuit for a gaseous tube sweep oscillator used in oscilloscopes is shown by Fig. 13. The black dot inside the tube symbol indicates a gaseous or gas-filled tube, as

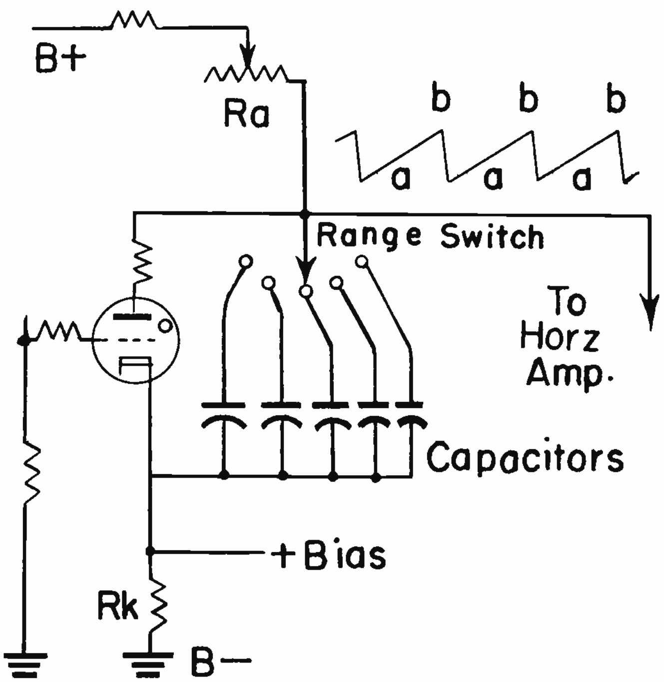

Fig. 13. The circuit of a thyratron or gaseous tube horizontal sweep oscillator.

distinguished from a vacuum tube. The grid is negatively biased by voltage drop across a resistor in the cathode lines. Any capacitor selected by the range switch is charged by electron flow from B-minus to the capacitor, and from the capacitor through adjustable resistor <u>Ra</u> to B-plus. During the relatively slow charge, capacitor voltage increases along slopes <u>a</u> of the sawtooth waveform.

When capacitor voltage and voltage on the connected thyratron plate increases to a value at which the grid no longer can prevent electron flow, there is instant ionization or "break-down" of the thyratron, and the capacitor discharges through the tube. The sudden

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decrease of capacitor voltage forms the steep downward slopes at b on the sawtooth wave. When discharge ceases, as de-ionization becomes complete, the tube again becomes non-conductive. This allows recharging of the capacitor, and the whole process repeats. Free-running frequency of this oscillator is determined by the time constant of the selected capacitor and resistance at Ra.

SYNCHRONIZING THE SWEEP. In order that any number of cycles of an observed voltage may remain stationary on the screen of the oscilloscope there must be a certain relation between frequencies of observed voltage and of horizontal sweep. The time per cycle of observed voltage must always divide into the time per sweep with no fraction left over. This is the same as saying that the sweep frequency must divide into the observed frequency with no fraction of a cycle left over. For example, with sweep frequency of 30 cycles per second you can observe applied voltages having frequencies of 30, 60, 90, 120 or any other number of cycles per second which results from multiplying the sweep frequency by a whole number. The reason is explained as follows.

Look back at the trace shown as B of Fig. 2, where the sweep rate is 30 per second and the frequency of the observed voltage is 60 cycles per second. This trace looks like only two cycles, and it would be formed by only two cycles were it possible to watch the screen for exactly 1/30 second, no more and no less. Actually we see many successive pairs of cycles. Every pair is like every other pair, and, provided all of them begin at the same point on the screen, all cause the electron beam to follow the same path across the screen.

At the completion of one pair of observed cycles the beam flies back to the left-hand side of the screen in time to catch the beginning of the next pair of cycles. The beam must begin every horizontal trace at precisely the same point on a cycle of observed voltage. Then, no matter how long you watch, all the pairs of cycles which are occuring every 1/30 second cause traces along the same path, and persistence of vision allows seeing all these traces as one steady line of light on the screen.

It would be difficult to adjust the free-running frequency of a sweep oscillator to match exactly any whole multiple of observed cycles, with no fraction of a cycle left over. Even could you make such an adjustment, it would hold only for a short time because there are so many variables tending to make slight changes of oscillator frequency. Therefore, the sweep frequency must be forced into step with the observed voltage, and must be held in that relation. That is, we must synchronize the oscillator frequency with the frequency of the observed voltage.

This becomes possible when we adjust capacitors and resistors in the oscillator circuit to make the free-running frequency just a little slower than the observed frequency. Then we apply to the grid of an oscillator tube a voltage derived from the one being observed, and, of course, having the same frequency. Connections are shown by Fig. 14, where we have tube 1 from the multivibrator circuit of Fig. 11. The grid of this tube is connected to the slider of a potentiometer marked "Sync Control". One end terminal of this control goes to ground and the other to the plate circuit of a vertical amplifier tube.

Any voltage to be observed is applied to the vertical input terminals, and acts through a gain control on the grid of the vertical amplifier tube. This voltage, strengthened, appears in the plate circuit of the amplifier, from where a part is taken through resistor Rs to the sync control potentiometer.

Each negative alternation of voltage from the vertical amplifier makes the grid of the oscillator tube negative. As we learned earlier, a sawtooth cycles starts in the multivibrator when the first grid is made sufficiently negative to cut off plate current. Then plate voltage rises, a grid capacitor is charged, the second tube becomes conductive, and there is discharge of the capacitor in the sawtooth circuit.

To cause all this to happen, the free-running frequency of the multivibrator is adjusted to a frequency slightly slower than that of the observed voltage. Then, just before the oscillator would go through a sawtooth cycle of its own accord, one of the negative

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alternations of observed voltage makes the oscillator grid negative. This starts a sawtooth cycle in time with, or synchronized by, the observed voltage. Sawtooth cycles might be thus started at points such as a-a on the synchronizing voltage in Fig. 14.

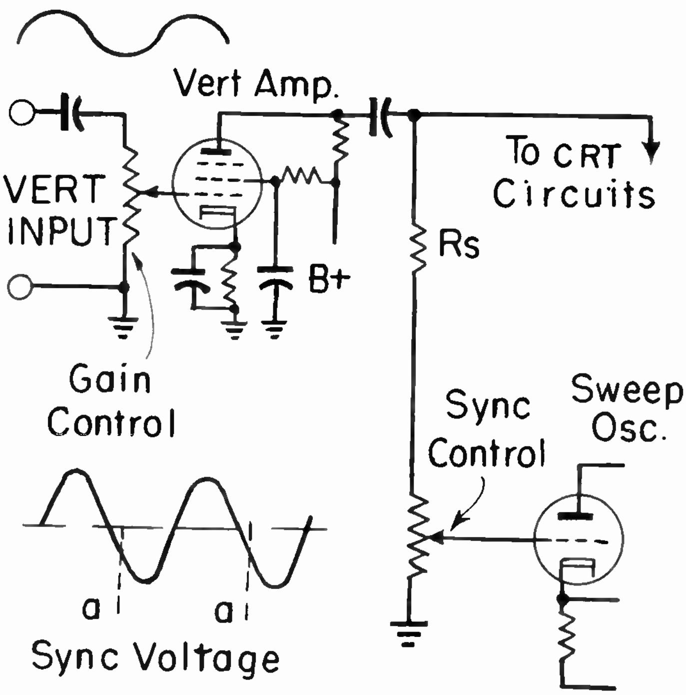

Fig. 14. How a sweep oscillator may be synchronized from an observed voltage going through the vertical amplifier.

The same general method of synchronizing the sweep rate with an observed voltage could be applied to the gaseous oscillator of Fig. 13. Then the sweep rate would be timed by positive alternations of synchronizing voltage, because a gaseous oscillator starts a sawtooth cycle when its grid is made positive.

Moving the slider of the sync control potentiometer applies more or less of the synchronizing voltage to the oscillator grid. This adjustment is set to apply just enough synchronizing voltage to hold the oscillator in synchronization and thus to keep the trace steady on the screen of the oscilloscope. The pointer or knob which operates the sync control is on the front panel of the scope. It moves over a dial usually marked "Sync Control" or "Sync Amplitude" or something of equivalent meaning.

Still to be explained is the reason why the oscillator is not forced to go through a sweep cycle by every cycle of synchronizing voltage, and why it is possible to view any number of cycles of observed voltage during one sweep. The reason is illustrated by Fig. 15. Up above are several groups of cycles of an observed or synchronizing voltage, all at the same frequency. Below are sawtooth voltage cycles produced by a sweep oscillator. The time included in each sawtooth is

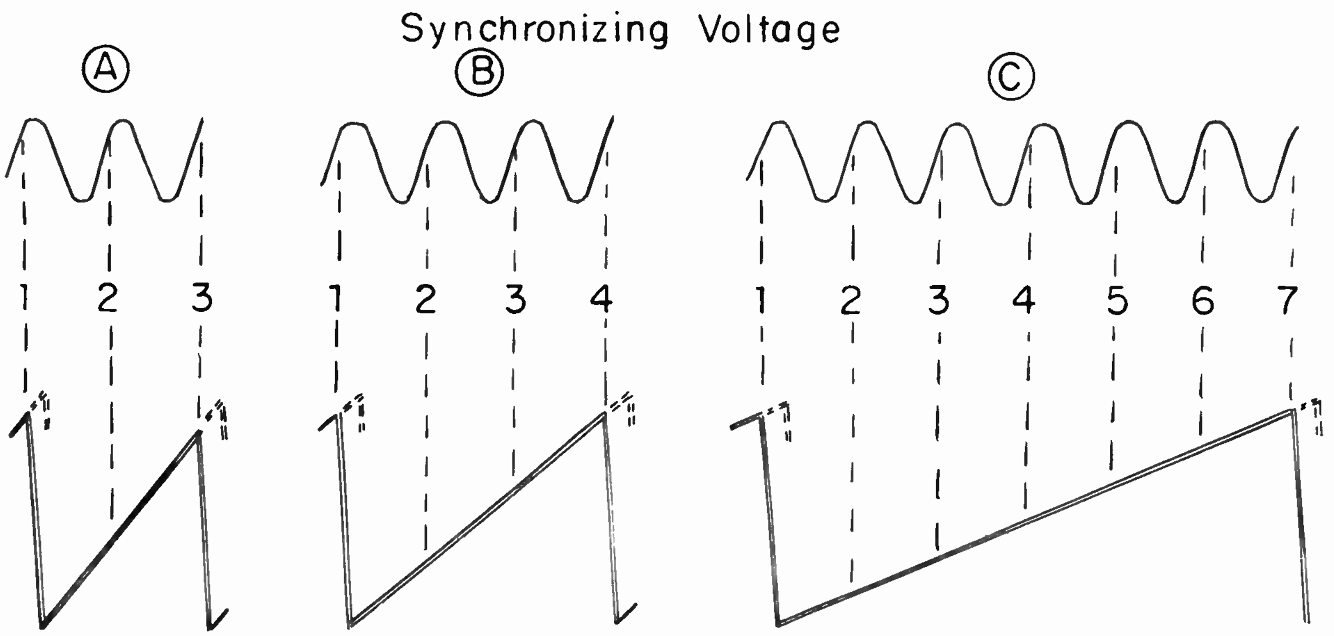

Fig. 15. During each horizontal sweep there may occur various numbers of cycles of an observed voltage.

determined primarily by the free-running frequency of the oscillator. This frequency can be made anything desired by selection of suitable capacitances and resistances in the oscillator circuit.

Each sawtooth wave represents the change of voltage on the charged capacitor and at the plate of an oscillator tube. The oscillator tube can be made conductive, to discharge the capacitor and start a sweep cycle, in either of two ways. First, when plate voltage rises to a value which overcomes the cutoff effect of a negative grid. Second, when grid voltage changes in a manner which allows conduction with whatever plate voltage may exist.

A sync voltage applied directly or indirectly to an oscillator grid must be of only moderate strength. Too much sync voltage would distort the sawtooth waves and prevent true reproduction of observed voltages on the screen of the scope. A small sync voltage can start a sawtooth cycle only when oscillator plate voltage has risen almost high enough to start such a cycle even were no sync voltage present. Consequently, a sweep cycle can be started by a sync voltage only at instants when the sawtooth wave at the free-running frequency has risen almost to the point of starting a cycle without any sync voltage.

At A in Fig. 15 a sawtooth sweep cycle will be started by the sync voltage at instant 1 and again at instant 3, because at these times sawtooth cycles are about to start at the free-running frequency. At instant 2, oscillator plate voltage is still too low for the weak sync voltage to have any effect. Under these conditions a sweep cycle can be started only by every second cycle of sync voltage, and we can see two cycles of observed voltage during each horizontal sweep.

The same reasoning applies at B, where the free-running frequency has been made such that each sweep cycle is as long as three cycles of observed and sync voltages. At instants 1 and 4 the oscillator is nearly ready to start a free-running sweep cycle, and it is easily "triggered" by the sync voltage. But at instants 2 and 3 the oscillator plate voltage is still too low for triggering, and we see three cycles of observed voltage on the screen. At C there can be triggering only at instants 1 and 7, not at any of the intervening cycles of sync voltage, and six cycles of observed voltage appear during every horizontal sweep.

With some types of oscilloscope sweep oscillators it is necessary to provide sharp pulses of triggering or sync voltage. These pulses are obtained from special "integrating" circuits connected between a vertical amplifier and the sweep oscillator. Fig. 16 shows oscillator tube connections for such a system. To the grid of tube 1 are applied negative sync pulses which are of the same frequency as that of the observed voltage. From the plate of tube 1 the pulses, strengthened and inverted in polarity, are applied to the grid of tube 2.

Each positive pulse on the grid of tube 2 makes this tube conductive. There is electron flow from ground or B-minus to capacitor Ca, from this capacitor to the cathode of tube 2, and through this tube to B-plus. This flow, which continues only while the tube is conductive, charges capacitor Ca in the polarity marked. The rise of capacitor voltage during charge is indicated at a on the sawtooth waveform.

When tube 2 again becomes non-conductive, capacitor Ca commences to discharge through high resistances at Ra and Rb. The decrease of capacitor voltage is indicated at b on the sawtooth waveform. At the next pulse of positive voltage on the grid of tube 2 there is another capacitor charge, at c on the sawtooth waveform. The free-running frequency is adjusted to suit the frequency of sync voltage pulses applied to the grid of tube 1.

FREQUENCY CONTROLS. As we have seen in circuit diagrams for various sweep oscillators, the principal means for varying the sweep rate or sweep frequency is by selection of one of several capacitors whose charging and discharging provide the sawtooth voltages. The selector switch is operated by a knob or pointer of some such style as in Fig. 17, located on the front panel of scope. A dial shows the approximate range of frequencies which may be had at each position of the switch. The pointer, as illus-

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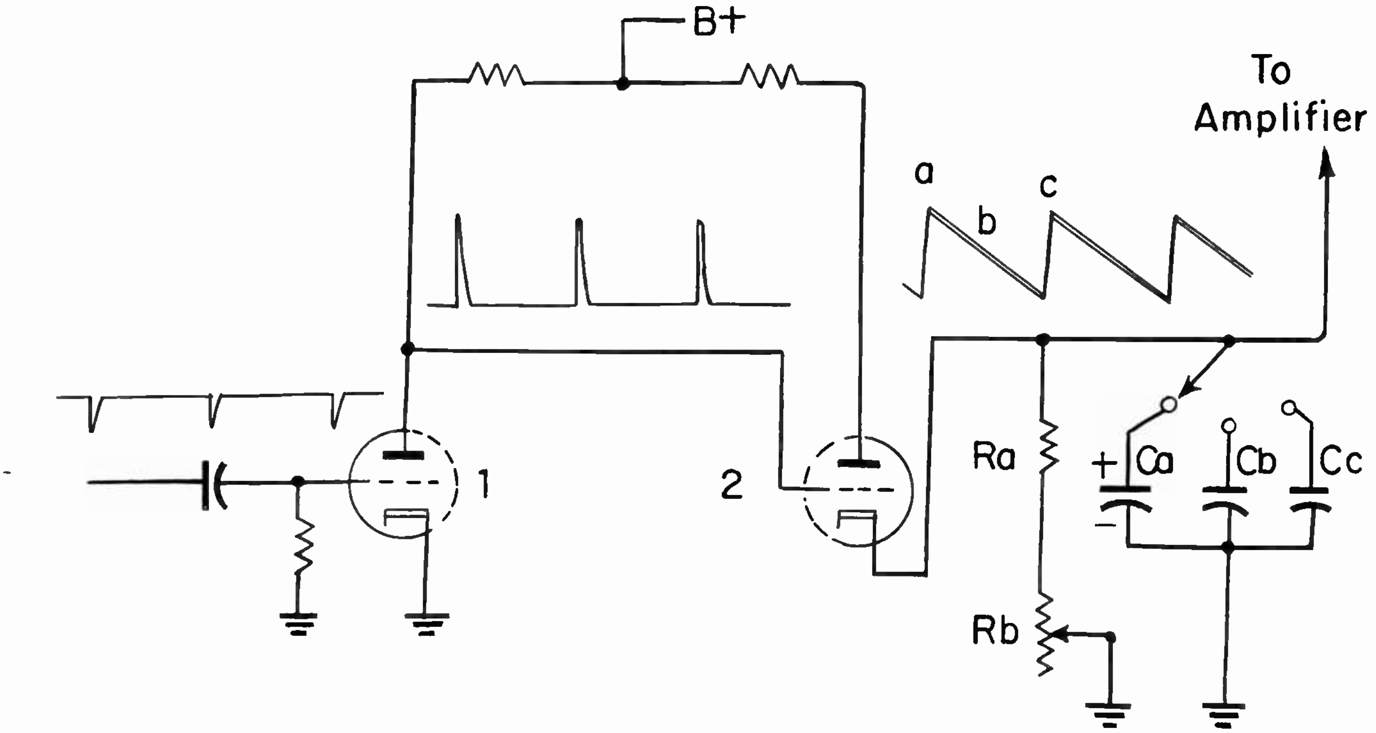

Fig. 16. Triggering of an oscillator by sharp pulses of sync voltage.

trated, is at a position allowing sweep frequencies from about 75 to 360 cycles per second. This control usually is marked "Coarse Frequency" or "Frequency Range", or something of equivalent meaning.

Frequencies within the range covered by each selected capacitor are obtained by varying an adjustable resistor in the sweep circuit. This is resistor Ra in Figs. 11 and 13, and Rb in Fig. 16. This control, on the front panel of the scope, usually is marked "Fine Frequency" or "Vernier Frequency" or any words of this general import.

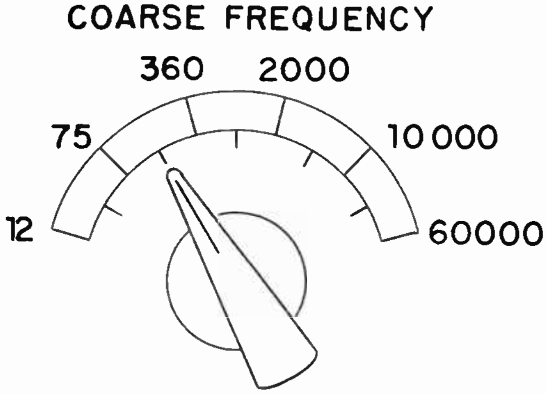

Fig. 17. A selector for frequency range or coarse frequency.

Maximum sweep rates in service oscilloscopes having multivibrator oscillators usually go to 60,000 cycles per second or slightly higher. No other sawtooth oscillators used in this class of work are capable of going any higher than the multivibrator. With gaseous oscillators the maximum sweep rate is about 30,000 per second, a limit set by time required for de-ionization. Various other oscillators provide maximum sweep rates intermediate between these two. A maximum sweep frequency of either 60,000 or 30,000 per second is ample for television servicing, for reasons which follow.

For satisfactory inspection of waveforms there is a limit to the number of cycles of observed voltage which may be on the screen at one time, as you will realize by looking at Fig. 18. At A the sweep timing is twice the period of one cycle of observed voltage, or sweep frequency is half that of the observed voltage. The time for one sweep is equal to the time for two cycles of observed voltage. Part of this total sweep time is taken for the end of one cycle at the left. The next cycle is in full view from its beginning to end. The remaining sweep time is taken up by the beginning of a third cycle, at the right.

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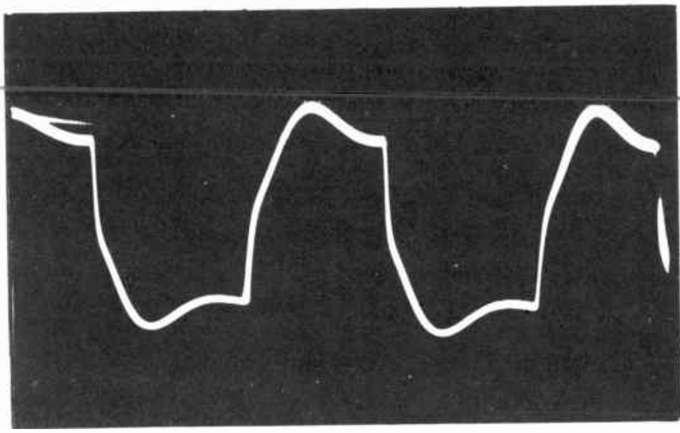

Fig. 18A.

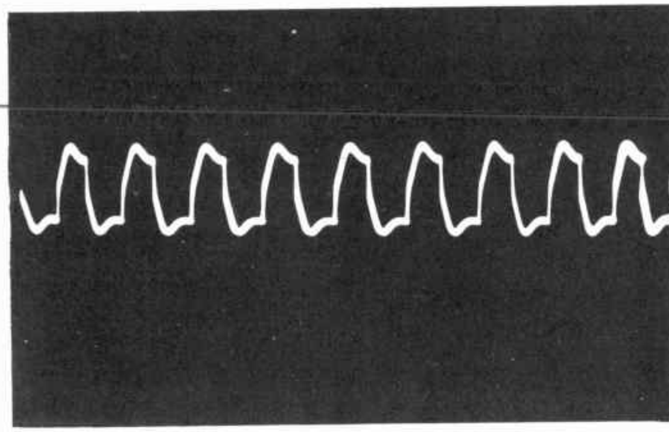

Fig. 18B.

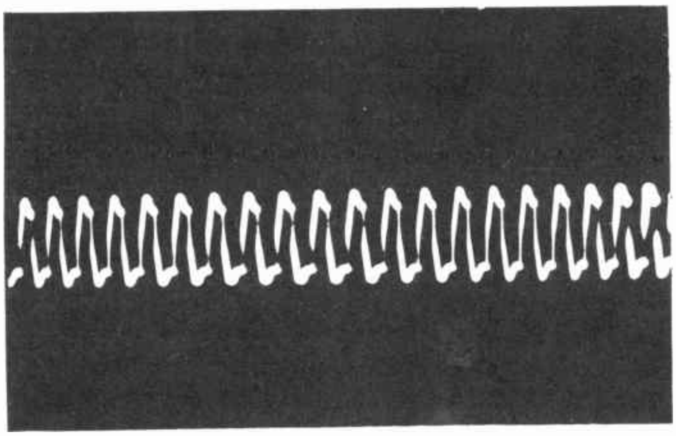

Fig. 18C.

Fig. 18. Waveforms become difficult to examine when there are two many observed cycles on the screen at one time.

At B the sweep frequency is one-ninth the frequency of observed voltage, bringing eight complete cycles onto the screen. It still is possible to examine the waveform of any one cycle quite satisfactorily. At C the sweep frequency is one-twentieth that of the observed voltage, and waveform examination is becoming rather difficult. When working with oscilloscopes you will find that the practical limit of observed frequency is about ten times the sweep frequency. With maximum sweep of 60,000 cycles this brings the limit of observed frequency to about 600,000 cycles or 600 kilocycles, and with maximum sweep of 30,000 cycles the limit of observed frequencies would be about 300,000 cycles or 300 kilocycles per second.

Of course, the greater the diameter of the cathode-ray tube the greater the number of cycles which may be examined for waveform. Considering useful screen diameters, which are less than nominal diameters, a tube of 5-inch nominal diameter is 63 per cent better than a 3-inch tube, and a tube of 7-inch nominal diameter is 33 per cent better than a 5-inch tube.

In television we have to deal with carrier frequencies between about 50 and 900 megacycles, with intermediate frequencies from about 20 to 50 megacycles, and with video frequencies up to nearly 5 megacycles. Waveforms at none of these frequencies can be examined with any service type oscilloscope, for all the frequencies mentioned are far higher than 600 kilocycles.

Then we come down to sound frequencies, which go no higher than 20,000 cycles per second, to the horizontal line frequency of 15,750 cycles, to field frequency of 60 cycles, and to power supply frequencies of 60 and 120 cycles per second. All of these frequencies are well within the range of a horizontal sweep rate which is either 60,000 or 30,000 cycles per second.

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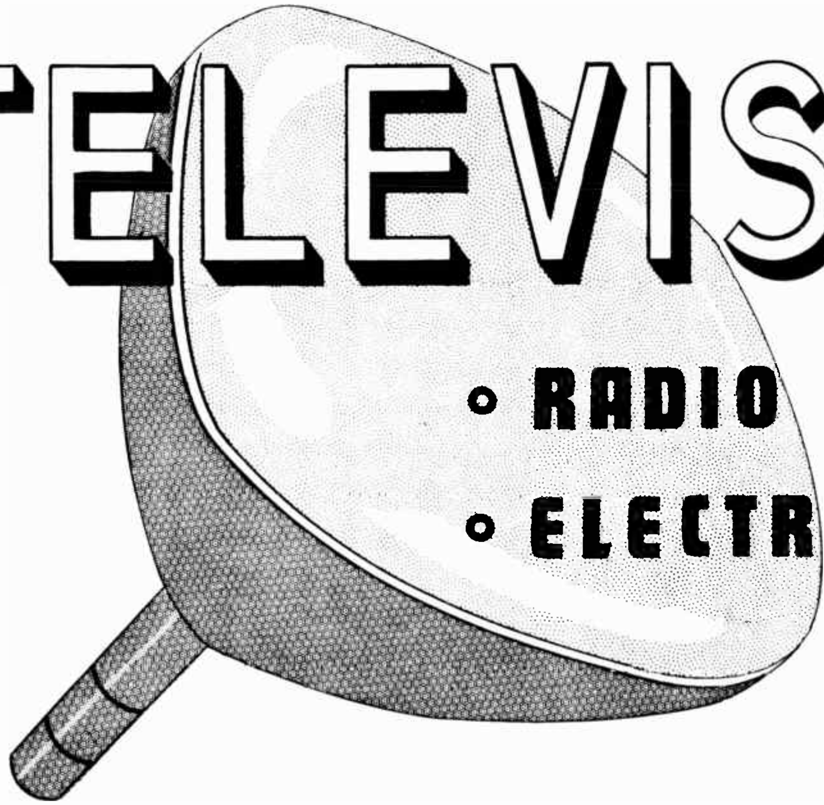

• RADIO
• ELECTRONICS

LESSON 52 — OPERATING THE OSCILLOSCOPE

Coyne School

practical home training

Chicago, Illinois

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Lesson 52

OPERATING THE OSCILLOSCOPE

Always present on even the simplest service oscilloscopes are eleven controls. These essential controls may be classified in four groups, as follows.

1. Electron beam controls.
   a. Intensity, for varying brightness of traces.
   b. Focus, for sharp traces.

2. Vertical controls.
   a. Position, for centering or shifting traces up or down.
   b. Gain, to vary height of traces.

3. Horizontal controls.
   a. Position, for centering or shifting traces sideways.
   b. Gain, to vary width of traces.

4. Sweep controls.
   a. Coarse frequency.
   b. Fine frequency.
   c. Sync amplitude, for strength of synchronizing voltage.
   d. Sync selector, for source of synchronizing voltage.
   e. Sweep selector, for input to horizontal amplifier.

The arrangement of these controls on the panel will vary with different makes and models of oscilloscopes. It has, however, become farily common practice to follow some such scheme as illustrated by Fig. 2. Electron beam controls, our group 1, are near the exposed face of the cathode-ray tube. Vertical controls, group 2, are at the left. Horizontal controls, group 3, are at the right. Sweep controls, group 4, are in the center and toward either side of the panel.

On the left hand side of the panel is a selector switch marked "Vertical Attenuator" which, in connection with the "Vertical Gain" potentiometer control immediately above, regulates the height of traces on the CRT screen. At position 1 of the attenuator the full voltage connected to the vertical input is applied to the vertical amplifier system. Amplification of this amplifier then may be regulated by the gain control. In position 10 of the attenuator the input voltage is divided by 10, and in the other positions by 100 or 1,000, before it reaches the input to the amplifier. The vertical gain control is used with the attenuator in any position.

On the right-hand side of the panel in Fig. 2 is a switch marked "Horizontal Selector". This is a multi-section switch serving two distinctly different purposes. It is a sync selector and a horizontal sweep selector. These two functions will be explained separately, because they are not always handled by the same combination of switch sections.

SYNC SELECTOR. The sync selector switch or switch section allows using a voltage from any of several sources for synchronizing the horizontal sweep oscillator which produces sawtooth voltages. Typical connections are shown by Fig. 3.

The grid of the sweep oscillator tube is connected, as usual, to the slider of the sync amplitude potentiometer which regulates the strength of synchronizing voltage. When first we examined this method of synchronizing the sweep oscillator, the high side of the potentiometer was connected through a resistor to the plate circuit of a vertical amplifier tube. Now we have the same connection, but it is made through the sync selector switch which, in the diagram, is turned to the position marked INT.

When the sawtooth sweep oscillator is thus synchronized by a voltage from a vertical amplifier within the oscilloscope, we refer to the method of operation as "internal sweep". The switch marking, INT, is an abbreviation for internal synchronization or internal sweep.

Another position of the sync selector switch is marked LINE, which indicates synchronization at power line frequency.

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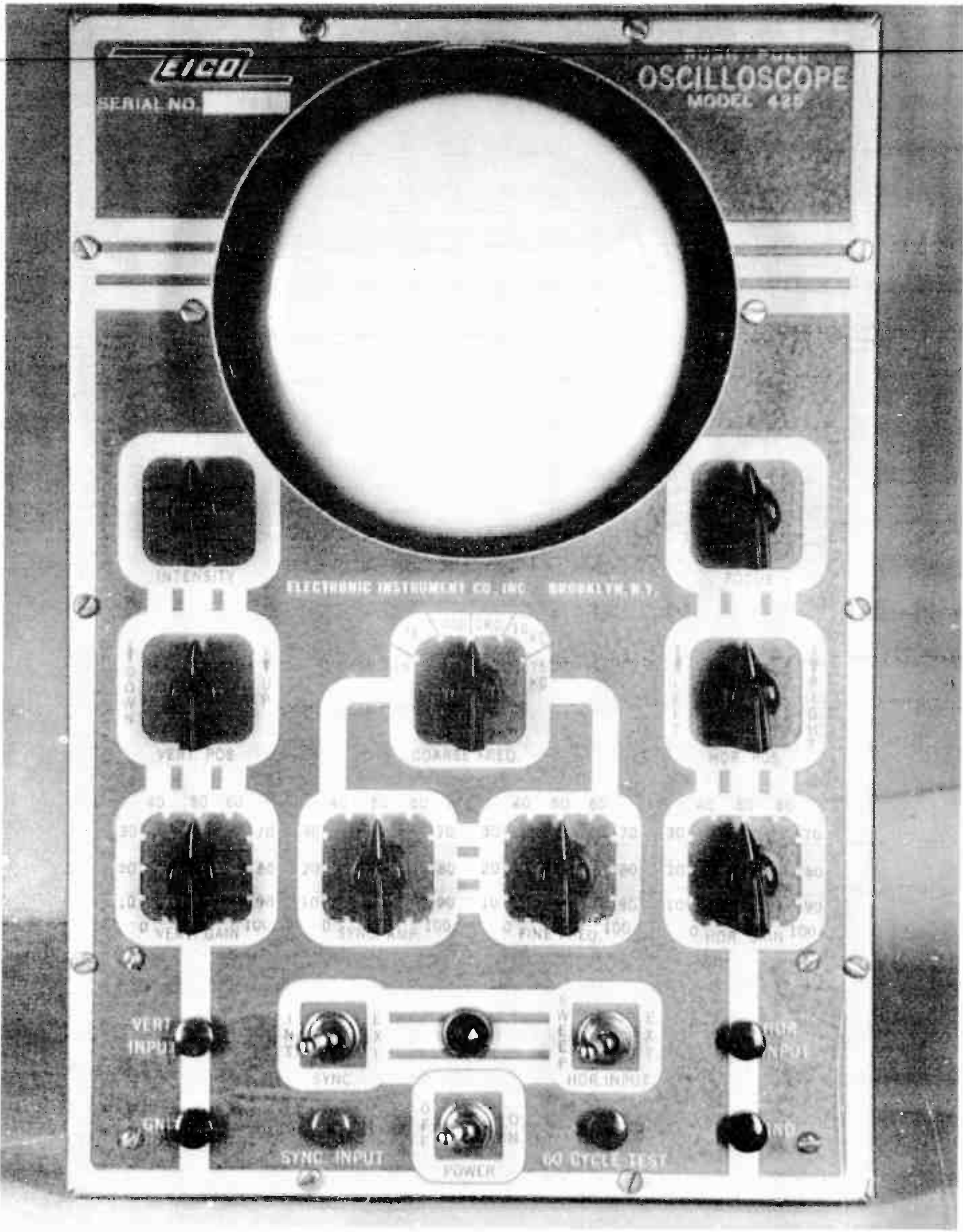

Fig. 1. Controls and terminals on the front panel of an oscilloscopes.

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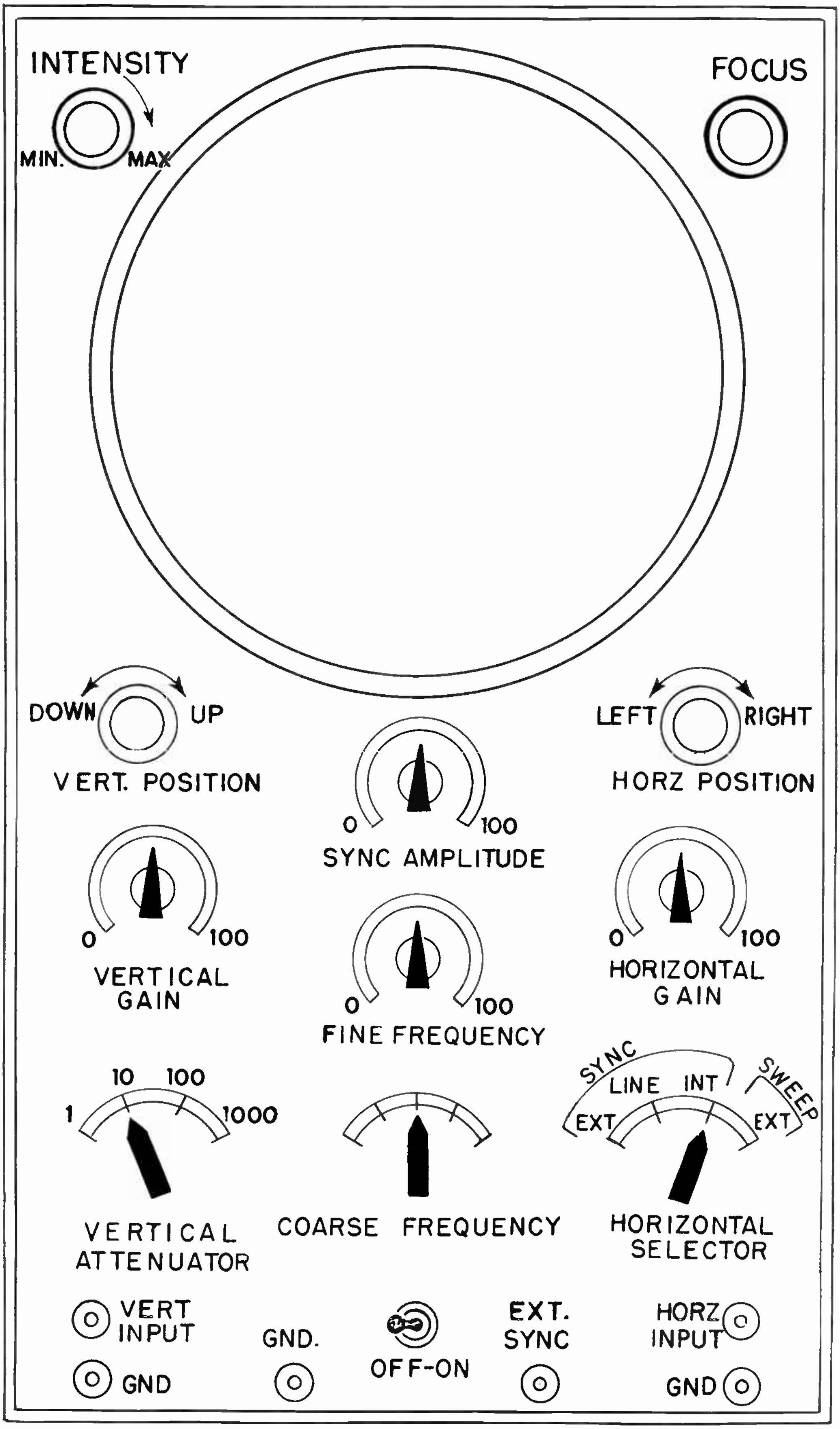

Fig. 2. A typical grouping of controls on the panel of a service oscilloscope.

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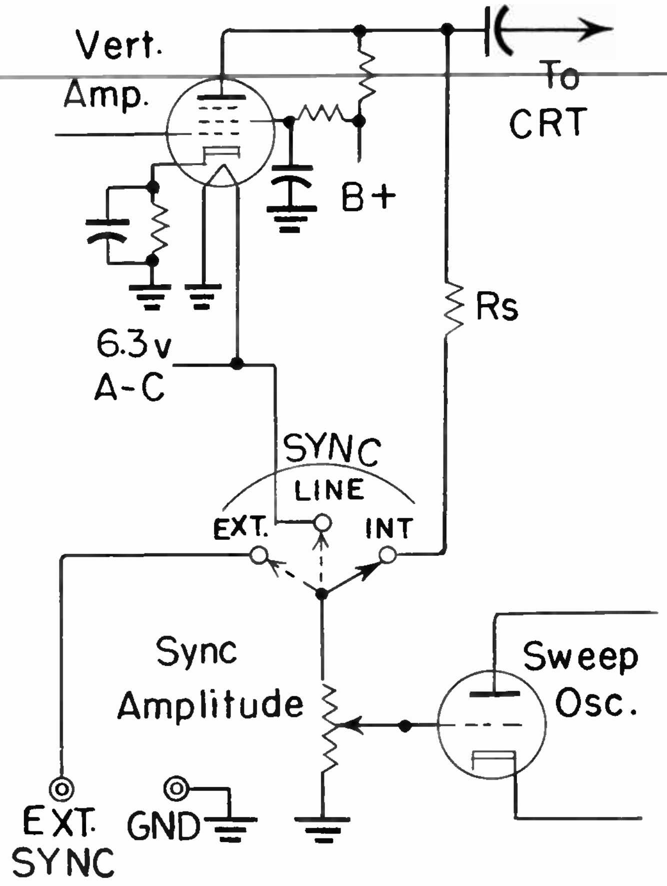

Fig. 3. Connections for a sync selector switch.

With the selector switch in this position, the sync amplitude potentiometer is connected to the heater circuit for tubes, in which there is power line frequency, usually 60 cycles per second. The sweep oscillator then is synchronized only for observed voltages having 60-cycle frequency, or any multiple of 60 cycles.

For line synchronization the coarse frequency and fine frequency controls must be adjusted for 60 cycles or for a multiple of this frequency. Line frequency synchronization is useful in many commercial and industrial applications of the oscilloscope, but seldom is employed for television or radio servicing.

A third position of the sync selector switch is marked EXT, for external synchronization. In this position of the switch the sync amplitude potentiometer is connected to a panel terminal marked EXT SYNC. When any external source of alternating voltage is connected between this terminal and ground, the voltage is applied through the potentiometer to the grid of the sweep oscillator. Then the oscillator is synchronized at the frequency of the external voltage or for any multiple of that frequency.

When using external synchronization it is necessary to set the coarse frequency and fine frequency controls for the synchronizing frequency or a multiple of this frequency, just as when using internal synchronization. External synchronization is needed for only a few rather special service operations in television and radio.

<u>SWEEP SELECTOR.</u> Connections for a horizontal sweep selector switch or switch section are shown by Fig. 4. When this switch is in the position marked INT, for internal sweep, the horizontal gain control which leads to the horizontal amplifier is connected to the output of the sweep oscillator. Then the horizontal amplifier operates on the sawtooth voltage output of the oscillator, and there is sawtooth horizontal deflection of the electron beam in the CRT.

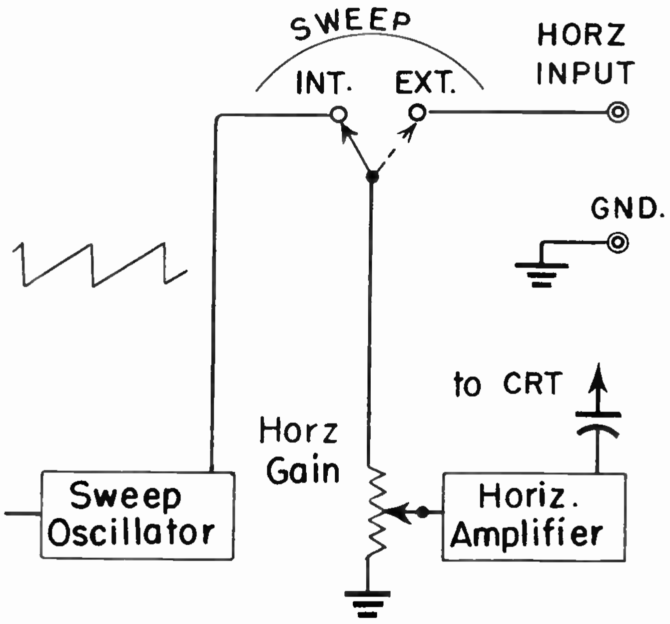

Fig. 4. Connections for a sweep selector.

With the sweep selector switch in its EXT position the sawtooth oscillator is disconnected from the amplifier, and the amplifier, and the amplifier is connected through the gain control to a panel terminal marked HORZ INPUT. Any external alternating volt-

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age applied between the HORZ INPUT terminal and ground now goes through the horizontal gain control and amplifier, and causes horizontal deflection of the beam in the CRT.

The principal use for an external horizontal sweep voltage in television servicing is during observation of frequency responses when voltages covering a wide range of frequencies are furnished by a sweep generator and applied to the vertical input of the scope. We shall become acquainted with sweep generators and their uses in lessons to follow.

The switch for selecting a horizontal deflecting voltage sometimes is a separate unit, as in Fig. 4. More often it is combined either with the sync selector switch, as in Fig. 1, or else with the coarse frequency selector. This latter combination might appear on the panel as in Fig. 5.

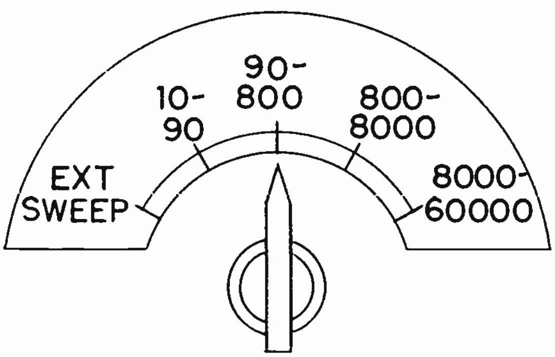

Fig. 5. A sweep selector position on a switch for coarse frequency.

No matter what switching arrangement or combination may be used, when the horizontal amplifier is connected to panel terminals it is disconnected from the sweep oscillator. As a consequence, the sync selector can have no effect on horizontal sweep of the CRT beam, because the sync selector operates only on the input for the sweep oscillator, and with this oscillator disconnected the sync selector also is disconnected.

It is equally true that coarse frequency and fine frequency adjustments can have no effect when the horizontal amplifier is connected to the horizontal input on the panel. These frequency adjustments operate only on the sweep oscillator, and with the oscillator disconnected they cannot affect horizontal deflection.

CONNECTIONS TO TERMINALS. There are two operating conditions which require the use of a shielded cable between the vertical input terminal of the oscilloscope and the source of observed voltage. Such a cable is necessary when the source of voltage is itself of high impedance, possibly 50,000 to 100,000 ohms or more. This refers to the impedance or resistance across which the vertical input is connected at the source end of the cable.

A shielded cable for the vertical input is required also when the observed voltage is so weak that the oscilloscope must be operated at high vertical gain. In either of these cases the central conductor of the cable is connected to the vertical input terminal and the high side of the voltage source, while the shield is connected to ground, both at the instrument and at the source.

The purpose of shielding is to prevent pickup on the vertical input connection of 60-cycle magnetic and electric fields which always are present in rooms where there are a-c power and lighting lines. When voltages induced by these fields are amplified in the oscilloscope, traces at all frequencies will contain waves at the power line frequency, or will contain many closely spaced lines which may appear separated or may combine to make horizontal portions of traces excessively thick.

Cable shielding is of little or no advantage when the observed voltage is taken from a source of low impedance, such as the load resistor of a video detector, in which resistance would be less than 10,000 ohms. This is true also when input voltages are so strong that the vertical gain must be low, as when taking signals from some points in sync and sweep circuits of television receivers.

While a shielded input cable prevents trace distortion due to energy pickup from surrounding fields, it introduces other troubles of its own. These other troubles arise from the fact that there is considerable capacitance between the central conductor and the outer shield of the cable. This capacitance is effectively connected between the high side of the voltage source and ground. If the observed voltage is at frequencies of

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several megacycles, or contains such frequencies, the capacitance to ground may so distort the voltage that you do not see what actually exists when the cable is not in use.

There are high frequencies in all the sync pulses of television signals. Even though the pulse rate is only 60 cycles per second for vertical deflection and 15,750 cycles for horizontal, the changes of voltage occur at far higher rates. For instance, when voltage changes from the pedestal level to a pulse peak, the change is as rapid as in a signal whose frequency is several hundreds of kilocycles at the very least. Changes from pulse peaks back to the pedestal are just as rapid.

Fig, 6 shows some traces of horizontal line periods as taken from the load of a video detector. The trace at A was photographed with an unshielded cable in use, the one at B with a shielded cable, and the one at C with a shielded cable having special compensation for high and low frequencies. Cables of this latter type will be examined in connection with the subject of frequency-compensating attenuators.

Shielded cable should be used for the horizontal input of the scope when the external source of horizontal deflecting voltage has high impedance, or if the horizontal gain control must be adjusted to a high level. Such cable should be used also on the external sync terminal when the source of synchronizing voltage has high impedance.

The several ground terminals on the panel of the oscilloscope, as in Fig. 2, are connected together inside the instrument, and usually also to the metal case or housing. More than one ground terminal is needed in order to allow connection of more than one external voltage. A voltage to be observed is connected between the VERT INPUT terminal and one ground. An external sync voltage would be connected between the EXT SYNC terminal and another ground, or an external voltage for horizontal deflection would be applied to the HORZ INPUT terminal and a ground. One of the ground terminals may be used for connecting the case of the oscilloscope to a metal test bench.

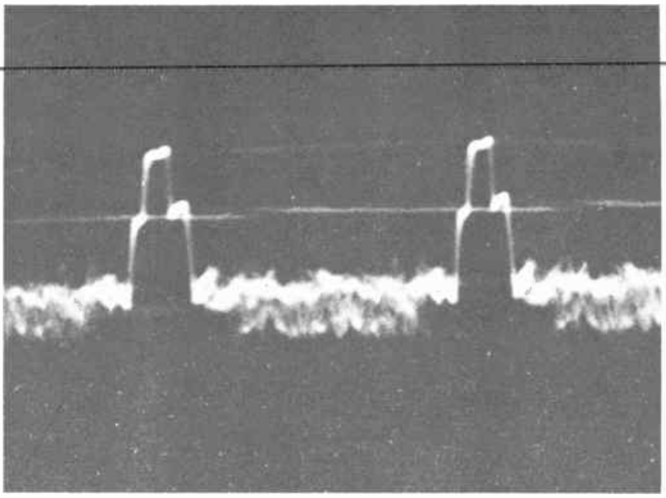

Fig. 6A.

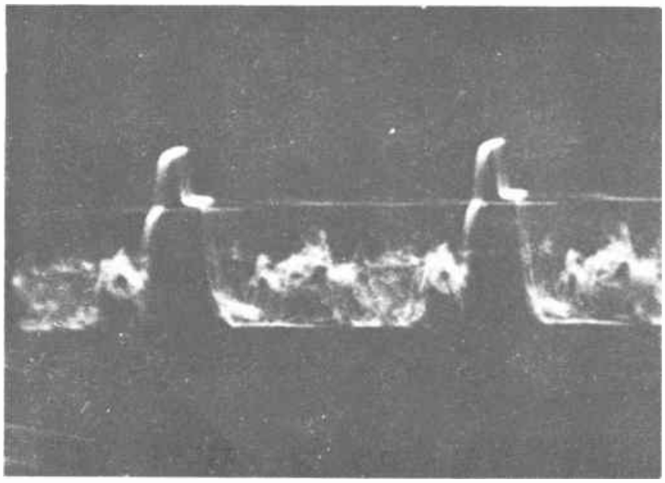

Fig. 6B.

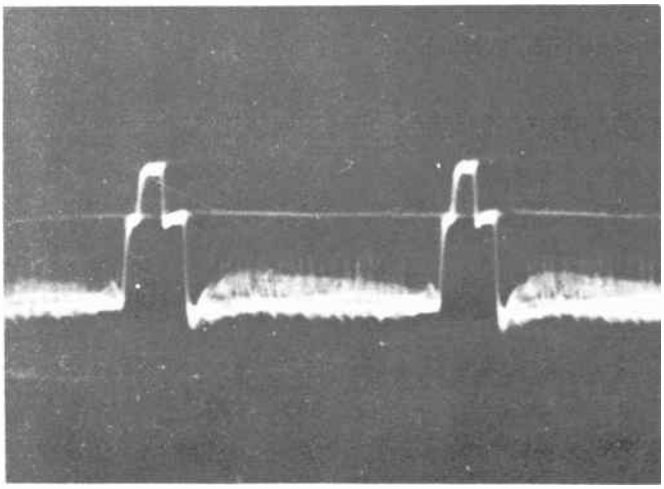

Fig. 6C.

Fig. 6. Traces from a video detector, or video amplifier, are little affected by the kind of connecting cable.

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LESSON 52 – OPERATING THE OSCILLOSCOPE

STEPS IN OPERATING. The following list outlines very briefly the steps to be taken when placing the oscilloscope in operation and observing a voltage waveform by means of the internal sawtooth sweep.

1. External connections.
   a. Vertical input to high side of source of voltage to be observed.
   b. Ground terminal to chassis ground or B-minus of receiver, or to low side of source of observed voltage.

2. Preliminary adjustments.
   a. Intensity at minimum.
   b. Focus, vertical and horizontal positioning, vertical and horizontal gain, and fine frequency, to approximately the middle of their ranges.
   c. Vertical attenuator, if on panel, to position for maximum attenuation or to position used for strongest observed voltages.
   d. Sync amplitude advanced about one-fourth of its range from minimum.
   e. Sync selector switch to INT, to internal synchronization.
   f. Sweep selector, if not combined with other controls, to position for internal sawtooth sweep, not for external horizontal input.
   g. Coarse frequency to approximate frequency of observed voltage, if known.

3. Turn on the power switch. On some scopes this switch is operated with the intensity control.

4. Gradually advance the intensity control until trace lines are clearly visible on the screen of the CRT. Make the trace no brighter than necessary.

5. Adjust the fine frequency control to hold the trace stationary on the screen, or so that there is only slow movement to either the right or left.
   a. If the trace cannot be held stationary, or if it consists of many confused lines, set the coarse frequency control at a higher or lower position which does allow bringing the trace almost to a standstill by adjustment of the fine frequency control.

6. Adjust the coarse frequency to bring the desired number of cycles of observed voltage onto the screen.
   a. Every change of coarse frequency will require readjustment of fine frequency in order to prevent excessive movement of the trace.

7. Adjust the sync amplitude control to the lowest setting at which the trace remains stationary on the screen.
   a. Keep retarding the sync amplitude control while readjusting the fine frequency to find the least synchronizing voltage which will prevent sidewise movement of the trace.

8. Adjust the focus control for the finest or narrowest trace lines.

9. Adjust the vertical and horizontal gain controls to make the trace of desired height and width.
   a. If there is a vertical attenuation control, use it for an approximate adjustment of height, then make a further adjustment with the vertical gain control.

10. Use the vertical and horizontal positioning controls to bring the trace to the position allowing most convenient observation.

In order to operate the oscilloscope to best advantage it is desirable to have additional information relating to many of the steps in the preceding outline. Details are explained in following paragraphs.

INTENSITY. The intensity control always should be turned as low as allows clear traces. High intensity causes excessive bombardment of the screen material with electrons, and the screen will become permanently darkened before the normal ending of its life.

Unless the beam is being deflected hori-

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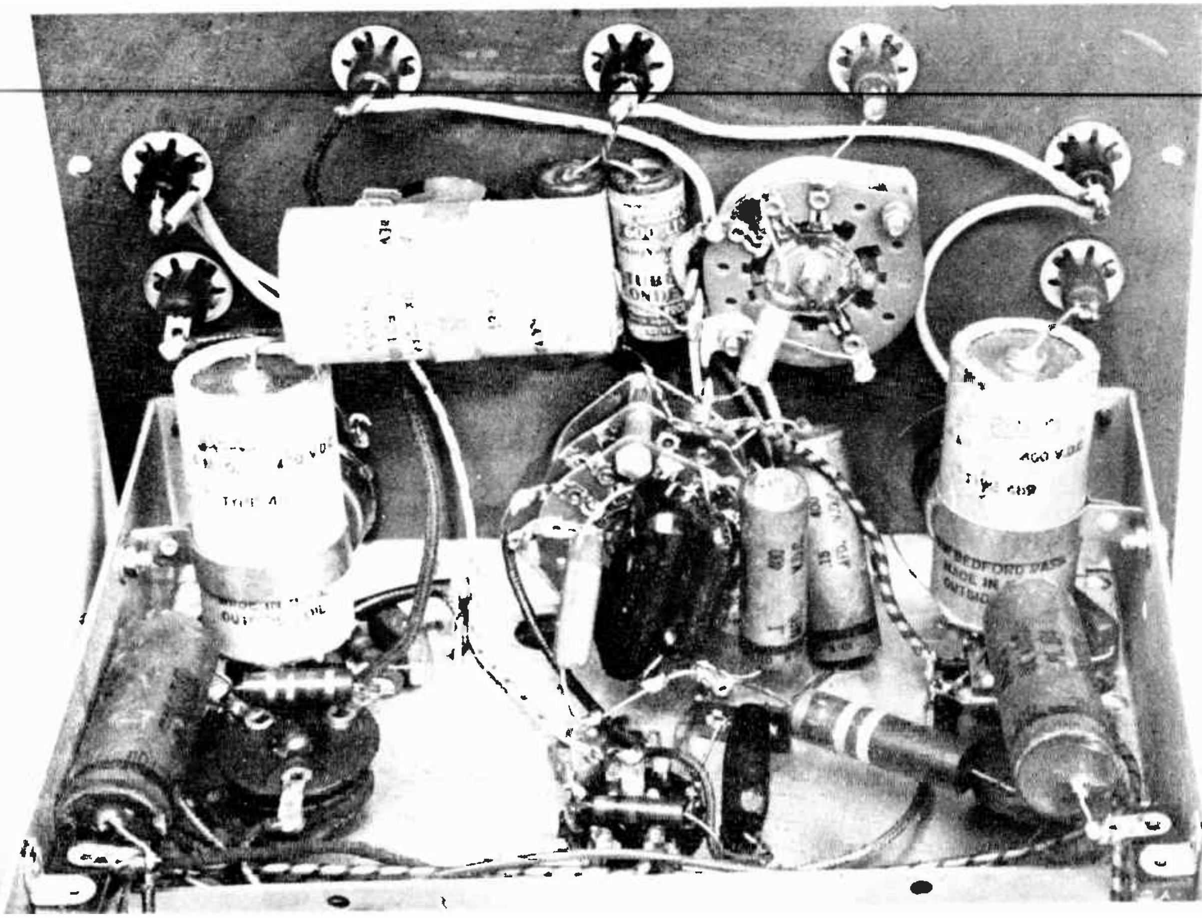

Fig. 7. Part of a control panel as seen from inside an oscilloscope.

zontally, vertically, or in both directions, keep the intensity low enough to cause only a visible line or spot. An undeflected spot, even when of low illumination, may eventually burn the screen.

To maintain any given brightness of the trace, the intensity control must be advanced for increases of sweep frequency and observed frequency, also when the trace is made wider or higher. Under these conditions the beam travels more rapidly over each inch of trace line, electron energy thus is spread more thinly, and more energy or increased electron flow is needed.

When you complete one observation, but expect to make others within a short time, reduce the intensity to leave a barely visible trace, or no trace at all, between times. This is better than turning the power off and on every few minutes, since such practice causes continual expansion and contraction of heaters and cathodes in all the tubes.

FREQUENCY CONTROLS. It is not necessary to know the frequency of a voltage to be observed, nor is it necessary to know the sweep frequency at which the oscilloscope is operating. The only thing really necessary is to adjust the coarse and fine frequency controls until one or more cycles of the observed voltage appear on the screen of the CRT.

The coarse frequency selectors for service oscilloscopes go at least as low as 15 cycles, and many go as low as two, three, or four cycles per second. All go at least as high as 25,000 cycles or more. Since it is possible to distinguish as many as 20 cycles of observed voltage per sweep cycle, all voltages at frequencies up to 500,000 cycles or more may be recognized merely by suitable adjustment of the two frequency controls.

The fine frequency control never is calibrated or marked for certain frequencies, because there are so many operating con-

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ditions which vary the frequency to a greater or less extent. This control simply is adjusted for a trace which is stationary, or nearly so, without regard to any particular frequency. As the oscilloscope and the source of observed frequency continue to warm up during service operations, it is necessary to make slight readjustments of the fine frequency control.

When a trace moves slowly to the right or left, either steadily or in jerks, the motion may be stopped and reversed by turning the fine frequency control in one direction or the other. Shifting of the trace toward either side should be made as slow as possible by fine frequency adjustment before advancing the sync amplitude to lock the trace in one position.

A fine frequency control will have enough range of adjustment to bring any of several numbers of cycles onto the screen at one time. For example, with the coarse frequency remaining in some one position, adjustment of the fine frequency from one end to the other of its range might bring either one, two, three, or more cycles of observed voltage into view. Advancing the fine frequency reduces the number of observed cycles, while retarding this control increases the number of cycles. To view some particular number of observed cycles it may be necessary to readjust the coarse frequency control. Using this control to increase the number of sweep cycles per second will reduce the number of cycles of observed voltage.

If the sweep frequency is made greater than the frequency of an observed voltage, a cycle of that voltage will be split into several sections. This effect is shown in Fig. 9. At A is a single cycle, brought into view by making the sweep frequency equal to the observed frequency. At B the sweep frequency is doubled, and the single cycle is divided into two parts. One part extends from 1 to 2, the other from 3 to 4. At C the sweep frequency is three times the original rate, which splits the cycle into three parts. The first part goes from 1 to 2, the second from 3 to 4, and the third from 5 to 6.

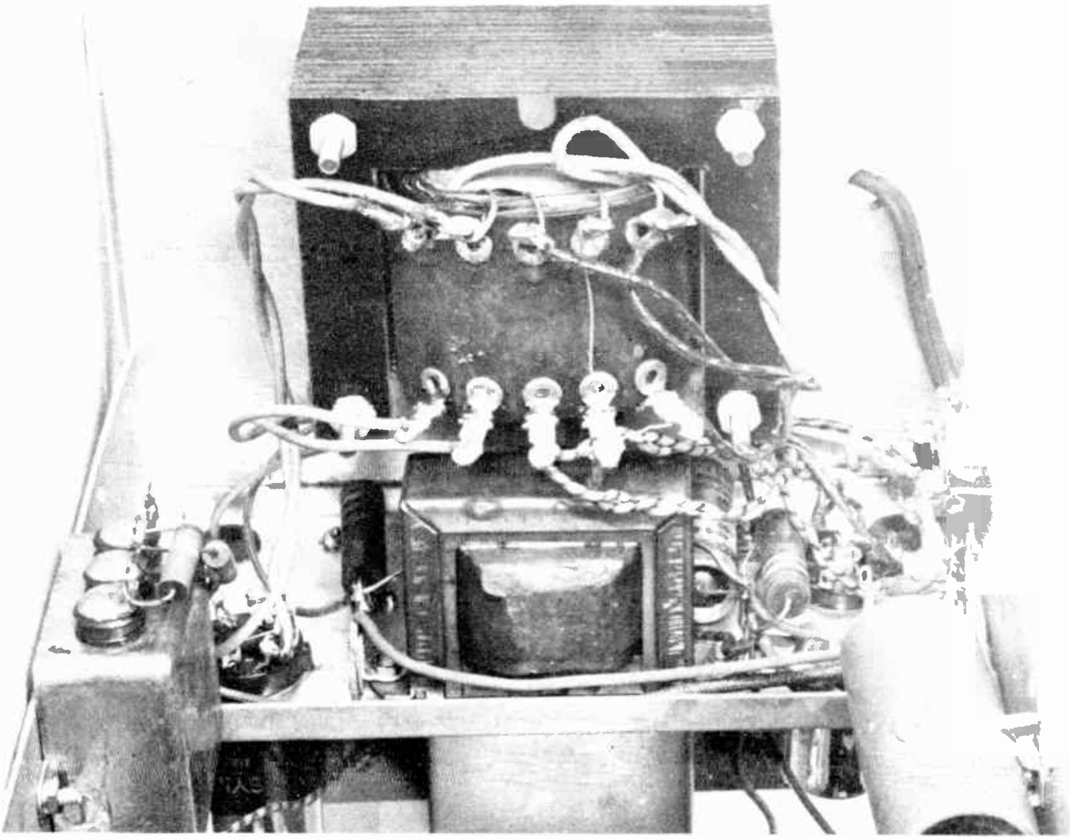

Fig. 8. Power transformers in a service oscilloscope.

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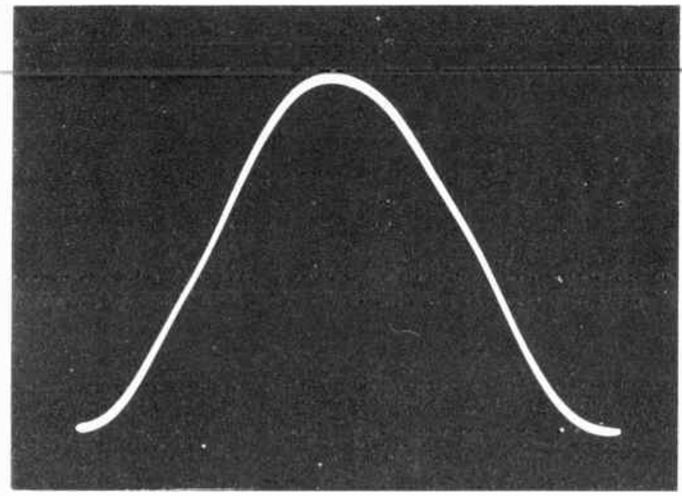

Fig. 9A.

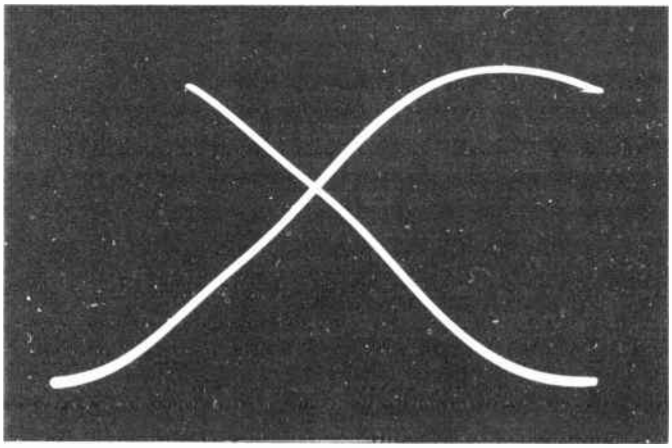

Fig. 9B.

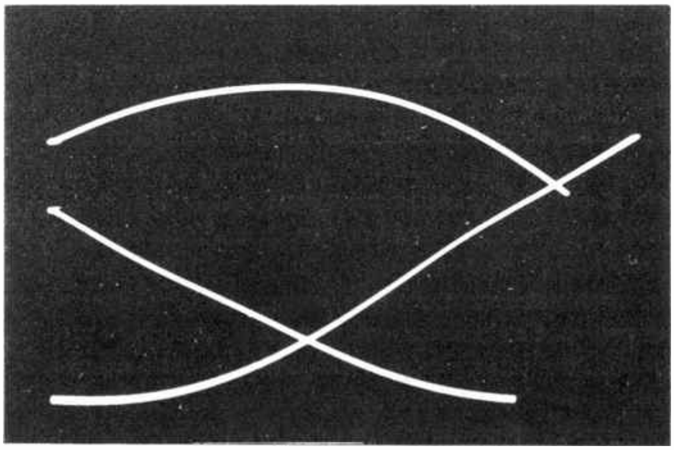

Fig. 9C.

Fig. 9. Sweep frequencies higher than observed frequencies split the cycles into various numbers of parts.

Increasing the sweep frequency still further in relation to the observed frequency will break the cycle into more and more lines. Such operation of the oscilloscope has no practical applications in servicing, it is illustrated merely to explain what is happening when you see such traces.

SYNC AMPLITUDE. Until some synchronizing voltage is applied to the grid of a sweep oscillator the observed trace will move to the right or left on the screen. This movement should be reduced as much as possible by fine frequency adjustment, then the sync amplitude should be advanced only far enough to hold the trace stationary. As the oscilloscope and receiver, or other source of observed voltage continue to warm up it will be necessary to make slight readjustment of fine frequency. Do not increase the sync amplitude when actually the fine frequency should be readjusted to hold a trace stationary.

Too much sync amplitude will trigger the sweep oscillator before the normal end of a sweep cycle. This shortens the sweep time, or increases the sweep frequency. The result is a reduction in number of observed cycles appearing on the screen at one time, and possible distortion of the trace at one side or the other.

FOCUSING. Adjustment of the focusing control will produce narrowest and sharpest trace lines when intensity or brightness is low or moderate. In CRT's of early types the focus changes with every readjustment of intensity, but this effect is not noticeable with later types.

When a trace is enlarged to occupy a considerable area on the CRT screen, the focus may not be equally sharp at all points. This effect may be examined by turning both the vertical and the horizontal gain controls to zero and reducing the intensity to leave only a barely visible spot. By using the vertical and horizontal positioning controls this spot may be brought to the center of the screen, then made of smallest size and most nearly perfect roundness by means of the focus control.

If the spot now is moved up and down by means of the vertical positioning control, and to the left and right by means of the horizontal positioning control, the shape of the spot

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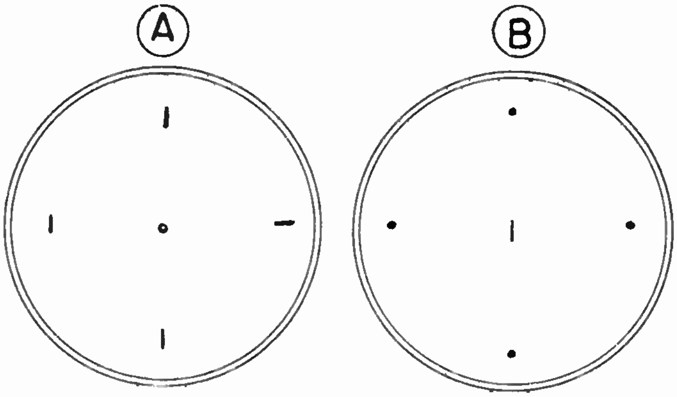

Fig. 10. Astigmatism distorts the spot when at various positions on the screen.

may change as shown at A in Fig. 10. The spot will lose its circularity, and become a short vertical line in some positions, and a short horizontal line in other positions. Portions of a trace which extend into these positions then will be slightly thickened either vertically or horizontally, while being composed of thin, sharp lines near the center. This distortion of the spot is called astigmatism.

Astigmatism is caused by variations between the average of deflecting voltages applied to the deflecting plates and the voltage of the second anode in the CRT. Some service oscilloscopes have an astigmatism control which usually acts to change the voltage on the second anode in relation to average voltages on the deflecting plates. When an astigmatism control is used, in connection with the focusing control, it is possible to obtain sharp focus at the top, bottom, and sides of the screen as at B. Then there may be slight distortion of the spot at the center of the screen.

The focus and astigmatism controls are used together for best overall focus. At A in Fig. 11 is a trace without an astigmatism control, and at B is a trace of the same waveform when this control is adjusted. The astigmatism control need be used only for close examination of critical waveforms. Once this control is correctly set it may remain so, without further adjustment, for the majority of observations.

GAIN CONTROLS. If the oscilloscope is provided with a vertical attenuator in addition to a vertical gain control, the attenuator is set for the approximate desired height of trace and then the gain control is used for closer adjustment of height. When there is no attenuator, the gain control is used for adjusting the trace height from minimum to maximum.

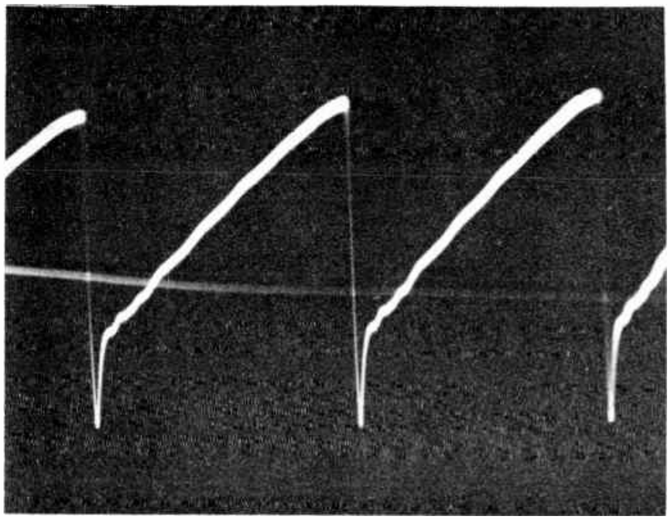

Fig. 11A.

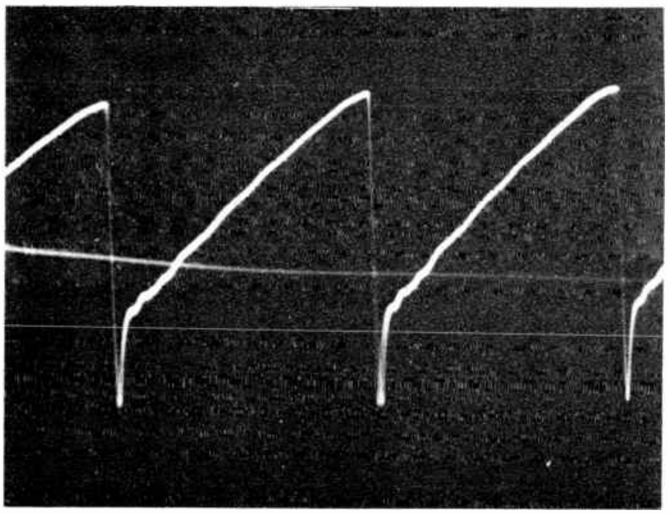

Fig. 11B.

Fig. 11. Average focus at all points on a trace may be improved by using an astigmatism control.

Seldom if ever is there a horizontal attenuator, but always there is a horizontal gain control. This gain control will vary the width of trace regardless of the source of horizontal deflecting voltage and regardless of the method of synchronization. That is, the horizontal gain control is effective for both sawtooth sweep and for any voltage ap-

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plied to the horizontal input terminals. It is effective also with internal, external, or line synchronization.

The horizontal gain control may be advanced far enough to make the sidewise sweep of the beam much greater than the width of the screen in the CRT tube. Then only part of the observed waveform is in view. The trace is thus enlarged horizontally when you wish to examine details at some particular portion of a waveform.

As an example, we might have a trace as shown at A of Fig. 12, which illustrates damped oscillations. For close examination of only that portion of the wave in which the damping occurs, the trace may be stretched out from side to side by means of the horizontal gain control. Then the horizontal positioning control is used to bring the damped oscillations onto the central portion of the screen. The result is the trace shown at B. Any portion of any waveform may be thus centered on the screen and enlarged as desired.

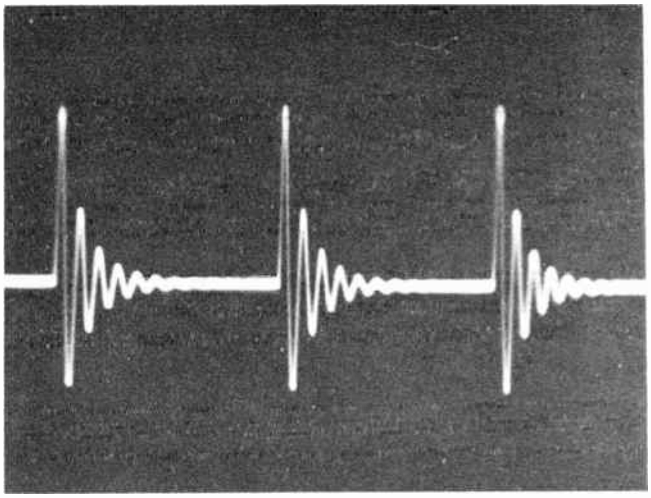

Fig. 12A.

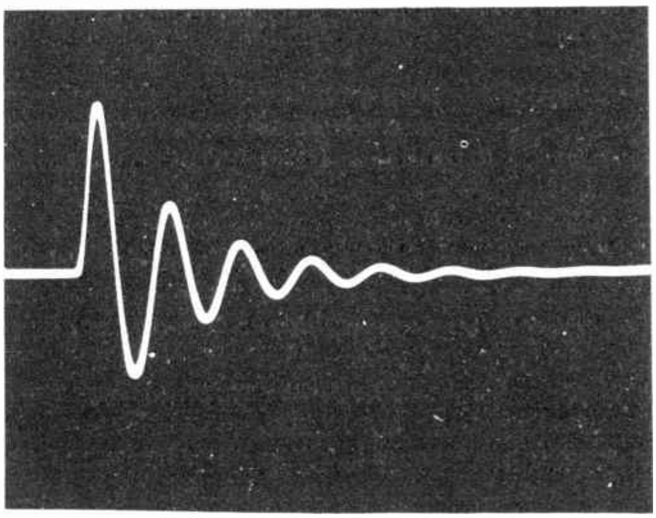

Fig. 12B.

Fig. 12. Any one portion of a trace may be widened for closer examination of voltage changes.

The vertical and horizontal gain controls may be used to greatly alter the appearance of any given waveform. As a general rule these two controls are adjusted to make the height of the trace somewhere near equal to the width of one cycle. This general relation between height and width is found so often that we come to think of various television signals as being only of the proportions thus obtained.

At A in Fig. 13 is a trace in which the peak-to-peak height has been made almost exactly equal to the width of one cycle. The trace at B shows the effect of increasing the vertical gain. The actual peak-to-peak voltage being applied to the vertical input terminals has not been changed in the least, but this voltage is being amplified to a greater extent within the oscilloscope. The waveform at B is exactly the same as at A.

To produce the trace at C the horizontal gain has been reduced, with vertical gain remaining the same as at B. Now the horizontal amplifier within the scope is not spreading the trace so far across the screen, but frequency of observed voltage has not been altered. Also, the waveform at C is the same as at A and at B. The trace at D shows the effect of decreasing the vertical gain while increasing the horizontal gain. Once more, there has been no change whatever in the voltage applied to the vertical input of the scope, and the waveform shown at D is the same as that shown by the other three traces.

The waveform of any voltage is determined by the instants during a cycle at which there are changes of amplitude and potential, by the polarity of direction in which the changes occur, and by the rates of change or durations of changes. None of these things are altered by manipulation of any oscillo-

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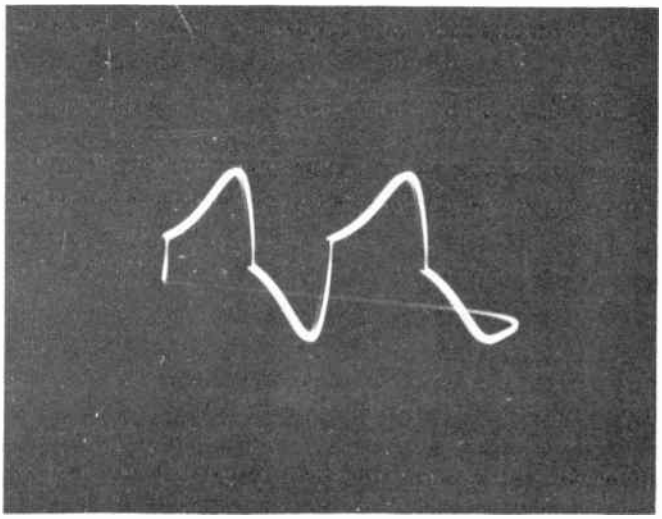

Fig. 13A.

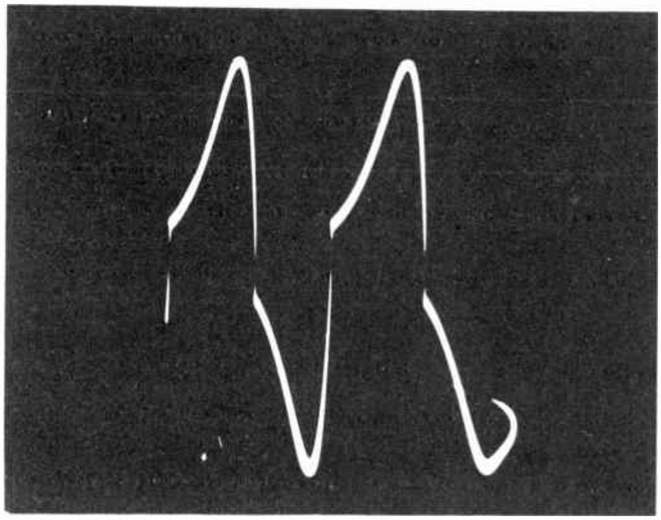

Fig. 13B.

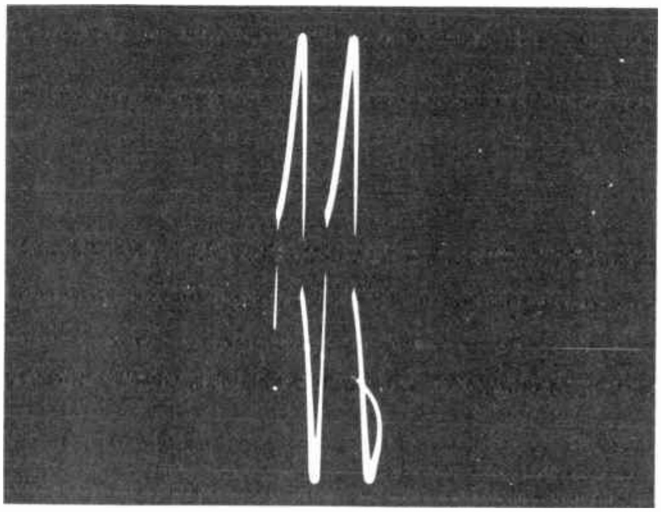

Fig. 13C.

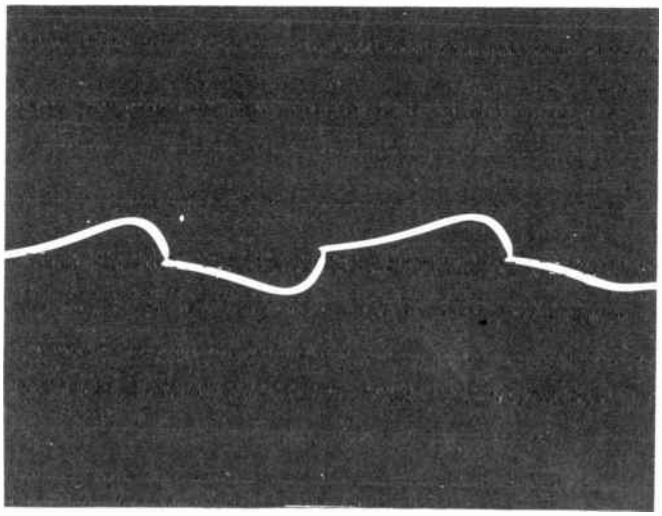

Fig. 13D.

Fig. 13. Vertical and horizontal gain adjustments may greatly alter the appearance of any given waveform.

scope controls. The controls can vary the appearance of traces produced by a given waveform, but they cannot vary the waveform itself.

OSCILLOSCOPE CHARACTERISTICS

Before discussing those characteristics of an oscilloscope which determine its usefulness we should understand that this instrument is used for two distinctly different kinds of measurement or observation. One class of work includes examination of frequency response curves during alignment of r-f, i-f, and sound amplifiers. A typical trace showing frequency response of an i-f amplifier is shown by Fig. 14. Methods of obtaining such frequency response curves are explained in another lesson.

The other class of work includes observation of signal waveforms in all circuits from the video detector through the sync, sweep, and deflection systems. Here we encounter waveforms such as illustrated by Fig. 15. The trace at A was obtained with an oscilloscope in which vertical amplification is nearly constant throughout a wide band of frequencies, in which there is high sensitivity, and reasonably high input impedance. The trace at B, from the same signal in the same receiver, was formed by a scope of relatively poor characteristics.

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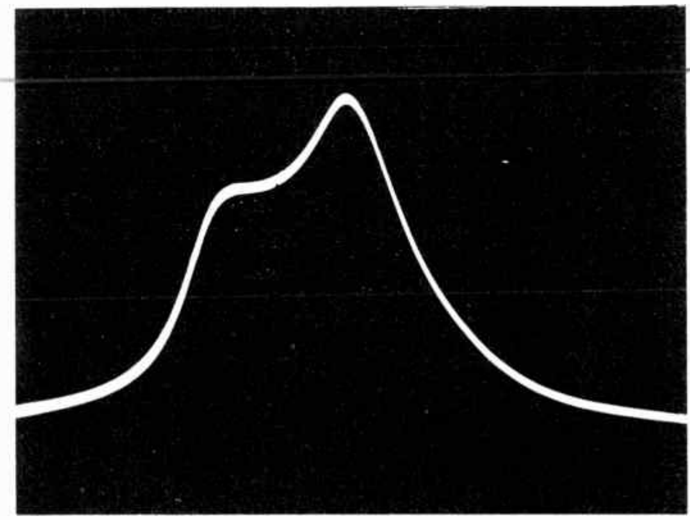

Fig. 14. An oscilloscope needs only moderately good characteristics for showing frequency responses, like this one.

The trade at A, which quite accurately portrays the signal waveform, allows faster, more accurate, and more certain identification and location of troubles than the trace at B. But the less accurate trace is far from being useless. Once you become familar with the manner in which a certain oscilloscope presents signal waveforms taken from receivers in good condition, you readily recognize many of the more common failures and can identify most of the troubles causing them.

The vertical amplifier and vertical gain control determine the three characteristics which most directly affect waveform observations. The first important characteristic is frequency response, meaning the range of frequencies throughout which there is nearly uniform gain or amplification. Second is sensitivity, the strength of input signal voltage required to cause a given vertical deflection of the CRT beam and a given height of trace on the screen. Third is input impedance, which fixes the extent to which the oscilloscope loads the circuits being tested.

FREQUENCY RESPONSE. Maximum frequency response of an oscilloscope usually is specified as the frequency of a sine-wave voltage at which vertical gain drops three decibels or drops to about 70 per cent of that for a frequency of something like 1,000 cycles per second. On this basis, various service oscilloscopes have high-frequency limits all the way from 100 kc up to about 4 mc.

During waveform observations we encounter the highest television signal frequencies in the horizontal sync, sweep, and deflection systems. Here the fundamental horizontal line frequency is only 15,750 cycles or 15.75 kc per second. But in the square-cornered pulses are frequency components at least 20 times as high as the fundamental, which means frequencies to at least 315 kc per second. Consequently, the vertical response of a television service oscilloscope should be practically flat to about 300 kc, or

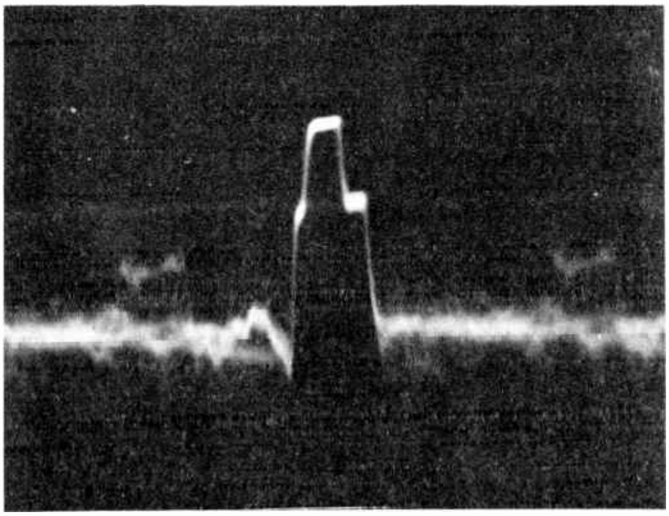

Fig. 15A.

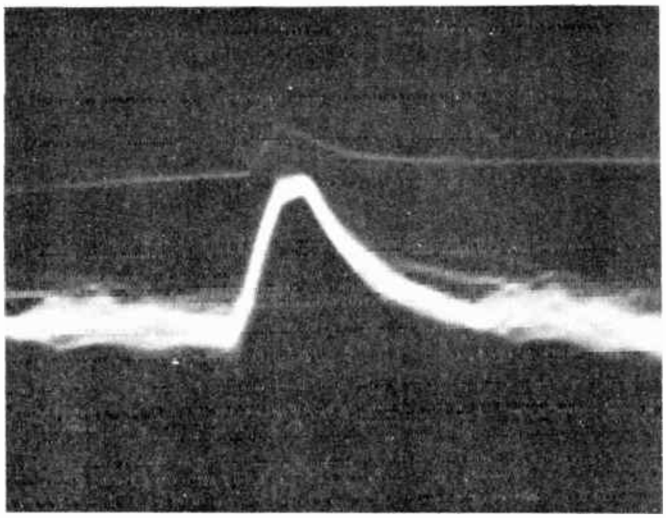

Fig. 15B.

Fig. 15. Requirements are quite stringent for accurately tracing waveforms which contain high frequencies.

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more, if pulse voltages are to be traced with accuracy.

The high-frequency response of any service oscilloscope is sufficient for alignment work. The response of Fig. 14 was taken from the same instrument as the waveform at B in Fig. 15. Tracing of television frequency responses does require, however, good oscilloscope response at low frequencies. Excessive falling off of amplification at frequencies from 60 cycles down to around 5 cycles per second will cause enough phase shift to distort the response curve of a television receiver. The curve is likely to be so tilted, in relation to actual receiver gains, that you may misalign the receiver because of a fault which lies in the oscilloscope.

Wide-band amplification in oscilloscope amplifiers is secured by precisely the same methods employed in video amplifiers of television receivers. Low-frequency compensation is provided by large coupling and bypass capacitances, by suitable relations between plate load resistances and grid resistances, by degeneration, and by all the other methods explained when we studied video amplifiers. For high-frequency compensation we find shunt and series peaking inductors, high quality circuit elements, and careful layout to lessen stray and distributed capacitances.

<u>ATTENUATOR COMPENSATION.</u> As mentioned earlier, no television signal consists of a single frequency, all are made up of many widely different frequencies. Unless all these frequencies are amplified to practically the same degree in the oscilloscope, waveform traces will not correctly represent the signals.

An oscilloscope amplifier may be so well compensated for low and high frequencies as to provide practically equal gain for a wide band of frequencies. But to take full advantage of such an amplifier the signal voltages fed to its input must come through the gain control or attenuator with equal attenuation of voltages at all frequencies. This can be accomplished only by frequency compensating circuits in an attenuator.

A gain control without frequency compensation is shown by Fig. 16. The vertical input terminal connects through a large capacitance at <u>Ca</u> to the top of a potentiometer whose slider goes to the grid of the amplifier tube and whose lower end goes to ground. This potentiometer acts for input signals as an adjustable voltage divider of the resistance type.

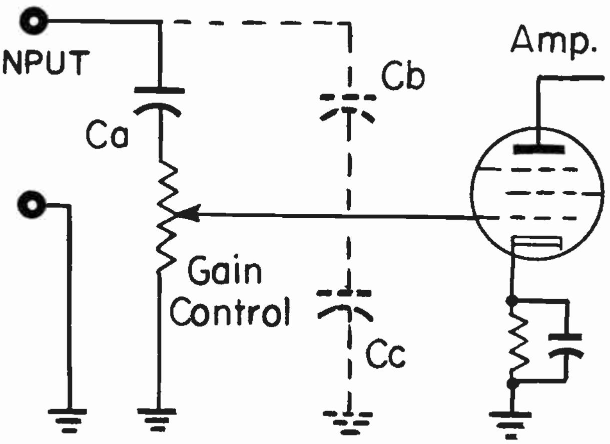

Fig. 16. Stray capacitances cause frequency discrimination with this simple type of gain control.

There are stray capacitances from amplifier grid to input, represented at <u>Cb</u>, and from grid to ground, represented at <u>Cc</u>. These form a capacitance voltage divider, with the two capacitive reactances affecting division of signal voltage for the amplifier grid. The capacitances and their relative reactances are little affected by adjustment of the potentiometer, but the reactances decrease steadily with increase of signal frequency. As a result, high frequencies are attenuated less than low frequencies. This condition becomes worse as the potentiometer is adjusted to reduce signal voltage at the amplifier grid, or adjusted for handling strong signals. Frequency discrimination would be absent only when the gain control is fully advanced.

Fig. 17 shows a simple form of frequency compensating attenuator. The control is a two-section rotary switch with four positions. When this switch is at position 1 the vertical input terminal is connected through the large capacitance at <u>Ca</u> to the grid of the amplifier, with signal voltage acting across resistor <u>R1.</u>

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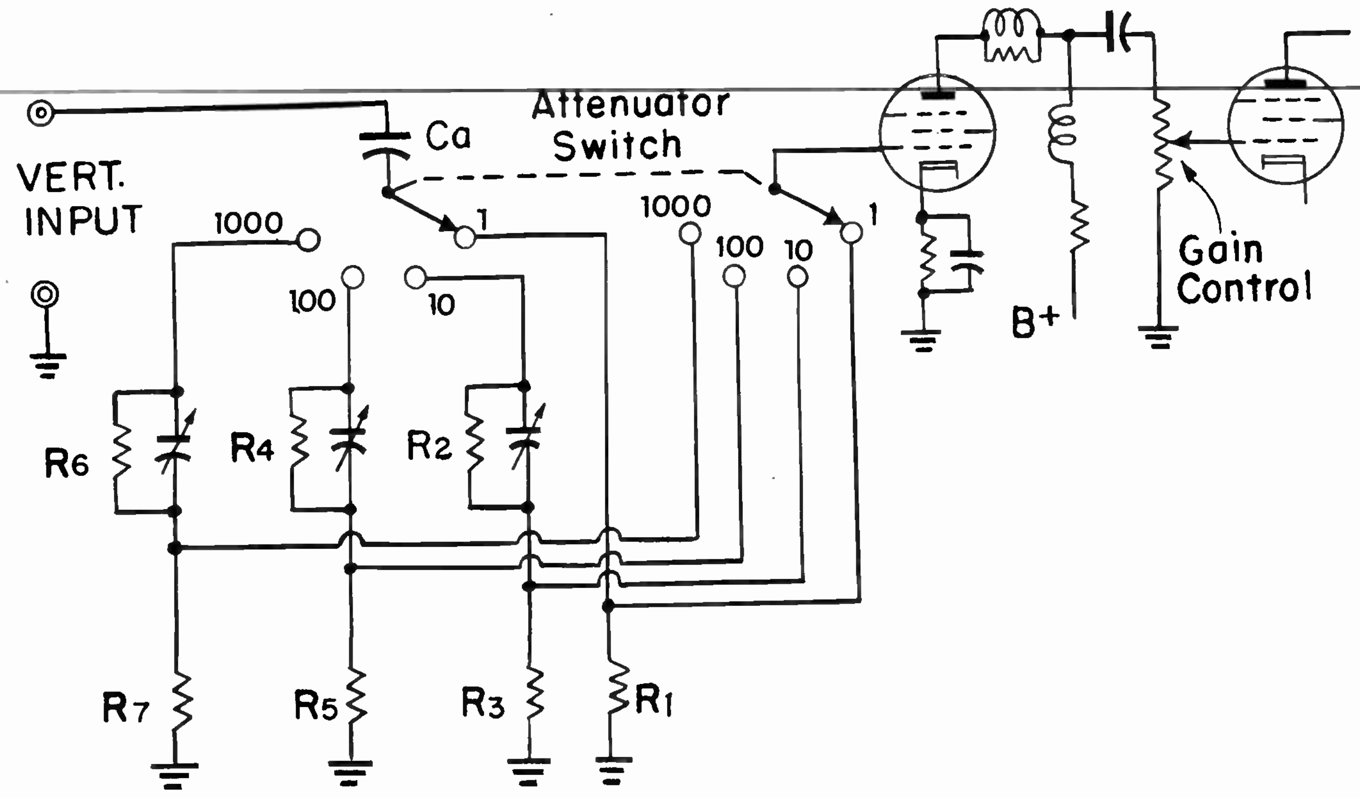

Fig. 17. Connections for one kind of frequency-compensating attenuator.

The full strength of signal voltage developed across R1 is applied to the grid, and there is no attenuation. This position is equivalent to having the gain control slider of Fig. 16 at the top of its travel, where there is no frequency discrimination.

Switch position 10 is equivalent to moving a gain control slider away from its highest setting. Now the input voltage goes through resistors R2 and R3 in series, with the amplifier grid lead from between the two resistors. Resistance at R2 is 9 times that at R3. Consequently, 9/10 of the input voltage is across R2, and only the remaining 1/10, across R3, is applied to the amplifier grid. At switch position 100 the ratio of resistances at R4 and R5 is 99 to 1, and at position 1,000 the ratio is 999 to 1. Thus the grid voltage is reduced at these positions to 1/100 and to 1/1000 of the incoming signal voltage.

To prevent frequency discrimination, the ratio of capacitive reactances must equal the ratio of resistances above and below the grid connection at each position of the switch. This is made possible by trimmer capacitors which are in parallel with resistors R2, R4, and R6. These trimmers are in parallel also with stray capacitances above the grid connection, and by adjustment of the trimmers the total capacitance above the grid may be varied in relation to stray capacitance from grid to ground.

A frequency compensating attenuator regulates input signal voltage only in large steps. For adjustment of amplifier gain and height of traces within each one of these steps it is necessary to provide another control for making gradual changes of amplification. One such gain control is shown in Fig. 17. It consists of a potentiometer between the plate of the first amplifier and the grid of the second amplifier tube. Various other types of gain control may be used. They apply more or less of the output from one amplifier to the input of a following amplifier.

FREQUENCY COMPENSATING PROBES. A frequency compensating attenuator would allow uniform frequency response only were it possible to apply an observed voltage directly to the vertical input terminals. In

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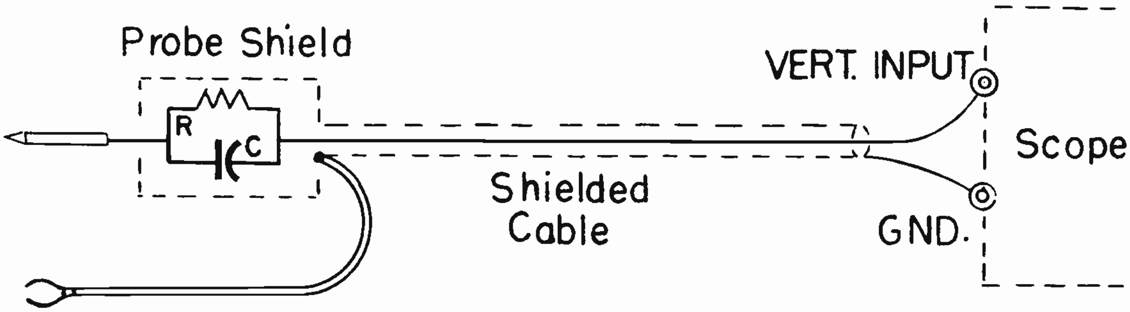

Fig. 18. A low-capacitance probe reduces frequency discrimination and increases effective input impedance of the oscilloscope.

practice, the observed voltage often is taken from its source to the oscilloscope through a shielded cable. Between the central conductor and shield of good quality cable there is capacitance of 20 to 25 mmf per foot of length, and in poor quality cable there may be 80 to 100 mmf per foot. With a cable of usual length, about three feet, cable capacitance of at least 60 to 75 mmf will be connected across the measured circuit, in addition to input capacitance of the oscilloscope. High frequencies will be bypassed to ground much more than low frequencies through the cable capacitance, and there will be frequency discrimination.

Waveform distortion, as well as loading of measured circuits, is reduced by using a low-capacitance frequency compensating probe on the pickup end of the vertical input cable, as shown by Fig. 18. In series with the central conductor of the cable is capacitor C paralleled by resistor R. Capacitance at C usually is on the order of 5 mmf. It is in series with the cable capacitance, and reduces effective shunting capacitance to a low value.

The series capacitance used alone would readily pass high frequencies but would seriously attenuate low frequencies. The paralleled resistance at R, which may be from 1 to as much as 50 megohms, allows passage of low frequencies. There will be nearly equal attenuation over a wide band of frequencies when the product of resistance and capacitance in the probe is equal to the product of input resistance of the scope and combined cable capacitance and input capacitance of the scope.

When a probe contains fixed resistance and fixed capacitance it must be designed for the oscilloscope with which used. Some probes contain adjustable capacitors which may be set for almost any service oscilloscope in which there is a frequency compensating attenuator. A frequency compensating probe would be useful with the gain control of Fig. 16 only while this control is set for maximum gain or at some other fixed position and kept there.

All low-capacitance frequency compensating probes reduce vertical sensitivity of the scope, usually to about 1/10 of that when no probe is used. At the same time, loading of measured circuits is reduced to about 1/10 of that when no special probe is employed. This allows continued normal performance in receiver circuits, even where there are high frequencies.

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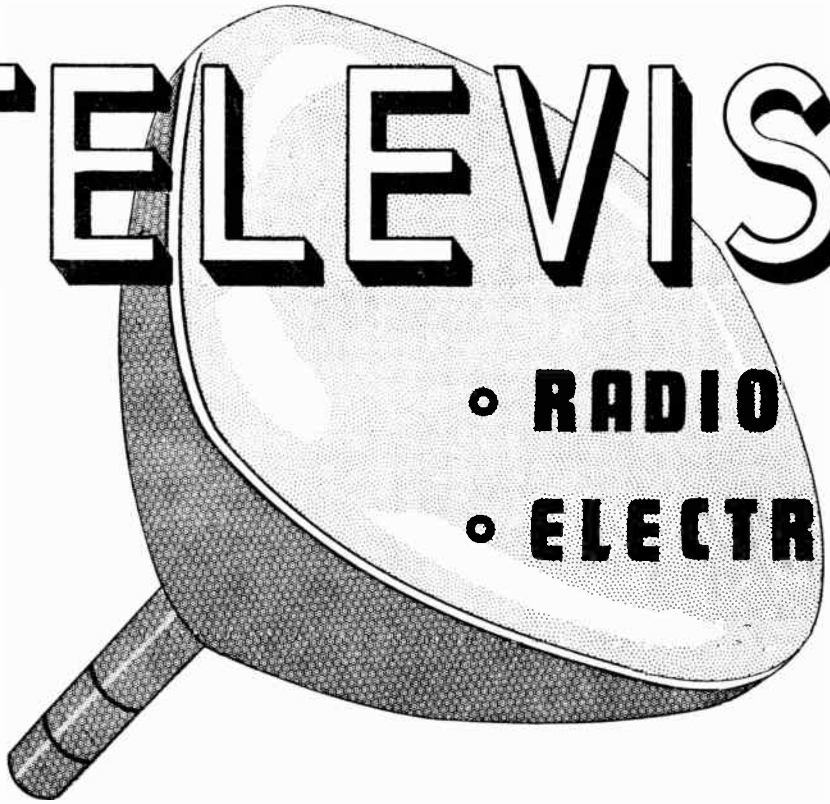

• RADIO
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LESSON 53 — OSCILLOSCOPE CONTROLS AND TROUBLES

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Lesson 53

OSCILLOSCOPE CONTROLS AND TROUBLES

SENSITIVITY. Vertical sensitivity of an oscilloscope is specified as the r-m-s alternating voltage which, at the input terminals, will produce a trace one inch high on the screen when attenuator and gain controls are adjusted for maximum deflection. Since input required for a trace one inch high always is less than one volt, it is convenient to specify sensitivities in millivolts, which are thousandths of a volt. The less the number of millivolts for one inch deflection, the greater is the sensitivity.

Sensitivities of service oscilloscopes may be anything from less than 10 to as much as 500 millivolts per inch. For general television servicing it is desirable that vertical sensitivity be at least as good as 50 r-m-s millivolts, and always better than 100 millivolts per inch. Sensitivity of 20 to 10 millivolts per inch is advantageous, but means higher instrument cost when the amplifiers provide uniform gain throughout a wide band of frequencies.

Sufficient horizontal amplification for sawtooth sweep always is designed into an oscilloscope. Horizontal sensitivity listed in millivolts per inch refers to application of voltages at the horizontal input terminals. This input is used chiefly for observing frequency responses, and for this purpose needs no better than 200 to 300 millivolts per inch.

The need for vertical amplifiers to increase signal voltages, and for attenuators to reduce these voltages, is evident from the following: To produce a trace one inch high on the screen of a typical CRT used in service instruments there must be at least 10 to 15 r-m-s volts, not millivolts, at the vertical deflecting plates. Video, sync, and deflecting voltages most often observed during television servicing are equivalent to r-m-s values from less than 0.5 up to 250 volts or more. For weakest observed voltages we need amplification of at least 20 times, and for strongest voltages need attenuation to about 1/25 for traces one inch high.

Although oscilloscope sensitivity is specified in r-m-s or effective alternating volts per inch of deflection, we seldom are concerned with r-m-s voltage values of observed waveforms. Rather we wish to know peak-to-peak values. When receiver service instructions show waveforms which should exist at certain places, such as the examples of Fig. 2, it is peak-to-peak voltages which always are listed.

To arrive at the difference between r-m-s and peak-to-peak sensitivities, let's assume that the trace of Fig. 3 is only one inch high from peak-to-peak, and that this height results from applying to the vertical input an alternating voltage whose peak-to-peak value is 1.00 volt. The amplitude of either the positive or negative peaks then will be 0.50 volt, and the r-m-s or effective value will be approximately 0.35 volt.

In this example we have one inch peak-to-peak deflection for 0.35 r-m-s input volt, or a sensitivity of 35 millivolts per inch. But in order to obtain the one inch vertical deflection, the peak-to-peak value of any input signal would have to be 1.00 volt, not 0.35 volt. Peak-to-peak sensitivity, in millivolts per inch, is about 2.8 times the r-m-s sensitivity as usually listed. For instance, were listed sensitivity to be 20 r-m-s millivolts per inch, peak-to-peak sensitivity would be about 56 millivolts per inch.

INPUT IMPEDANCE. Impedance placed across a source of observed voltage when the oscilloscope is connected to that source is specified as a combination of input resistance and input capacitance. Input resistances are from 0.5 to as much as 5.0 megohms in various service instruments.

Input capacitances range from about 25 to 50 mmf in service oscilloscopes. Reac-

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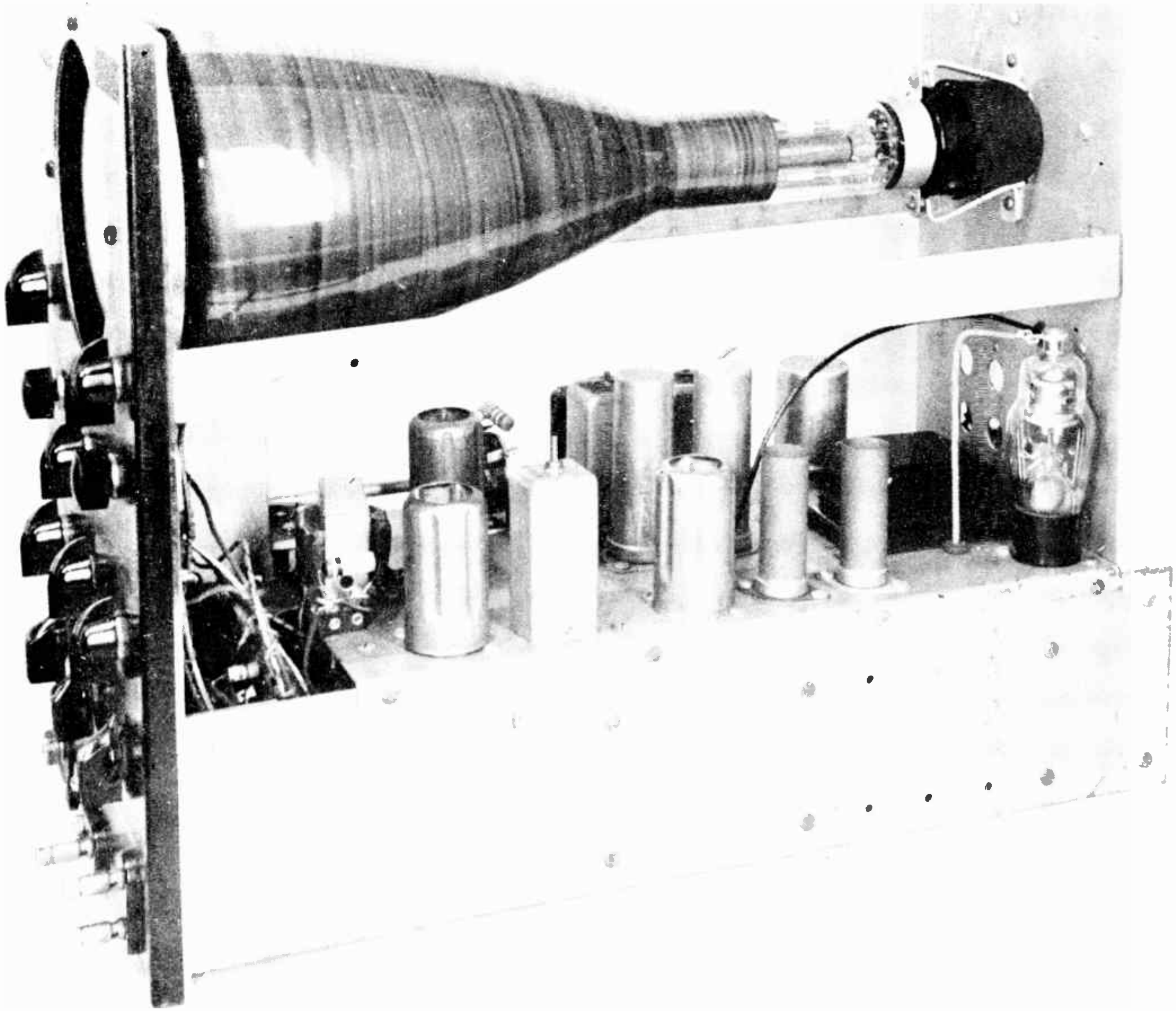

Fig. 1. The chassis of a service oscilloscope.

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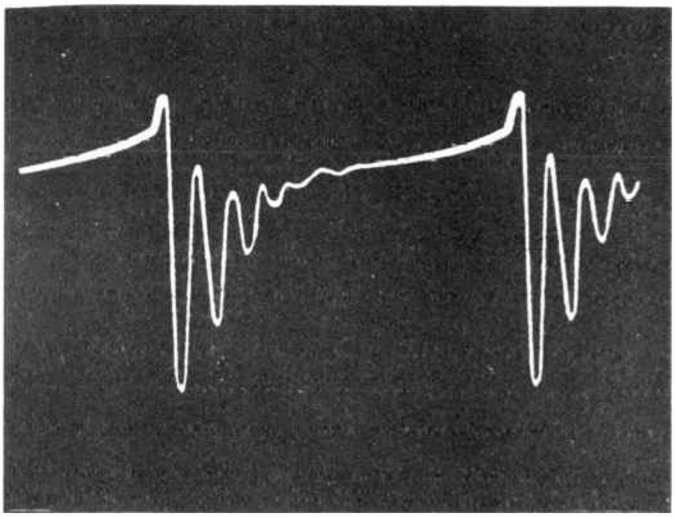

Fig. 2A.

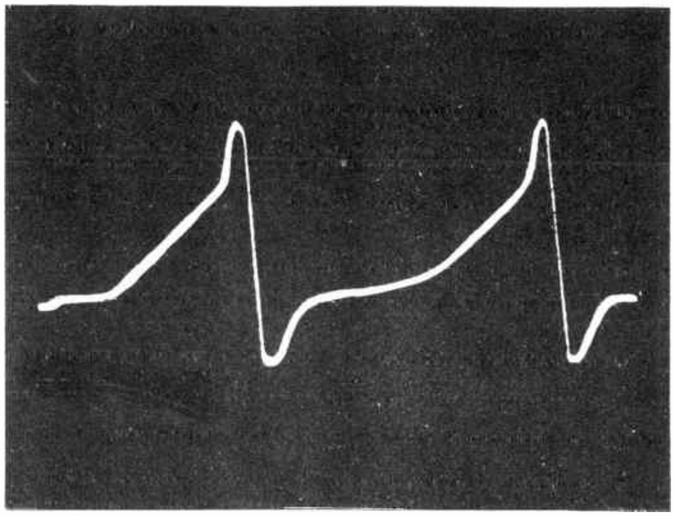

Fig. 2B.

Fig. 2. Waveform traces from a manufacturer's service manual. Voltages are 17 peak-to-peak at A, 180 peak-to-peak at B.

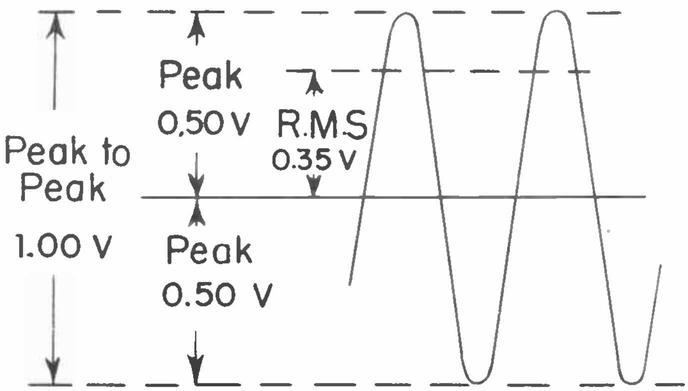

Fig. 3. Relations between peak-to-peak voltage, peak voltage, and r-m-s voltage.

tances of such capacitances at frequencies down around 100 cycles per second are 30 or more megohms, and have no effect on circuit behavior. But at the harmonic and other component frequencies existing in some pulse voltages, which may be as high as a half megacycle, these reactances drop to as little as 5,000 to 10,000 ohms.

The actual load on a voltage source is that due to input resistance and input capacitive reactance in parallel. At low frequencies the loading depends chiefly on input resistance, and at high frequencies almost entirely on input capacitance and capacitive reactance. Loading may become very heavy at high frequencies, and interfere seriously with performance of a tested circuit. Frequency compensating probes reduce input capacitance effects to about 10 per cent of that with ordinary connections, and capacitive loading is reduced in the same degree.

PUSH-PULL AMPLIFIERS. We learned earlier that voltage at one deflecting plate of a vertical or horizontal pair is inverted with reference to voltage at the other plate. This is accomplished by using vertical and horizontal amplifiers of the push-pull type. The principle of one kind of push-pull amplifier is illustrated by Fig. 4. Voltage waves shown on the diagram are of sawtooth form, as found in a horizontal system, but exactly the same amplifier connections could be used in the vertical system.

Referring to the diagram, input voltage from the gain control or attenuator is assumed to be of the polarity shown at 1. This voltage is applied to the grid of tube A. Polarity is inverted at the plate of this tube, and appears as at 2. This amplified voltage, without further change of polarity, goes through blocking capacitors Ca and Cb to one of the deflecting plates in the CRT.

There is a second tube B, or a second section of a twin tube, of the same kind and operated to have the same gain as tube A. Part of the plate signal voltage from tube A goes through resistors Ra and Rb to ground. Here we have a resistance type voltage divider which delivers to the grid of tube B a

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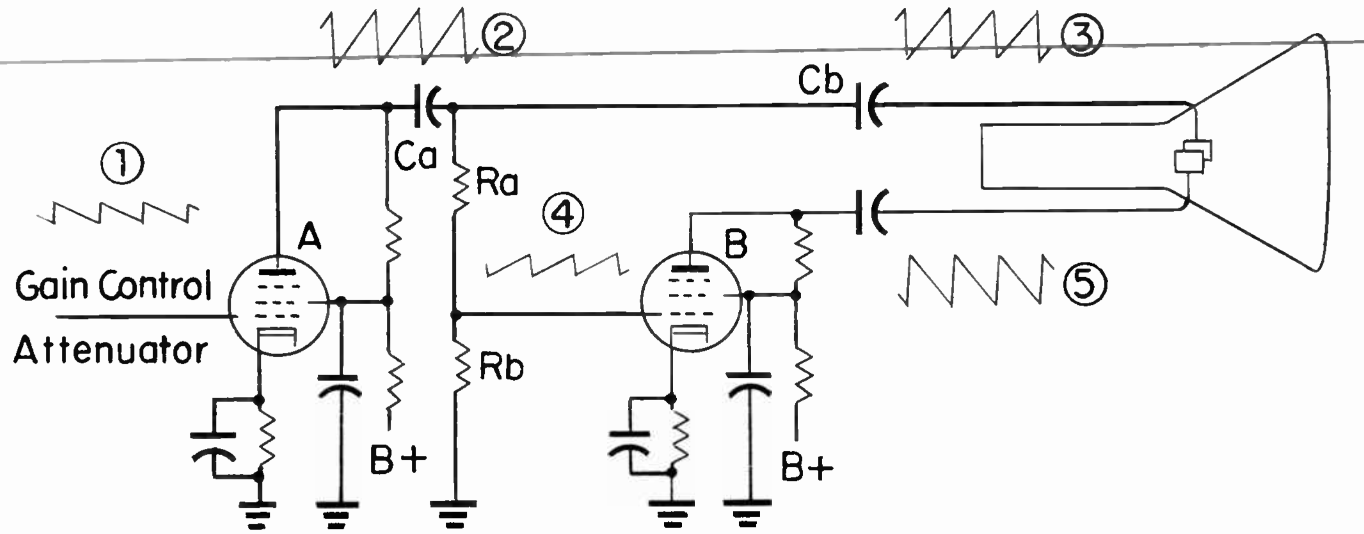

Fig. 4. Push-pull amplifier employing two tubes, one as combined amplifier and inverter.

fraction of the plate signal voltage from tube A. Resistance is greater at Ra than at Rb. The resistance ratio is such that the fraction of plate signal voltage across Rb, shown at 4, is equal in strength to signal voltage 1 at the grid of tube A.

Since both tubes have equal gains, and both receive equal signal voltages at their grids, signal outputs from their plates will be equal. But note that the signal at the grid of tube B is of opposite polarity to that at the grid of tube A, due to inversion in tube A. A second inversion in tube B produces the signal polarity at 5 for the second deflecting plate. This voltage is of opposite polarity, but of equal strength, to that shown at 3 for the first deflecting plate of the pair.

Another common type of push-pull amplifier is shown in principle by Fig. 5. Input signal voltage, 1, from the gain control or attenuator, is applied to the grid of tube A. Signal voltage at the plate of A is inverted,

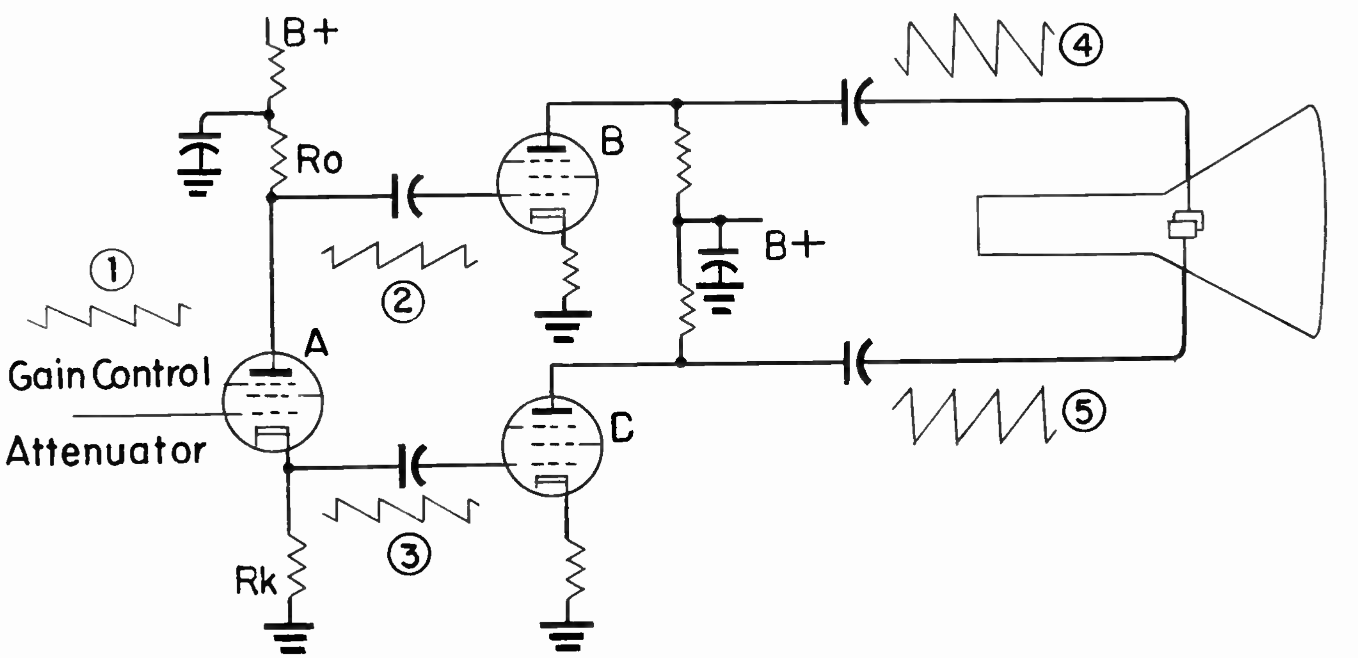

Fig. 5. Push-pull amplifier with a cathode-follower type of inverter.

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as at 2. Because plate load resistor Ro is small, maybe only 200 to 300 ohms, there is negligible gain from grid to plate. Signal voltage appears also at the cathode of tube A, in the same polarity as at the grid. This signal voltage, 3, is of the same strength as that at 2 when plate load resistor Ro and cathode resistor Rk are of equal or nearly equal values. Both resistances are small enough to allow Rk to act as a bias resistor for tube A.

Now we have signal voltage 2 at the grid of tube B, and at the grid of tube C have voltage 3 of equal strength but opposite polarity. These voltages are inverted and equally amplified by the two tubes, and go from the plates of these tubes, as shown at 4 and 5, to the two deflecting plates of a pair. Tube A is called an inverter. It contributes no gain, but provides signal voltages of opposite polarities. Tube B in Fig. 4 is a combined amplifier and inverter.

SPECIAL FEATURES AND CONTROLS. Up to this point we have become acquainted with circuits and controls found in practically all service oscilloscopes, also with some features, such as frequency compensation, found chiefly in the more costly instruments. Many other special features and conveniences may be added. A few which are in fairly common use will be described.

SYNC POLARITY REVERSAL. A sweep oscillator, depending on its type, may require either positive or negative voltage for synchronizing or triggering the start of each horizontal trace. When a signal applied to the vertical input and vertical amplifier contains both positive and negative alternations of fair amplitude, the oscillator will be triggered by alternations of suitable polarity, and opposite alternations will have no effect.

There are other signals, such as the one of Fig. 6, having strong pulses of only one polarity, which may be either positive or negative. If a scope is designed for triggering of the sweep oscillator by positive pulses, and a signal has only negative pulses, synchronization will be difficult and will require a high setting of the sync amplitude control. There is, of course, similar trouble with only negative signal pulses when the oscillator requires positive triggering.

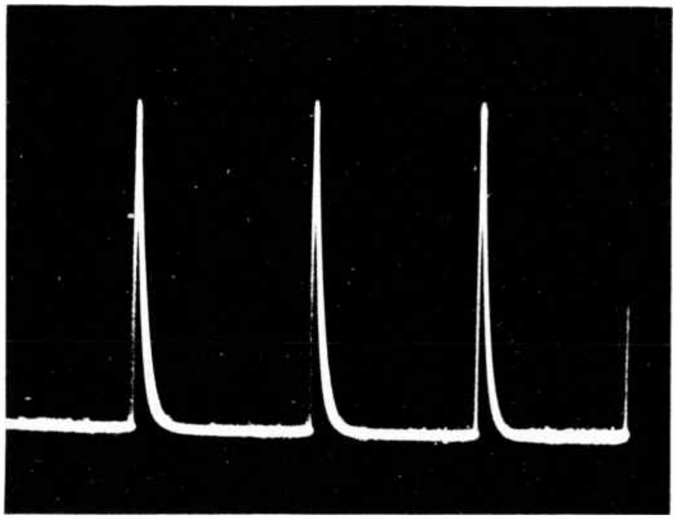

Fig. 6. There is high positive amplitude in the pulses, and negligible negative amplitude between pulses.

It is possible to provide triggering pulses or alternations of either polarity, regardless of the kind of input signal, by taking the sync voltage from either one or the other of two push-pull amplifier circuits. If alternations sharp enough or strong enough for triggering are of the wrong polarity in one push-pull amplifier, they will be of opposite polarity in the other amplifier. Either of these voltages may be taken to the sync amplitude potentiometer through a selector switch. With another method the sync amplitude potentiometer has a center tap which is grounded. The outer ends of the spot resistance connect to the two push-pull circuits, and the slider goes to the oscillator grid.

If a signal voltage contains both positive and negative alternations or pulses, and the sweep oscillator is triggered by positive pulses, part of a positive pulse or alternation will appear at the start of the trace, as at A in Fig. 7. When the oscillator is triggered by negative pulses the trace will start at the instant of a negative pulse, as at B. Most signals of irregular waveform may be more easily and certainly synchronized in one polarity than the other, and a reversing control allows using the most favorable polarity.

TRACE INVERSION. Most oscilloscopes are designed in such manner that a vertical

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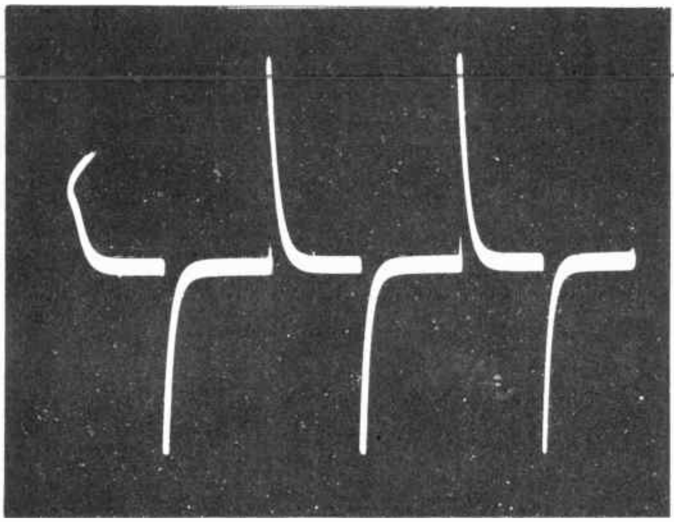

Fig. 7A.

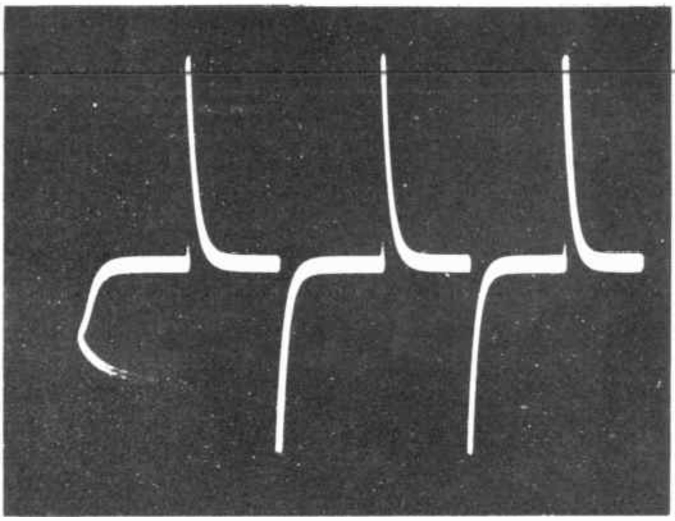

Fig. 7B.

Fig. 7. Triggering occurs from a positive pulse at A, from a negative pulse at B.

input voltage which is becoming more positive moves the beam upward on the screen of the CRT, and a voltage going negative with reference to ground moves the beam downward. Some instruments have provision for inverting the trace polarity, causing the beam to move downward during positive changes of input voltage, and upward during negative changes.

When a control of this kind is set for "positive upward", a video signal at the grid of a television picture tube will appear as at A in Fig. 8. This is because picture variations always are positive and sync pulses negative at the grid. The trace would appear as at B were it taken from the grid side of a video amplifier tube immediately preceding the picture tube, because there is inversion in every amplifier.

Were the control set for positive downward, a trace from the picture tube grid would appear as at B, and from the grid of a preceding amplifier as at A. Since signal voltages actually may be of either polarity at various stages and points in an amplifier system, trace inversion in the scope is not particularly useful when observing waveforms.

Trace inversion may be quite convenient when observing frequency responses. We are accustomed to thinking of voltage gains as

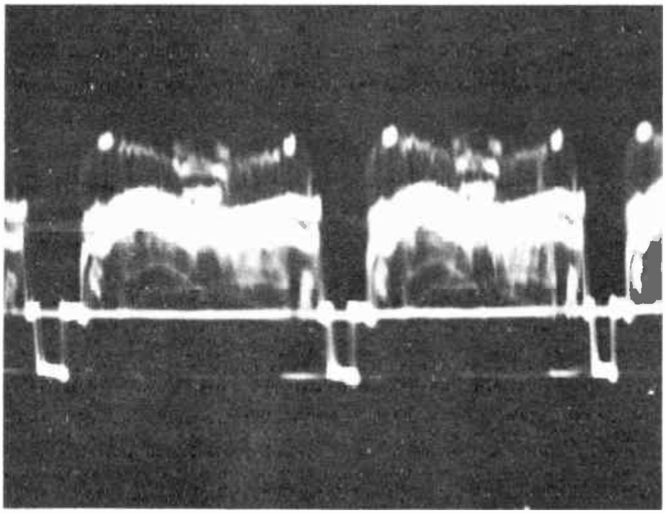

Fig. 8A.

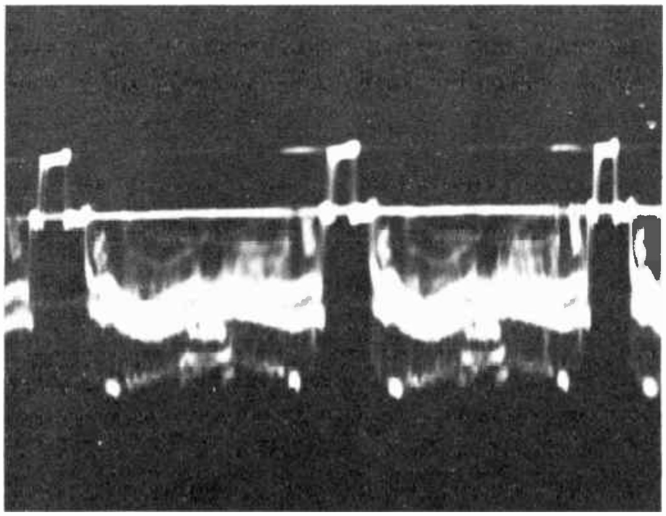

Fig. 8B.

Fig. 8. A given waveform may appear with positive alternations extending either upward or downward.

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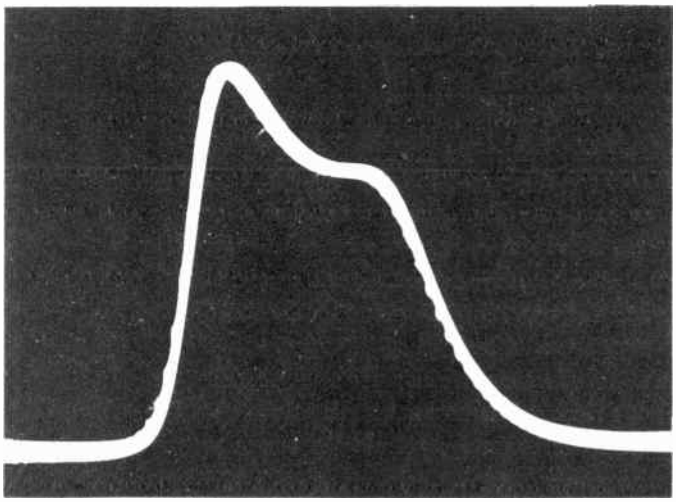

Fig. 9A.

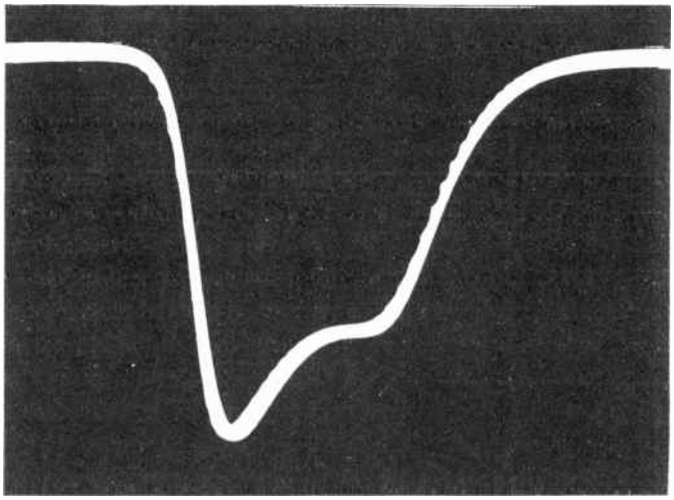

Fig. 9B.

Fig. 9. It is more natural to think of gains as extending upward, as at A, than downward, as at B.

extending upward from a base line or a line of zero gain, as at A in Fig. 9. With some combinations of sweep generators, oscilloscopes, and voltage sources, the frequency response may show gains extending downward, as at B. A trace inversion control will allow showing all frequency responses with gains upward.

Were a certain sweep generator and oscilloscope to show gain extending upward in a response taken from the video detector, gains would be downward when taken from the plate of a following video amplifier. Were there a second video amplifier, the gain again would extend upward in a response taken from its plate. Frequency responses are inverted between grid and plate of an amplifier, just as are waveforms.

Trace inversion in a scope may be accomplished by reversing switches for vertical deflecting plates of the CRT and for vertical positioning controls. With another method there are two inverter tubes or a twin tube immediately following the vertical attenuator. Switching the input to one of these tubes will allow positive alternations to move the beam upward or gain to extend upward in a frequency response. Switching to the other tube would invert the trace polarities. Only one of the two inverters is used at a time.

INTENSITY MODULATION. During normal operation of an oscilloscope, intensity of the electron beam and brightness of traces are varied by the intensity control. This control alters the grid bias of the CRT, or alters the grid voltage with respect to the cathode. The intensity control is adjusted for desired brightness of a trace, and remains without change during observation of any one waveform or frequency response.

This method of operation is quite different from that of the picture tube in a television receiver. Grid voltage or bias for the picture tube is fixed at an average value by the brightness control. Picture signal voltages cause continual variations from the average. We may say that beam intensity is modulated by picture signals applied to the grid.

When an oscilloscope has the feature called intensity modulation there is provision for applying to the grid of the CRT an external voltage. Variations of this external voltage then will alter the grid voltage, beam intensity, and trace brightness. As the external voltage goes positive it makes the CRT grid less negative and brightens the trace. As this voltage goes negative it makes the grid more negative and darkens or extinguishes the trace. Average brightness of the trace remains fixed by the regular intensity control, just as average brightness of television pictures remains fixed by the brightness control.

The simplest means for introducing intensity modulation is shown by Fig. 10. An

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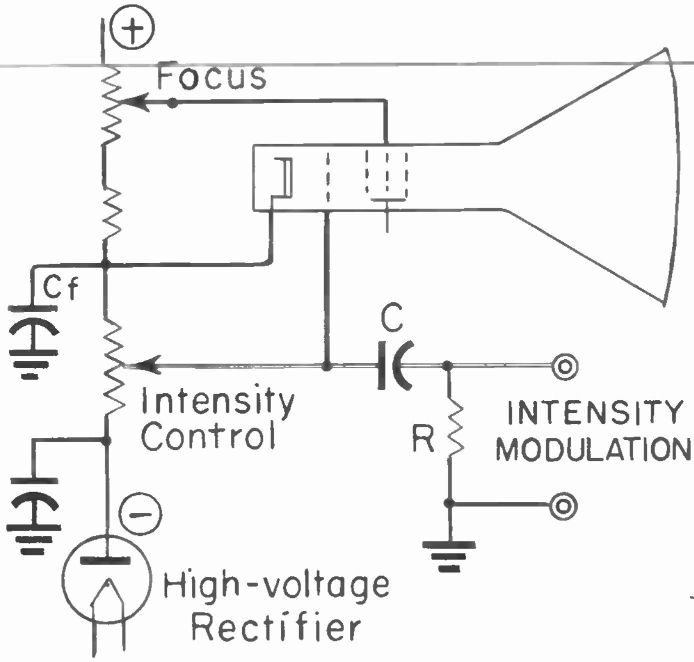

Fig. 10. A simple circuit for applying intensity modulation to the CRT grid.

alternating or pulsating voltage to be used for modulation is applied to the jacks or terminals marked INTENSITY MODULATION, and appears across resistor R. The high side of the modulating voltage goes to the grid of the CRT through capacitor C, while the low side goes through ground and a filter capacitor, Cf, to the CRT cathode. The CRT grid is highly negative with reference to ground, and rated working voltage of capacitor C must be in excess of the maximum negative grid voltage. Intensity modulation is not needed for any of the routing television service operations.

RETRACE BLANKING. When using the internal sawtooth sweep of the scope, the electron beam travels across the CRT screen to form the useful trace, then returns rapidly to its starting point to begin the following trace. While the electron beam is forming traces interrupted by retraces, the observed voltage is continuing its cycles without interruption. As a result, those portions of an observed cycle or cycles which occur during retrace intervals are not shown by the useful part of the trace.

What this means in practice is shown by Fig. 11 at A. The first negative alternation of observed voltage begins at the horizontal position for zero voltage, but the final positive alternation does not get back to the point of zero voltage before the trace ends. The remainder of this final positive alternation is occuring during retrace intervals, or during times in which the beam is flying back to the left.

The trace at A is of a low-frequency voltage, made with a correspondingly slow sweep rate. Retrace time is here but a small fraction of the total time for trace and retrace, and we lose only a small part of one cycle of observed voltage.

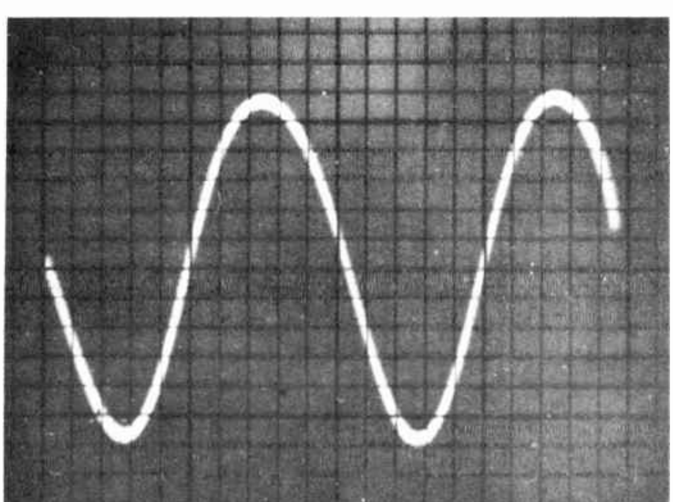

Fig. 11A.

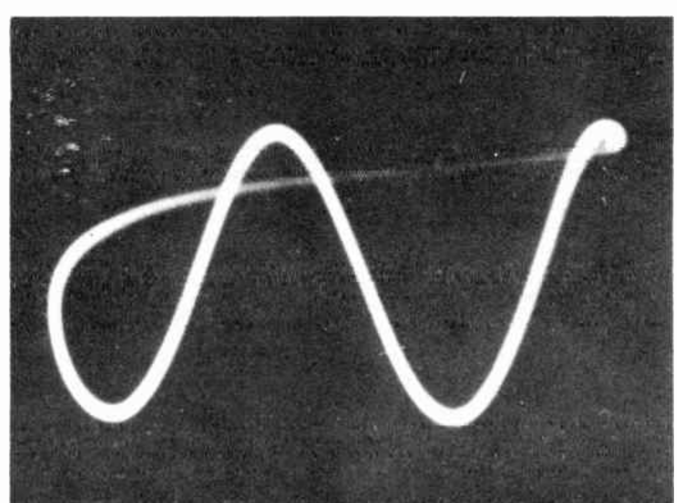

Fig. 11B.

Fig. 11.. The higher the sweep frequency, the more of an observed waveform will be lost in the retrace.

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At B is a trace of observed voltage at much higher frequency, made with a proportionately high sweep frequency. Retrace time is not altered by changes of sweep frequency. Now, because trace time is much shorter than before, while retrace time remains unchanged, the retrace time becomes a greater percentage of trace time. More of the observed wave is occuring during retraces, and does not appear in the useful trace from left to right.

At higher observed frequencies, with which there is a necessarily faster sweep rate, the beam is traveling almost as fast during the trace from left to right as during the retrace from right to left. Intensity is advanced to maintain satisfactory trace brightness at the high rate of beam travel, and we commence to see the retrace as a luminous line curving backward across the desired trace. This may be confusing.

When observing voltages of high and moderately high frequencies it is helpful to be able to blank the retrace. This requires making the grid of the CRT sufficiently negative during retrace intervals to cut off the electron beam. Negative blanking pulses for this purpose usually are derived from the sharp changes of sawtooth voltage, either at the output of the sweep oscillator or from the horizontal amplifier.

The pulses shown by Fig. 6 are of suitable form for retrace blanking. They actually were obtained by applying a sawtooth voltage from a horizontal amplifier to a small series capacitance and shunting resistance. These particular pulses were positive, but they would have been negative if taken from the cathode rather than the plate of the amplifier. In a number of oscilloscopes there is an additional amplifier tube used only for strengthening of retrace blanking pulses and for intensity modulation.

LOW-FREQUENCY SWEEPS. In television servicing we seldom need or use a sweep rate slower than 30 cycles per second, which allows observing video or pulse signals during two field periods or one frame period. Most service scopes provide sweep rates as low as 15 cycles per second, and many go lower.

In a few instruments there is provision for sweeps lasting a second or more. This is done by means of a large external capacitance used instead of capacitances regularly connected into the sawtooth generating circuit through the coarse frequency selector switch. This switch has an additional position, usually marked EXT C, at which the internal sawtooth capacitors are disconnected, while the oscillator circuit is connected to a panel terminal marked EXT C. The sweep rate is regulated by charging time of any external capacitor connected between this terminal and ground.

D-C AMPLIFICATION. In the majority of oscilloscopes there is a fixed capacitor between the vertical input terminal and the gain control or attenuator. Since a capacitor will pass only alternating voltages and currents, the oscilloscope can display traces only for alternating voltages.

When a voltage at the input terminals consists of both alternating and direct components, as, for example, in the plate circuit of a television amplifier tube, only the alternating component passes into the scope through the capacitor on the input terminal. The d-c voltage is blocked, just as any d-c voltage is blocked by capacitors in coupling circuits. With only alternating voltages entering the scope, internal amplifiers usually are made with resistance-capacitance interstage and output couplings, through which only alternating signal voltages can pass from one stage to another and eventually to the deflecting plates of the CRT.

Some oscilloscopes provide d-c amplification, meaning that the effects of a d-c component of an alternating voltage are retained from stage to stage. Methods, in general, are similar to those employed in video amplifiers of types which pass the d-c components of video signals, and with which d-c restoration is not needed at the picture tube. When the scope is to be operated with d-c amplification, a switch short circuits the capacitor which normally is in series with the vertical input.

D-c amplification systems are useful chiefly when observing voltages which have components of very low frequency. Low-fre-

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quency changes are essentially similar to slow changes in strength and polarity of a direct voltage.

SINGLE SWEEP OR DRIVEN SWEEP. In many industrial and commercial fields, but not in routine television servicing, it is desirable to observe a change of voltage which occurs only at irregular intervals. A sweep oscillator, as usually operated, does not allow tracing such "transient" voltages, because the oscillator causes sweeps to recur at regular intervals which would match a transient voltage only by chance if at all.

For observing transients, some oscilloscopes provide what is called a driven or single sweep. The action is essentially as follows: Plate and grid voltages on the sweep oscillator are adjusted to values just short of those which would allow discharge of the sawtooth capacitor when this capacitor becomes fully charged. The capacitor does not discharge, there is no horizontal deflection, and the CRT beam forms a stationary spot near the center of the screen. This spot is shifted to one side by adjustment of the horizontal positioning control.

When a transient voltage enters the vertical amplifier, this amplifier delivers to the sync amplitude potentiometer a voltage pulse which triggers the oscillator. Then the CRT beam makes a single sweep across the screen, tracing the transient voltage. After this one sweep, the beam returns to its former position and again forms a stationary spot until another transient enters the vertical amplifier and again triggers the oscillator.

DIRECT CONNECTION TO DEFLECTING PLATES. Many service oscilloscopes allow an observed voltage to be connected directly to a pair of deflecting plates instead of through one of the internal amplifiers to the plates. Fig. 12 shows typical arrangements for vertical deflecting plates. Similar connections may be provided for the horizontal deflecting plates.

The two deflecting plates are connected to a two-pole two-position switch. With this switch in one position the plates are connected to the output of the vertical amplifier, for normal operation. In the other switch position the deflecting plates are connected to external terminals or jacks to which may be applied any voltage to be observed.

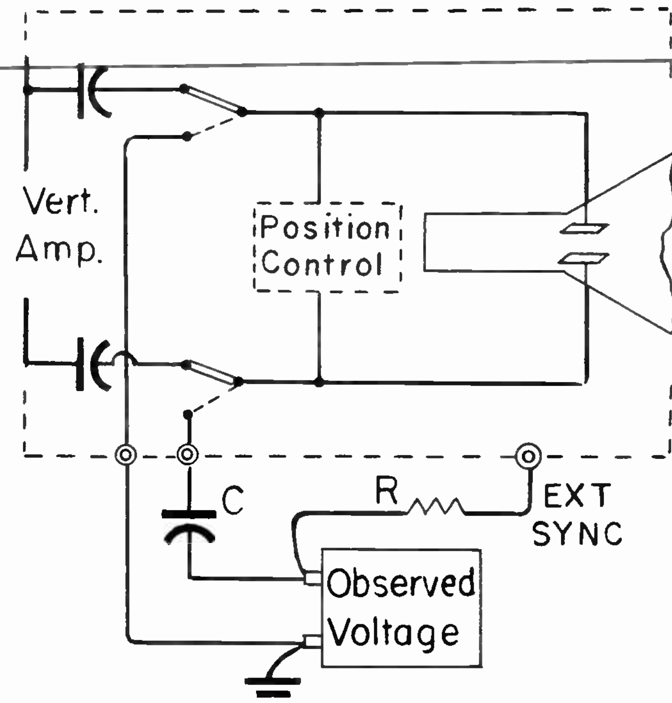

Fig. 12. External or direct connections to vertical deflecting plates.

The high side of the observed voltage may go to either terminal and either deflecting plate, with the other terminal connected to ground and the low side of the voltage source. Instead of a switch, connections between deflecting plates and scope amplifier may be made with studs or screws joined by a jumper, which is removed when direct external connections are to be made.

The high side connection for an alternating voltage should be made through a blocking capacitor C. For observing low frequencies, as well as high ones, the capacitance should be at least 0.25 mf. D-c working voltage of 400 or more will be ample for this capacitor, since deflecting plates are no more than 200 to 300 volts above ground potential with all usual designs of service oscilloscopes. The observed voltage will not go through the internal amplifier, and internal sync cannot be used. The high side of the voltage source should be connected to the EXT SYNC of the scope through resistor R of one megohm or greater resistance. Controls for horizontal sweep frequency and for hori-

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zontal gain may be employed in the usual ways.

Sensitivity will be only that of the CRT itself, without benefit of the internal amplifier. Depending on the type of CRT and on its operating voltages, 25 to 40 peak-to-peak volts of observed signal will be needed for a trace one inch high from peak to peak. Of all the sync and sweep waveforms observed on a typical television set, more than 60 per cent would have peak-to-peak voltages giving satisfactory trace heights with direct connections to vertical deflecting plates. Principal advantages of direct connection are practical elimination of frequency discrimination due to amplifiers, and greater input impedance than usually exists at the regular vertical input terminals.

OSCILLOSCOPE TROUBLES

As you will have realized, the oscilloscope is far more complex in its circuits and controls than any other service instrument in general use. This complexity leads to the possibility of various faults and troubles, which may be due to original design or to failures which are normal in long-continued operation. Faults are more noticeable in the oscilloscope than in other instruments because we see their effects on the screen of the CRT.

Some of the more common difficulties and their causes will be discussed. We are not now concerned with such characteristics as frequency response, sensitivity, and input impedance, because an oscilloscope is either good or poor in these respects. Should these characteristics suddenly become worse, the methods of trouble shooting are practically the same as in television receivers.

LACK OF SHARP FOCUS. Among the more common causes for difficulty in obtaining sharply defined trace lines are the following.

Insufficient high voltage between cathode and second anode of the CRT. The high-voltage rectifier may require replacing. High-voltage filter capacitors may be leaky. A shorted capacitor will completely cut off the high voltage.

If, instead of a very small round spot when there is no deflection, there is a short line or a small irregular figure, there may be defective filter capacitors or resistors in the high-voltage power system.

Sharp focusing may be impossible if the CRT is so far gone as to lack good emission from its cathode. This requires advancing the intensity control so far as to leave little grid bias when traces are reasonably bright.

Causes which are possible, but not probable, include voltage too low on the focusing anode (with reference to the cathode) or excessive heater voltage on the CRT.

Focusing may be affected when parts of the CRT electron gun, or steel parts close around the tube, have become permanently magnetized. This is likely only when someone has been "fooling around" with a strong permanent magnet near the CRT. Permanent magnetization usually affects positioning more than focusing.

Sharp focusing will be impossible when there is pickup of 60-cycle alternating magnetic fields by the CRT. A check for such pickup is carried out as follows.

Adjust the coarse and fine frequency controls for some simple fraction of 60 cycles. If necessary, temporarily feed a 60-cycle voltage to the vertical input while adjusting the frequency controls for three or more cycles on the screen. Make a direct short-circuiting connection with a piece of wire between the vertical input and a ground terminal on the scope. Adjust the horizontal gain for a trace no more than a half-inch long, and advance the vertical gain all the way. A wavy trace line indicates 60-cycle pickup.

If the magnetic field pickup is from the power system in the scope, nothing can be done about it other than redesigning. A power transformer, or its windings and magnetic fields, must be so positioned or oriented in relation to the CRT as to have little or no effect. Most of the trouble is from fields due to voltages for the high-voltage rectifier and power supply wiring or parts. Heater voltage is too low to cause any trouble, and there

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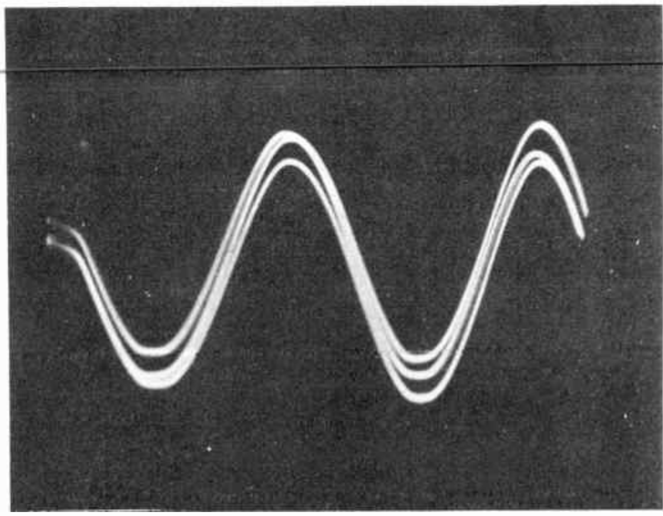

Fig. 13A.

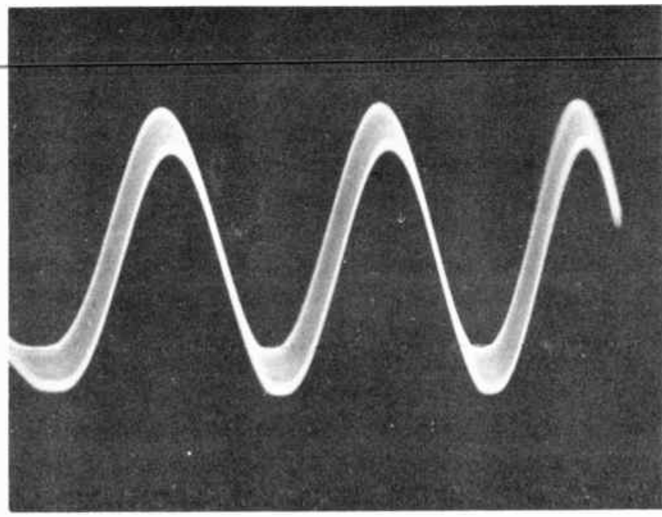

Fig. 13B.

Fig. 13. Effects on traces when there is strong pickup of 60-cycle magnetic fields.

is unlikely to be troublesome field radiation from the low-voltage B-supply.

A bad case of 60-cycle field pickup is illustrated by Fig. 13. At A the observed frequency is 360 cycles, an exact multiple of 60 cycles. You can see the additional trace lines where the 360-cycle trace is being raised and lowered a little ways. With the observed frequency increased to about 5,000 cycles the separated 60-cycle wavering no longer can be seen, but the entire trace is blurred and widened excessively at certain places. The two traces of this figure illustrate extreme conditions. Field pickup ordinarily is bothersome only when a high-sensitivity scope is used with high vertical gain.

Pickup from external magnetic fields sometimes is lessened by moving the scope to a slightly different position, or by turning it to a different position. This trouble is reduced also by connecting one or more ground terminals of the instrument to a good ground, such as a cold water pipe, leading into the earth.

POSITIONING DIFFICULTIES. When a spot or trace cannot be centered on the CRT screen, or requires turning a position control almost to the end of its range in one direction, the trouble usually is caused by a stray field. This field may be magnetic or electrostatic, but usually is due to permanent magnetization of the CRT electron gun or supporting metal. In some oscilloscopes the CRT is enclosed from its base nearly to the face by a metal shield whose purpose is to protect the tube from external fields.

Tube shields are made of iron alloys which carry magnetic lines of force with little opposition, but which do not tend to retain permanent magnetism. Initially the shield is completely demagnetized, but may become sufficiently magnetized to deflect the electron beam if carelessly handled. Such shields must be grounded to the chassis in order that they may be effective against electrostatic fields. An oscilloscope case made of steel is partially effective against external magnetic fields, and a case of any kind of metal excludes external electrostatic fields when the case is grounded.

Demagnetization of parts within a CRT or of any supports made of iron or steel requires special equipment. The magnetized parts are placed within a field produced by alternating current in a large coil. Then the current and its field are gradually reduced to zero, or else the affected parts are slowly withdrawn from the field. Offsetting of the beam and traces has been corrected by some technicians who place a single ion trap magnet on the tube base and adjust the position of this magnet to center a trace while the positioning controls are at the middle of their adjustment ranges. For this purpose it is desirable to use a weak or discarded trap magnet.

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It is, of course, entirely possible that difficulty in centering is due to poor connections or defective resistors or controls in the positioning circuits. Sudden shifting of a trace, with more or less gradual return to the original position, usually is caused by temporary variations of supply line voltage.

NON-LINEAR SWEEP. In the sawtooth output from a sweep oscillator and horizontal amplifier the voltage which charges a capacitor in the oscillator circuit should increase at a uniform rate, as at the left in Fig. 14.

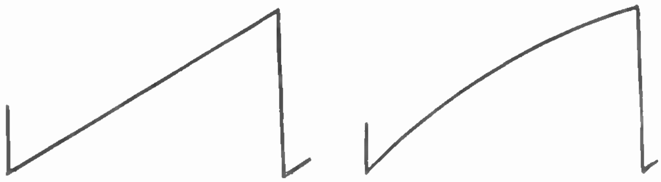

Fig. 14. Linear and non-linear sawtooth voltages.

But when any capacitor is charged through a resistance from a source of constant voltage, the rate of charge and increase of capacitor voltage are more rapid at the beginning of charge, and then slow down, as shown by the curve at the right. The sawtooth at the left is linear, and the one at the right is non-linear.

Horizontal deflecting voltage is made of satisfactory linearity by using only the first portion of the charging curve. The charge is cut off and a discharge (for retrace) is begun before the charging curve commences to turn appreciably. If this is not done, the electron beam in the CRT will move more rapidly at the left than at the right in all sweeps. This will spread the left-hand side of all traces and will compress the right-hand side.

A non-linear trace is shown by Fig. 15. To check an oscilloscope for linearity, bring four or more cycles of an observed voltage onto the screen. If horizontal distances between peaks are equal all the way across, the sweep is linear. Otherwise it is non-linear. As a rule, there is greater non-linearity at low sweep frequencies than at high ones.

Non-linearity may result also from unbalance in push-pull amplifier circuits. This might be due to a weak tube on one side or the other, to leaky coupling or bypass capacitors, or to resistors which have changed in value during use. In many scopes there are one or more adjustments for balancing the outputs of two push-pull amplifiers. Such adjustments may alter the grid biases, or they may be in the voltage divider system through which grid voltages go to an inverter tube.

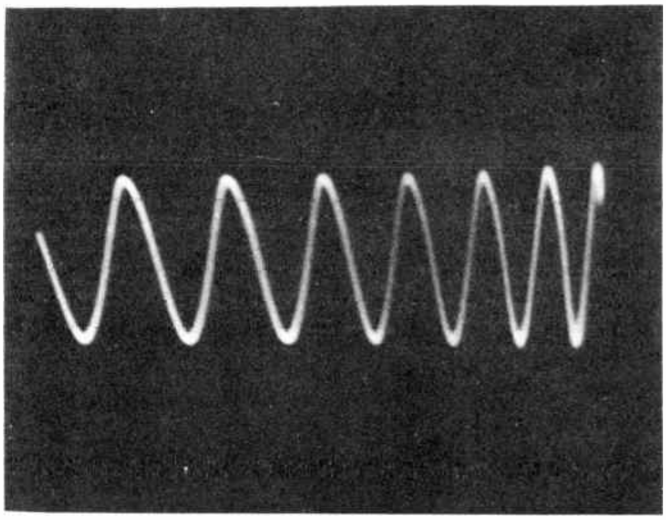

Fig. 15. The effect of non-linear sweep on an oscilloscope trace.

A moderate non-linearity causes no particular difficulties, especially in waveform observations. Excessive non-linearity can distort the appearance of television frequency responses. It is, however, common practice to measure the actual frequency at various points along a response curve. Then, even though the frequency is not varying uniformly all across the curve, alignment still can be made for the desired kind of response at all frequencies.

HIGH-VOLTAGE PRECAUTIONS. Never do any work or make any adjustments on the parts inside an oscilloscope unless the power cord plug is out of the wall receptacle. Do not depend on merely turning off the power switch of the instrument. High-voltage filter capacitors will retain charges only when there are opens in the voltage divider system which leads to ground. Even so, it is safe to discharge these capacitors by momentarily connecting an insulated wire, with tips bared, from the terminals to chassis ground.

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With usual oscilloscope design the maximum high voltage is negative to ground, but is just as dangerous as an equal positive voltage. Highest circuit voltages are at the CRT grid, at the cathode, at the heater (connected to the cathode) and at the intensity control potentiometer. The next highest voltages are at the focusing anode and focusing control. Lowest voltages in the CRT circuits are at the second anode, the deflecting plates, and the positioning controls.

CRT REPLACEMENT. Any of three conditions indicate that the cathode-ray tube is approaching the end of its useful life. They are: (1) Lack of trace brightness at low sweep rates with the intensity control advanced nearly all the way. (2) Streaks and spots on the screen. (3) Inability to obtain sharp force anywhere along trace lines. Other than heater burnout, the CRT deteriorates due to gradual reduction of cathode emission and to failure of the screen material. The screen may fail prematurely if you habitually use traces brighter than are necessary, or allow bright spots or very short lines to remain for long periods.

To replace the CRT it is necessary first to remove the chassis from the case or cabinet of the instrument. Almost always the chassis is secured by two or more screws passing through the back of the case into the chassis, and removable from the back. Also, in most instruments, there are a number of screws around the extreme outer edges of the front panel. These thread into a flange or brackets on the front of the case. When all fastening screws are removed, the chassis, with front panel attached, will pull out through the front of the case.

The face end of the CRT may slide into a cylindrical cushioned support on the front panel, or it may be held by some form of cushioned clamp. Always it must be possible to rotate the entire tube for correct alignment of horizontal and vertical trace lines with respect to horizontal and vertical case dimensions. The base of the CRT may support the socket, just as the base of a television picture tube supports its socket. The base then will be supported by some form of clamping device which allows the tube to rotate when loosened. In some designs the socket mounts in a bracket or vertical subpanel, and supports the base of the tube. Then the socket is rotatable.

The entire CRT must be rotated for horizontal and vertical alignment of trace lines because, with electrostatic deflection, all of the deflecting elements are within the tube. Make the alignment with no vertical input, but with internal sweep and with horizontal gain advanced enough to make a straight trace extend all across the screen. Note the error, if any, then pull the power cord plug. Rotate the tube in the required direction and again check the trace alignment. Do not rotate the tube while power is turned on. There is no separate alignment for vertical, and it is not needed. CRT's are so constructed that horizontal and vertical deflections are very nearly at right angles to each other.

ELECTROSTATIC DEFLECTION IN TELEVISION. Much that we have learned about oscilloscopes applies also to small television receivers having electrostatic deflection and focusing for their picture tubes. The majority of such receivers use the 7JP4 picture tube, whose base connections are shown by Fig. 17. The base is a medium-shell diheptal 12-pin type on which are positions for 14 pins. Positions 6 and 13 are vacant. Internal connections from pins 4 and 12 are used only during manufacture of the tube. The heater is operated at the usual 6.3 a-c volts and 0.6 ampere. As indicated by the final numeral "4" in the type number, the 7JP4 has the number 4 white phosphor, as used in other picture tubes.

The voltage divider system for the receiver high-voltage power supply usually is similar to voltage dividers in oscilloscopes. However, the maximum high voltage on the second anode and deflecting plates of the picture tube is positive with reference to ground, instead of negative as in nearly all oscilloscopes.

In these television receivers the brightness control is like the intensity control of the oscilloscope, the focusing control is unchanged, and centering controls are like the positioning controls in an oscilloscope. Each pair of deflecting plates is fed from a push-

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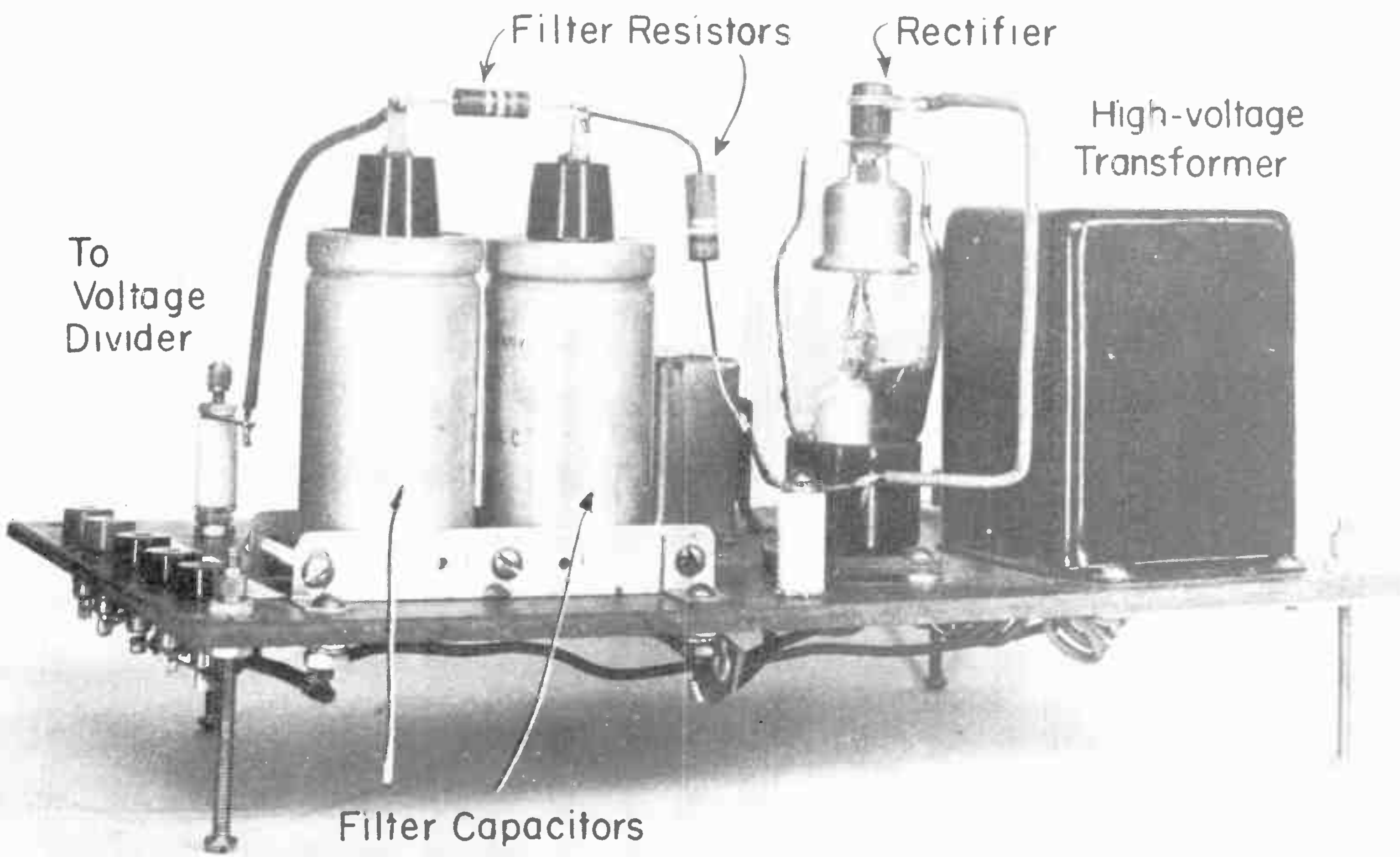

Fig. 16. A high-voltage power supply used for checking the performance of oscilloscope circuits.

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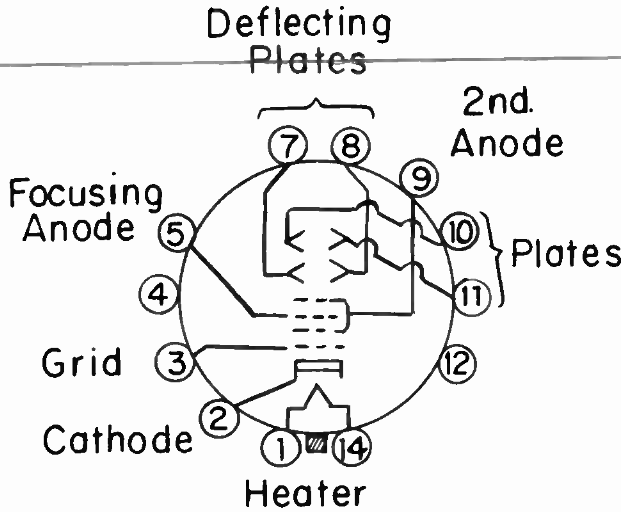

Fig. 17. Base connections of the 7JP4 electrostatic picture tube.

pull amplifier operating on the same general principles as explained in this lesson.

All of the high voltages in the electrostatic-deflection television receivers are higher than in most service oscilloscopes. It is common practice to apply about 5,000 volts positive to the second anode. Voltage on the focusing anode is about 30 to 40 per cent of that on the second anode, when measured as positive in relation to the cathode. This ratio of focusing voltage is found also with oscilloscope CRT's.

Sensitivity of the 7JP4 picture tube, at the deflection plates, is the same as that of the 7JP1 oscilloscope tube, and deflections per volt would be the same were both tubes operated with equal voltages on their second anodes. Actual sensitivity is inversely proportional to second anode voltage in all picture tubes and in all oscilloscope tubes. For example, with 3,000 volts on the second anode of any tube, sensitivity is only half as good as with 1,500 volts. With 5,000 volts on the second anode of a 7JP4 picture tube, sensitivity would be only 40 per cent as good as with 2,000 volts on this tube or on the second anode of a 7JP1 oscilloscope tube.

The face that deflection sensitivity improves with lower voltages on the second anode does not mean that high sensitivity thus attained will improve the overall performance. Unfortunately, the lower the second anode voltage with reference to the cathode the more likely we are to have fuzzy traces which lack brilliance. Conditions are exactly the same as with television picture tubes; higher voltages on the second anode increase brilliance and fine definition, while they decrease the deflection distance for any given deflecting voltages.

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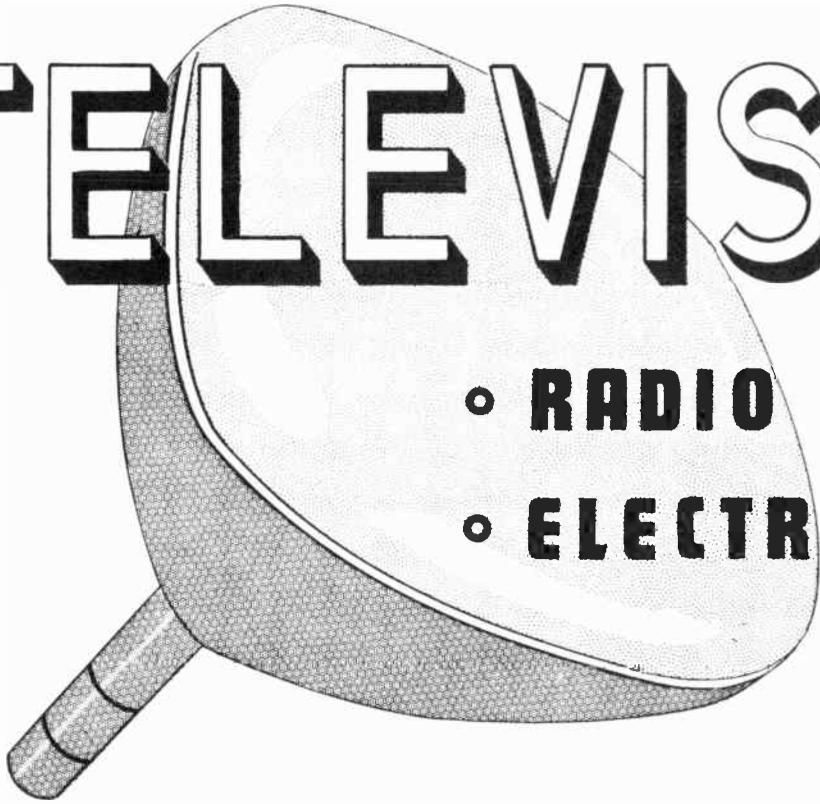

TELEVISION

- RADIO
- ELECTRONICS

LESSON 54 — TESTS AND MEASUREMENTS WITH OSCILLOSCOPES

Coyne School

practical home training

Chicago, Illinois

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Lesson 54

TESTS AND MEASUREMENTS WITH OSCILLOSCOPES

Were you to ask a television technician whether his oscilloscope is more useful in checking frequency responses or in observing waveforms, he might tell you this: The hardest jobs in television trouble shooting are found in the sync, sweep, and deflection circuits, and the only way to see what actually is happening in these sections is to bring the waveforms onto an oscilloscope. A good job of alignment can be done without an oscilloscope, by using a vacuum tube voltmeter, although a better job can be done with an oscilloscope.

Fig. 1 shows a few waveform traces taken from various points between the video detector and deflecting coils of a certain receiver in good operating condition. Any considerable variations, either in shape or in peak-to-peak voltage, would indicate troubles which can be identified and located by the particular manner in which actual traces depart from those known to be correct.

Fig. 2 shows where waveform traces can and cannot be obtained. The service oscilloscope will not form useful traces at observed frequencies in excess of a few hundred kilocycles. This excludes carrier and intermediate frequencies, which exist in sections of the receiver enclosed within broken line A. Traces can be taken after the i-f signals are demodulated by the video detector, which means from all points enclosed by broken lines B and C.

It is important to keep in mind that no demodulated video signals will exist in parts enclosed at B unless a carrier signal is coming through the i-f amplifier, to be demodulated by the video detector. Therefore, without special equipment furnishing the equivalent of modulated carriers, waveform traces can be obtained at B only while receiving a regularly transmitted signal.

The vertical and horizontal sweep oscillators generate their own oscillating currents and voltages, whether or not an external signal is being received. A received signal merely synchronizes or triggers the oscillators, to make their actual operating frequencies fall into step with received sync pulses, and remain so. Consequently, waveform traces may be taken from all parts enclosed at C even though no external signal is being received.

When preparing to observe waveforms from parts enclosed at B of Fig. 2, first tune in a picture and make the usual adjustments for best possible reception. If possible, keep the pictures synchronized by adjusting vertical and horizontal hold controls. In order that observed waveforms may indicate true conditions as you follow through the circuits, do not change stations or channels, do not alter the contrast control, and do not vary the fine tuning control during any one series of observations.

If you commence the work with a low-capacitance frequency compensating probe, continue with the same probe. This applies to all waveform observations, anywhere. Adjust the internal sweep rate of the scope to bring at least two cycles of observed voltage onto the screen. Often it is easier to examine waveforms by bringing in three cycles, then enlarging and centering the middle cycle.

Vertical and horizontal waveforms taken from the same point in a receiver are shown by Fig. 3. By vertical waveforms we mean those which include one or more field periods or vertical deflection periods. For such observations the coarse frequency will be set for a range including 20, 30, or 60 cycles. Then fine frequency, in connection with sync amplitude, is adjusted for steady traces.

A horizontal waveform is one showing clearly one or more horizontal line periods. The coarse frequency is set for a range that includes 15,750 cycles per second for observing one line period, for a range including 7,875 cycles to observe two line periods, or including 5,250 cycles for three line periods.

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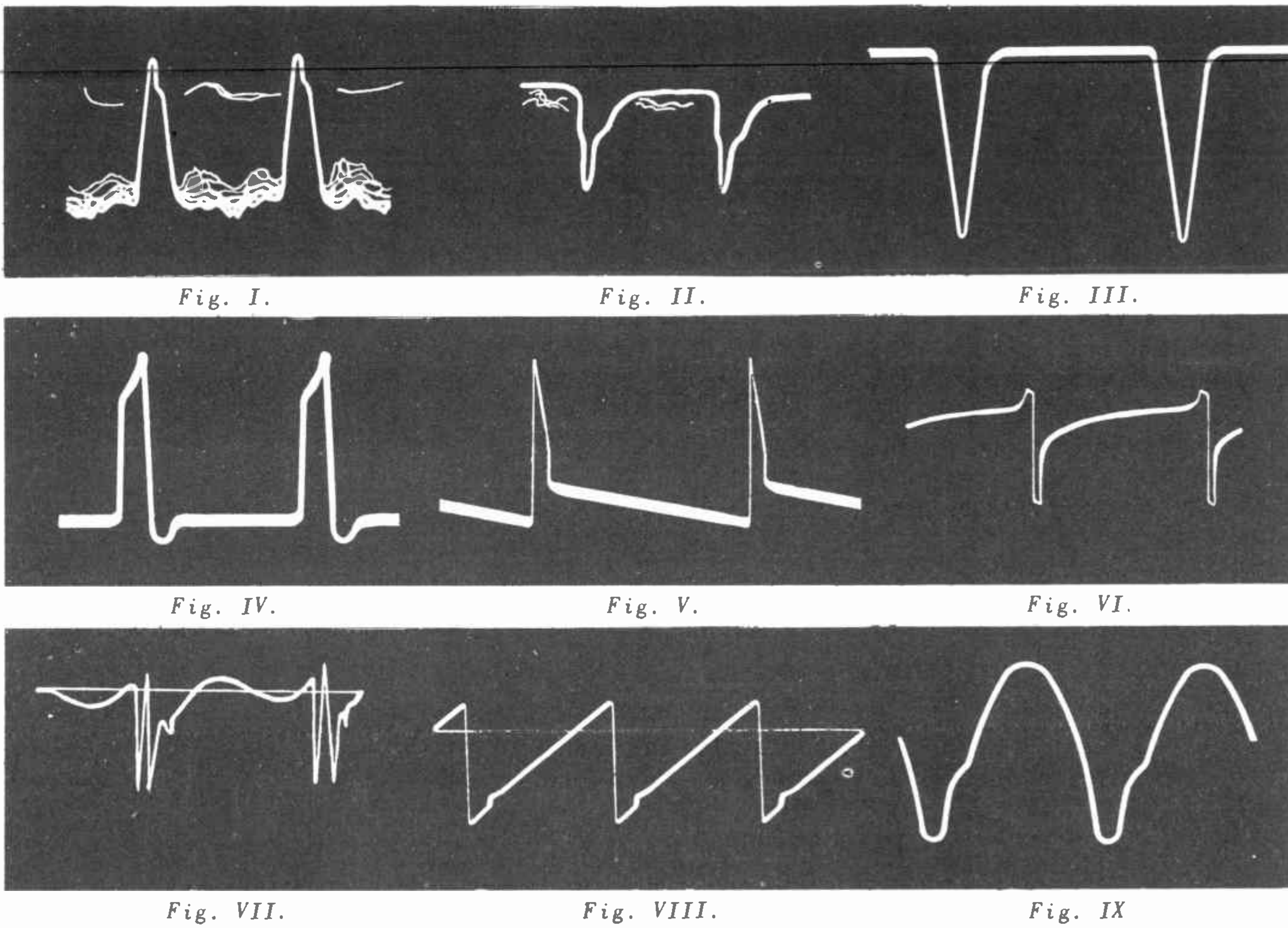

Fig. 1. These are normal waveforms observed between the video detector and deflecting coils of a television receiver.

Then fine frequency and sync amplitude are adjusted for steady traces.

You may take both vertical and horizontal waveforms only from points between the output of the video detector and either the picture tube grid-cathode circuit or the end of the sync section. At the end of the sync section, vertical and horizontal sync signals are separated and fed to their respective sweep oscillators. You cannot obtain vertical waveforms anywhere between the grid of the horizontal sweep oscillator and the horizontal deflecting coils, for here there are nothing but horizontal timing signals. Neither can you obtain horizontal waveforms anywhere between the grid of the vertical sweep oscillator and the vertical deflecting coils, for here there are only vertical timing signals.

At A in Fig. 3 is a vertical waveform from the cathode of a tube in the sync section of a receiver, taken with a sweep frequency of 30 cycles per second. At B is a horizontal trace from the same point, taken with sweep frequency of 7,875 cycles per second. These sweep frequencies are known only because two cycles of observed voltage appear on the screen, and we know that there will be two cycles only when sweep frequency is half the observed frequency. Often you will see certain sweep frequencies specified in service instructions. This does not mean that you should measure the sweep frequency, it indicates only whether the traces are for vertical or horizontal periods.

Observed waveforms may differ slightly from those shown in service instructions without indicating faulty performance in the

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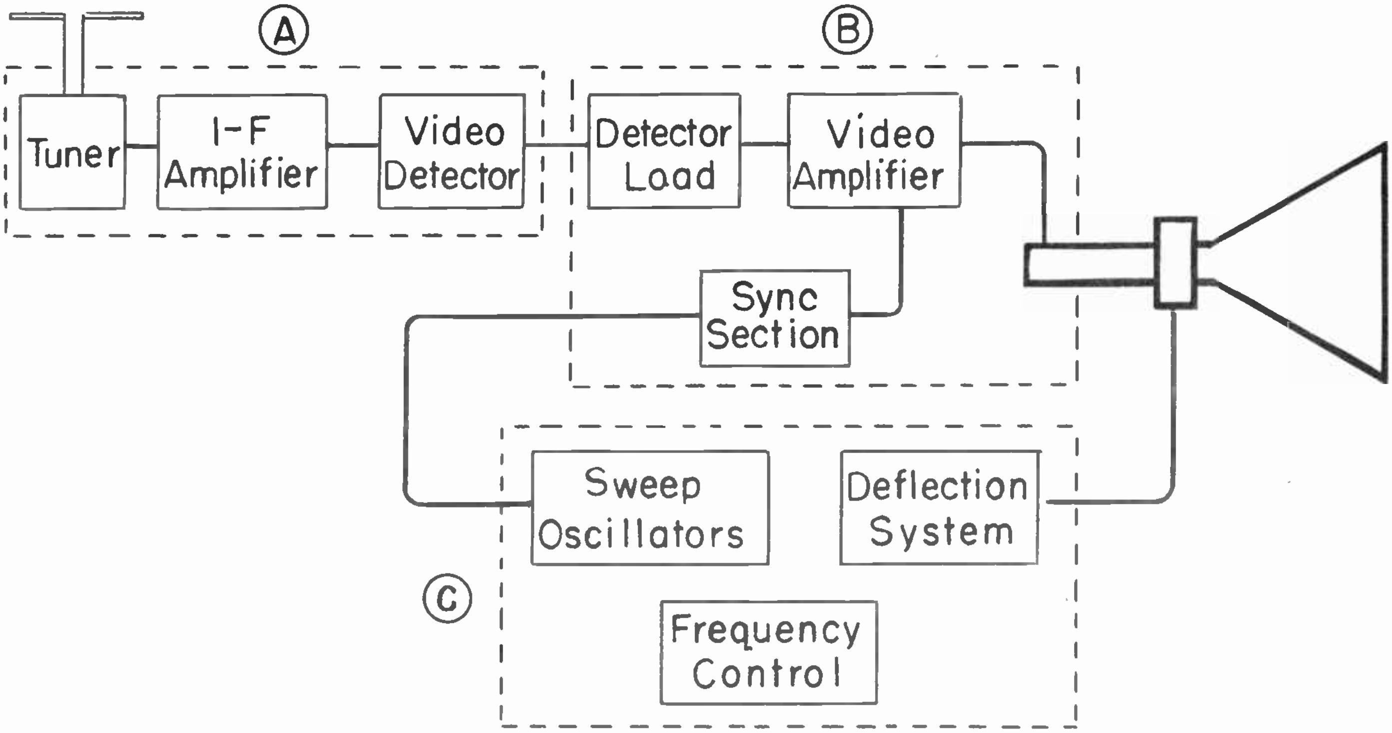

Fig. 2. Sections of a receiver in which waveforms can and cannot be obtained.

receiver. There are many reasons for such variations. First, in sections of the receiver enclosed at B of Fig. 2 the observed waveform will be affected by the received signal. Not all stations transmit identical forms of sync pulses, although all have similar effects, and all cause traces which are generally similar.

Second, tubes and other circuit elements in receivers of the same make and model will not have identical characteristics. This can cause minor differences in waveforms, but not enough to interfere with trouble shooting unless characteristics of some components are decidedly wrong - and then there is real trouble. Setting a contrast control too high, or wrong setting of a fine frequency control may seriously distort a waveform. It is to avoid such distortions that a picture should

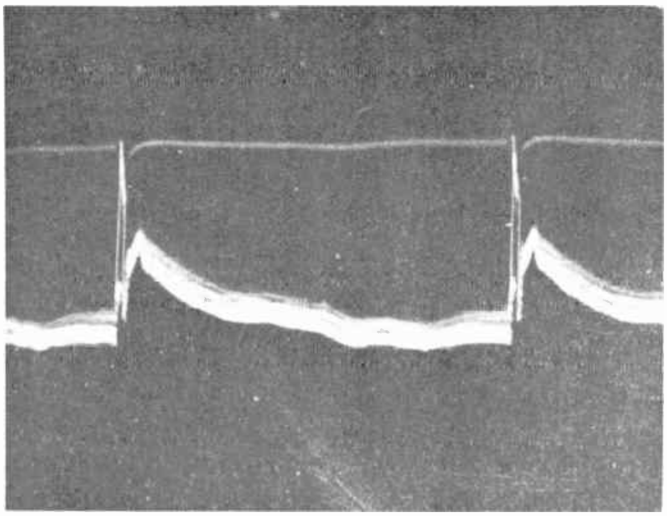

Fig. 3-A.

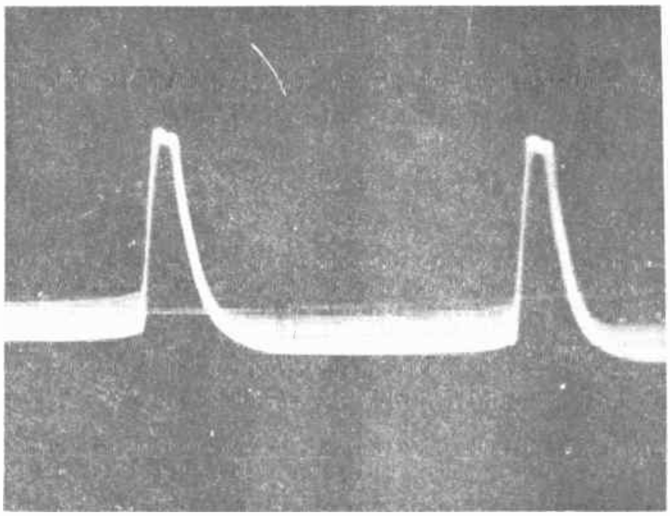

Fig. 3-B.

Fig. 3. To change from vertical to horizontal waveform observations it is necessary only to change the sweep frequency of the oscilloscope.

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be tuned in before commencing waveform observations.

Waveform distortion may occur in your oscilloscope, especially if it has narrowband frequency response or suffers from frequency discrimination. If the scope is sufficiently sensitive, and has a frequency-compensated attenuator, it is advisable to take all waveform voltages through the low-capacitance probe.

Fig. 4 shows the waveform from the plate of a sweep oscillator, where there are no components of very high frequencies. The trace at A of from a scope of limited sensitivity, with only a potentiometer for vertical gain control, used with a plain shielded cable. The instrument is of good quality, but not originally designed with television servicing in mind. At B is the same waveform taken with an oscilloscope designed for good performance in television trouble shooting. Because only moderate frequencies are involved, there is not enough difference between the traces to cause any confusion during servicing.

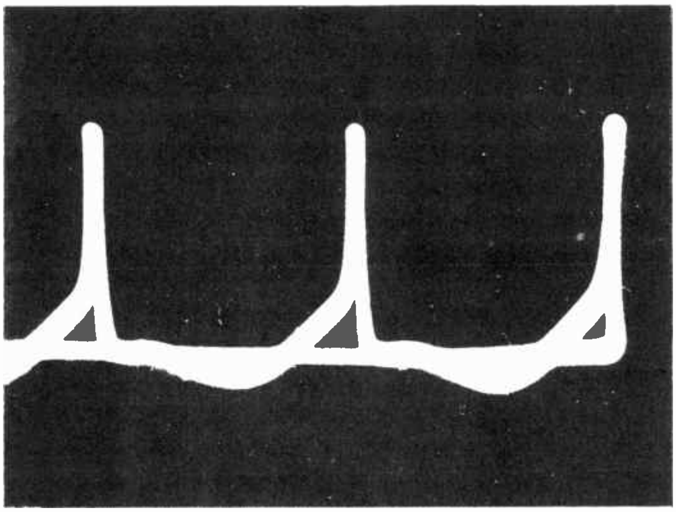

Fig. 4-A.

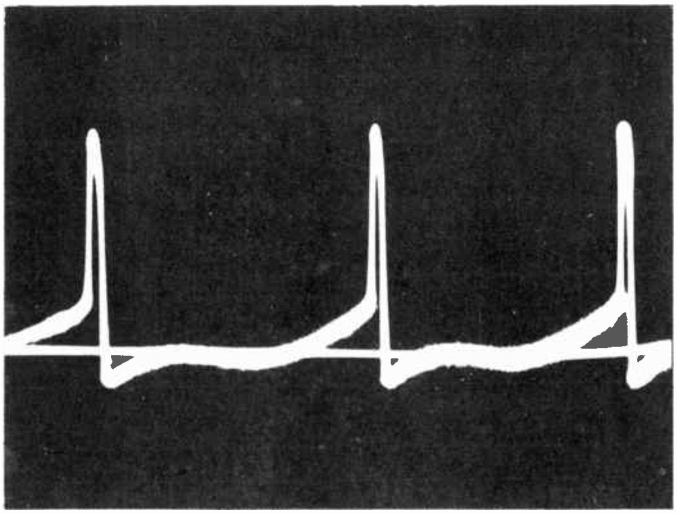

Fig. 4-B.

Fig. 4. The appearance of a waveform may be altered by characteristics of the oscilloscope.

WAVEFORMS AT HIGH VOLTAGES. The capacitor in series with the vertical input of the scope, inside the instrument, ordinarily is rated for 400 or more d-c working volts. Ratings as high as 600 to 1,000 d-c volts are found in some scopes, but in older designs the rating may be only 200 volts. If a d-c voltage or a peak voltage in excess of the capacitor rating is applied to the vertical input, the internal series capacitor may puncture and allow serious damage within the instrument.

Plate voltages of some amplifiers and other tubes may be high enough that, with added peaks of a component signal, the voltage may exceed the rating of the input capacitor of the scope. If there is the slightest doubt about capacitor rating, make connections to the vertical input only through a series external paper capacitor rated for at least 600 volts. This external capacitance need be no more than 0.25 mf to pass signals without appreciable attenuation.

Fig. 5 shows several points in sweep and deflection circuits where voltages are so high as to prohibit connections to the vertical input of any oscilloscope through either a direct or a low-capacitance cable probe. At the plate of the horizontal output amplifier (1) pulses nearly always are in excess of 4,000 volts, and at the plate of the high-voltage rectifier (2) would be in excess of 10,000 volts for most receivers. At the second anode or ultor connection on the picture tube (3) there is d-c voltage nearly as high as at the plate of the high-voltage rectifier.

The damper tube smooths the waveform of sawtooth current in horizontal deflecting coils. At the damper plate (4) and at the connected end of the horizontal deflecting coils are pulses usually exceeding 1,000 volts. In

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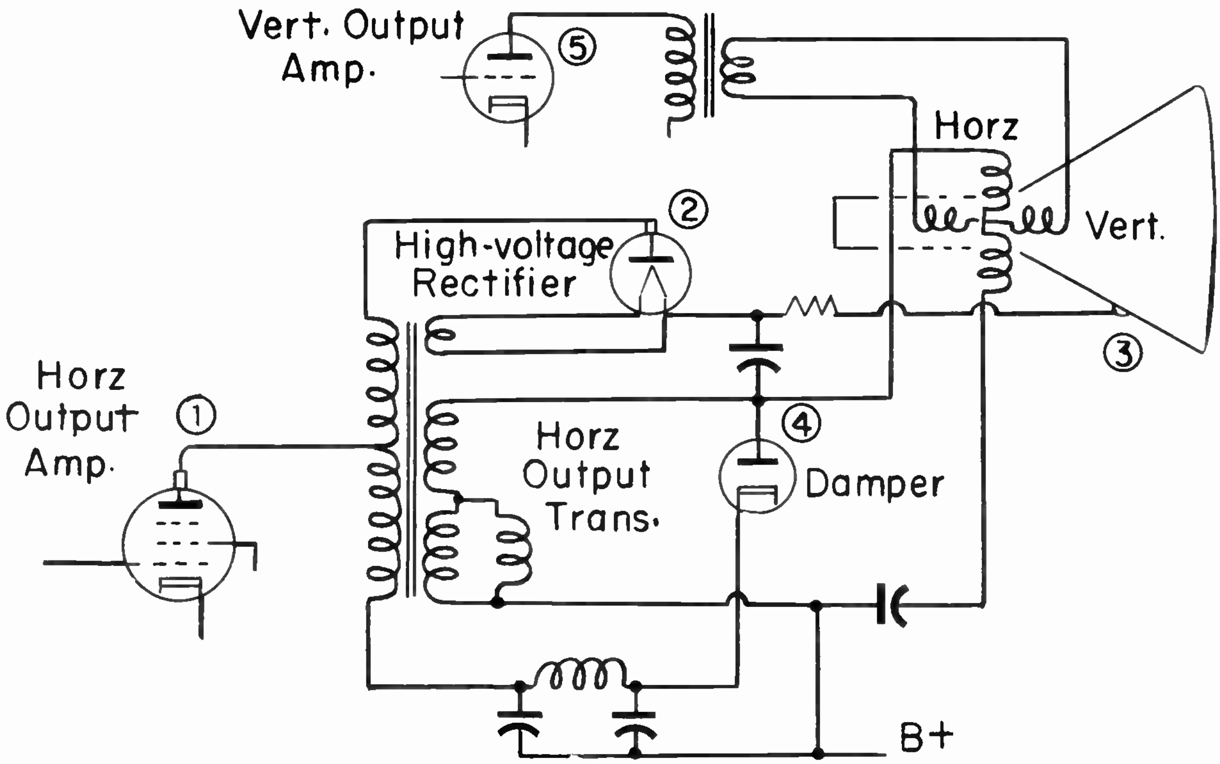

Fig. 5. Points at which it is unsafe to make waveform observations without suitable equipment and precautions.

some receivers there may be peaks of around 2,000 volts at the plate of a vertical amplifier (5).

There are several ways in which high voltages may be reduced for waveform observation without damaging the oscilloscope. The best way is by means of a capacitance voltage divider, whose principle is illustrated at A in Fig. 6. Across the source of high voltage are a large and a small capacitance in series. The smaller capacitance has high reactance, and across it there will be a large drop of alternating voltage. The larger capacitance has relatively small reactance, and across it there will be a proportionally small voltage drop. Total applied voltage divides proportionately to the capacitive reactances.

The small fraction of total voltage which

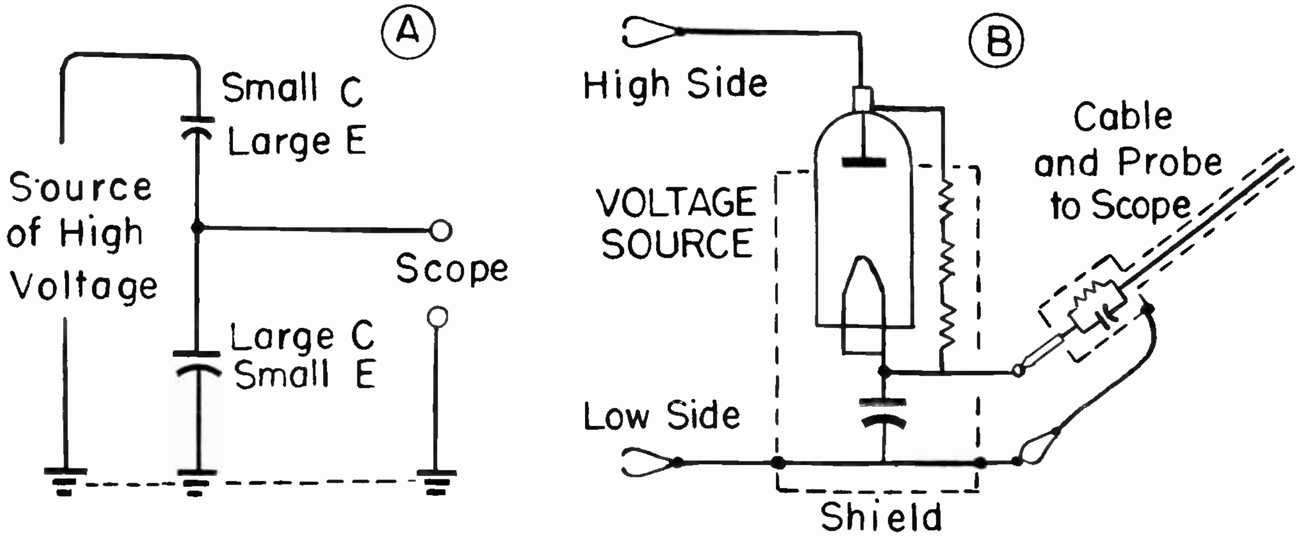

Fig. 6. A capacitance voltage divider and some of its construction details.

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appears across the larger capacitance is applied to the vertical input of the oscilloscope. Were the larger capacitance to be 100 mmf and the smaller one 1 mmf, the voltage division would be approximately in the ratio of 100 to 1, with about 1/100 of the high voltage going to the scope.

Some construction details of a capacitance voltage divider are shown at B of Fig. 6. Small capacitance in a form capable of withstanding high voltages is obtained by utilizing the plate to filament capacitance of a high-voltage rectifier tube. The rectifier is not operated with filament heating current, but is used solely for its internal capacitance.

The 1B3 rectifier tube has internal plate to filament capacitance of approximately 1.5 mmf and is rated for a maximum of 30,000 peak inverse volts. The 1X2-A, a miniature style, has capacitance of approximately 1 mmf and is rated for 18,000 peak inverse volts. Capacitances of these or other similar tubes are so small that external stray capacitances of all kinds add appreciably to the minimum capacitance obtainable in practical circuits. The capacitor furnishing the larger capacitance in the divider will be paralleled by capacitance in a connecting cable and in the scope. To realize a desired voltage division the connection to the scope usually is made through a low-capacitance probe.

Design of the voltage divider is further complicated by frequency discrimination in the smaller capacitance of the divider, since reactance of a capacitance alone is inversely proportional to frequency. To preserve reasonably correct waveforms it is necessary to compensate the capacitance with suitable resistance, usually 10 to 20 megohms or more. Fig. 7 shows principal parts of a capacitance voltage divider using a 1B3 tube. During use, all parts except the tube cap and its lead are enclosed within a grounded shield to prevent

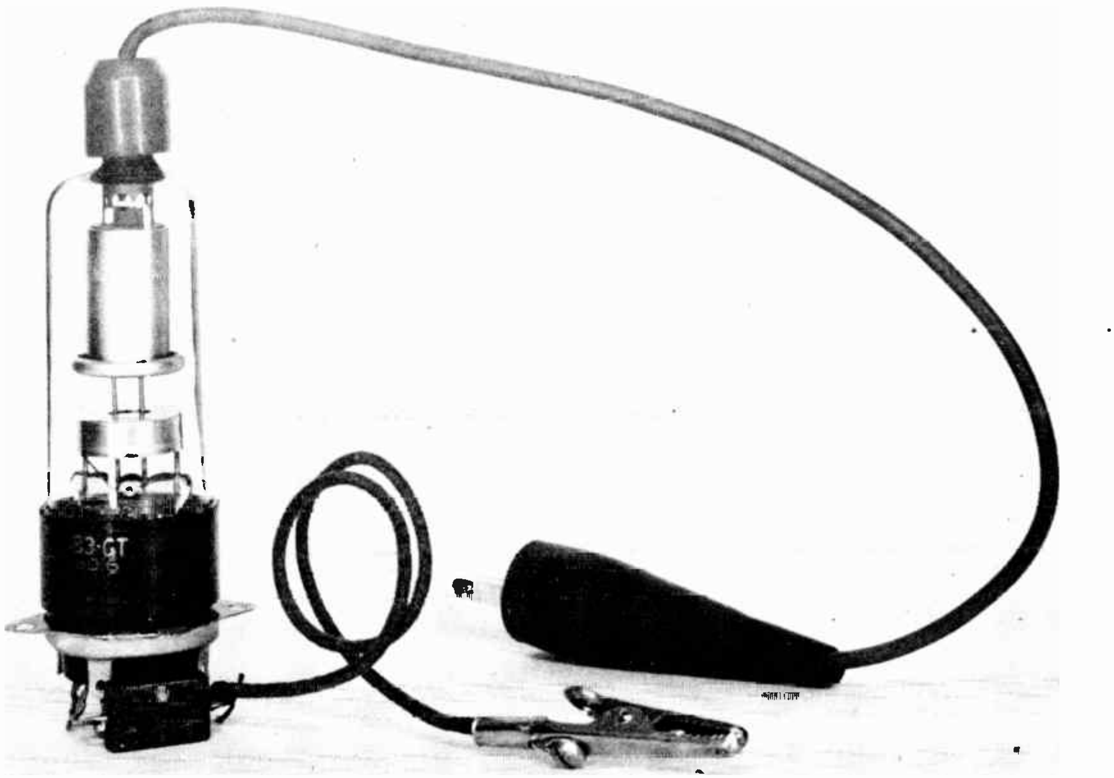

Fig. 7. Principal parts of a capacitance voltage divider employing a rectifier tube as the smaller capacitance.

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excessive pickup of surrounding magnetic and electric fields. The shield is not shown in the photograph.

Another method of reducing high voltages for waveform observation makes use of a "gimmick". A gimmick, in the language of television and radio, is a small capacitance formed by winding one wire around another, with one or both wires insulated. The wire conductors act as capacitor plates, the insulation acts as dielectric. Capacitance is increased by twisting the wires into more turns, is decreased by using fewer twists or fewer turns. The gimmick may be an inch or more of wire having high voltage insulation, with one end bared only enough for attachment of the clip on a vertical input cable. This wire is wound around any insulated lead carrying the high voltage to be observed.

With still another method the free end of the vertical input cable is fitted with a spring clip having smooth jaws, or the teeth may be filed off the usual style of clip. Any insulated lead carrying the high voltage to be observed is covered with additional wrapping of insulating tape, not friction tape. Then the prepared spring clip is placed over the protected portion of the high-voltage lead.

You may observe a high-voltage waveform also by slipping a tight-fitting piece of spaghetti over the tip of a low-capacitance oscilloscope probe, then holding the protected tip of the probe near to but not in contact with any lead or terminal carrying the voltage to be observed. This is not a very safe way of making high voltage observations.

The gimmick, the smooth jawed clip, and the protected tip of the probe all reduce high voltages by taking a portion through an uncompensated small capacitance. There will be a great deal of frequency discrimination, and observed waveforms will differ from those normally existing in circuits being checked. These method are useful chiefly for observing waveforms from a receiver in trouble and comparing them with waveforms from similar points in a receiver known to be in good condition.

Some service men observe high-voltage waveforms by connecting to the vertical input of the scope a high-voltage probe of the kind used with vacuum tube voltmeters for extending the meter range to 10,000 volts or more. This method seldom is satisfactory, because the unshielded probe and its unshielded cable allow excessive pickup of field energy from surrounding 60-cycle power lines and also from receiver and power supply voltages at various other frequencies. These added frequencies may so blur and confuse the trace as to almost completely obscure the waveform you wish to see.

No matter how you reduce high voltages for waveform observation, carry out the operation so far as possible in the following manner. The object is to protect yourself from severe shock.

1. Turn off the receiver by pulling the plug of the power cord.

2. Make all necessary high-voltage connections, using clips, small wires, or any other means to avoid the need of holding such connections by hand.

3. Make sure that all exposed high-voltage conductors are at least an inch from all other metal, to prevent arc-over.

4. Look over all high-voltage connections, to make sure they are right.

5. Keep your hands and arms well away from high-voltage parts.

6. Apply line power to the receiver, observe the trace, and again pull the power cord plug before touching any of the test connections.

PEAK-TO-PEAK VOLTAGES. A waveform may be of correct shape, but voltage or amplitudes may be too great or too little for satisfactory performance of the circuit and the receiver in general. As mentioned before, service manuals for perhaps the majority of receivers show normal waveforms as taken at points between video detector and picture tube. When waveforms are shown, they nearly always are accompanied by peak-to-peak voltage values which are normal or average for the receiver.

Peak-to-peak voltages cannot be mea-

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sured with a vacuum tube voltmeter unless the instrument is especially constructed and calibrated for such measurements. This is because common types of VTVM's, with the function selector set for alternating voltages, indicate only r-m-s values when measured voltage is of sine-wave form. Were the waveform of a measured voltage actually a sine wave, and were the VTVM to read 1.0 volt, the accompanying peak-to-peak value would be 2.8 volts, because peak-to-peak voltage of a sine wave is 2.8 times the r-m-s or effective voltage.

Television signal voltages are not of sine-wave form, they are of various complex waveforms. R-m-s or effective value nearly always is less than in a sine wave of equal peak-to-peak voltage. As an example, the signal voltage at A of Fig. 8 measures 0.5 r-m-s volt on the a-c scale of a VTVM. Multiplying by 2.8 gives 1.4 volts, which would be the equivalent peak-to-peak voltage of a sine wave. But actual peak-to-peak of this signal is 3.9 volts. The signal at B measures 26.5 a-c volts on the VTVM. Multiplying by 2.8 gives 74 volts. But actual peak-to-peak voltage is 320. There is no definite relation between the r-m-s and peak-to-peak voltages in complex waveforms.

PEAK-TO-PEAK MEASUREMENTS. There are two general methods by which peak-to-peak voltages may be measured on the oscilloscope. First, we may temporarily "calibrate" the screen so that all traces are of some certain number of peak-to-peak volts per inch of height. The measured height then may be translated into equivalent peak-to-peak volts for any observed trace.

Second, we may use a "comparison" method. The height of a trace of observed voltage is measured. Then, from a source of adjustable voltage, we produce another trace of equal height. Peak-to-peak voltage of the first trace then may be determined from the known adjustable voltage.

However we may measure peak-to-peak voltages it is necessary, or at any rate is highly convenient, to have in front of the oscilloscope screen a graduated transparent scale on which are ruled lines for inches and fractions of an inch. Such a scale, in use, is

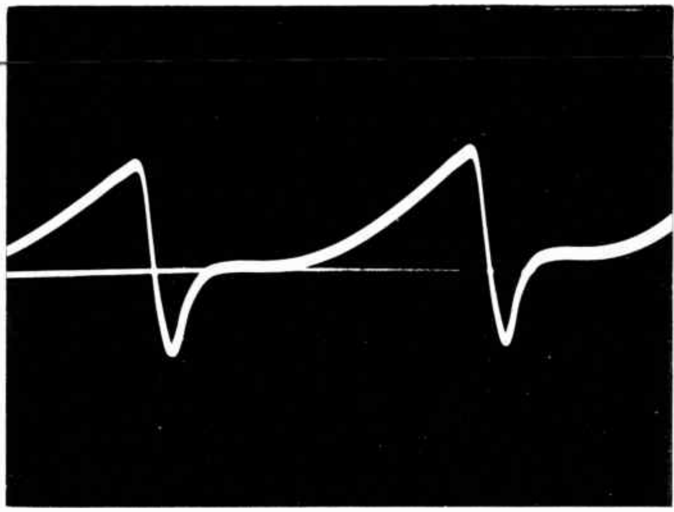

Fig. 8-A.

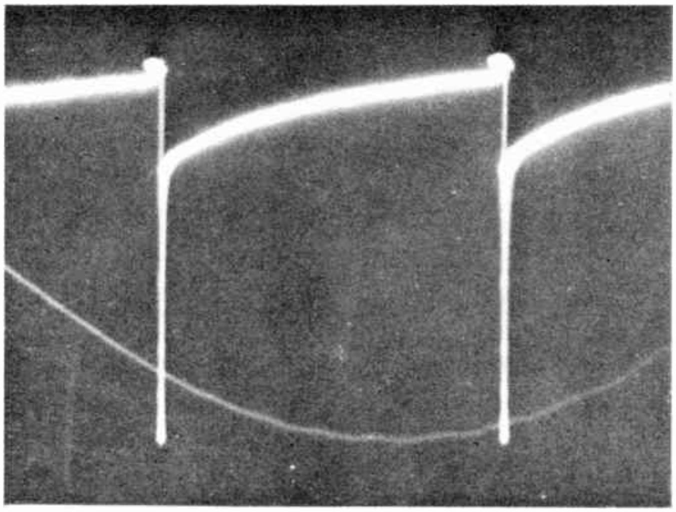

Fig. 8-B.

Fig. 8. There is no definite relation between peak-to-peak and r-m-s voltages of complex waveforms.

shown by Fig. 9. The heavier lines are at one-inch intervals, and the lighter intermediate lines are separated by fifths of an inch. The sine-wave trace here shown on the screen measures about three inches from peak to peak. The height could be measured more easily had the vertical positioning control been used to bring either the top or bottom of the trace to one of the inch graduations.

Most oscilloscopes are provided with removable calibrated scales, ruled in black lines. With the ordinary amount of external light on the screen, the black scale lines show very clearly. Some oscilloscopes have calibrated scales on which the lines may be illuminated by one or more small lamps

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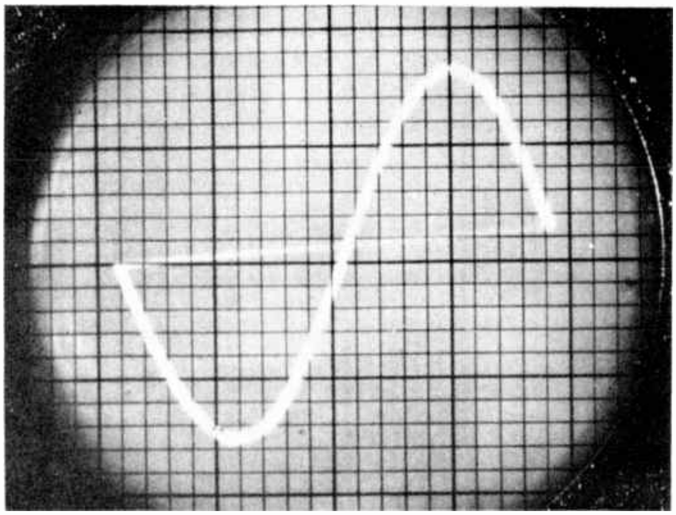

Fig. 9. A calibrated or graduated scale in front of an oscilloscope screen.

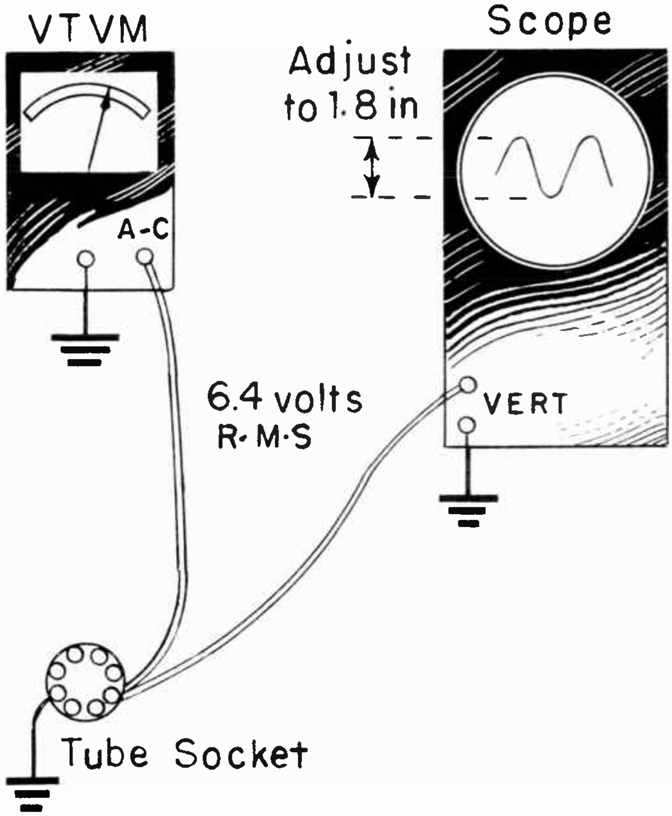

Fig. 10. Calibrating the oscilloscope from an a-c heater voltage.

within the instrument, thus providing bright lines when there is little or no external light on the screen. In some pictures to follow we shall use white scale lines, because black lines would not show well against the dark background of the screen which is necessary for photograph of traces.

CALIBRATING THE SCREEN. One method of calibrating the screen is illustrated by Fig. 10. Any available sine-wave voltage may be used. Tube heater voltage, nominally 6.3 volts in most cases, is convenient and sometimes is available from a terminal or jack on the panel of the scope. To learn the actual value, this voltage must be measured on a reasonably accurate VTVM or other a-c voltmeter.

For the example of Fig. 10. we may assume that the meter reads 6.4 r-m-s volts. To determine the corresponding peak-to-peak value of the sine wave, multiply 6.4 volts by 2.8, giving 17.92 volts or approximately 18 peak-to-peak volts. With this measured sine-wave voltage applied to the vertical input of the oscilloscope, adjust the vertical attenuator and gain for a trace 1.8 inches in peak-to-peak height. Since the height now is 1.8 inches for 18 peak-to-peak volts, the scope is calibrated for 10 peak-to-peak volts per inch, and will remain so as long as you do not alter the vertical attenuator and gain control.

It might be more convenient to adjust the peak-to-peak sine-wave height to occupy 18 scale divisions, whatever the divisions may be. Then the scope would be calibrated for one peak-to-peak volt per scale division, so long as the vertical attenuator and gain remain unchanged.

Calibration is easier if you have a source of adjustable alternating voltage, such as an audio signal generator. The setup is similar to that of Fig. 10, except that the source of adjustable voltage takes the place of tube heater voltage. Following is an example of calibration with adjustable voltage.

Adjust the voltage source for any voltage which may be easily and accurately read from the VTVM or other a-c voltmeter. Assume that you make the adjustment for 5.0 r-m-s

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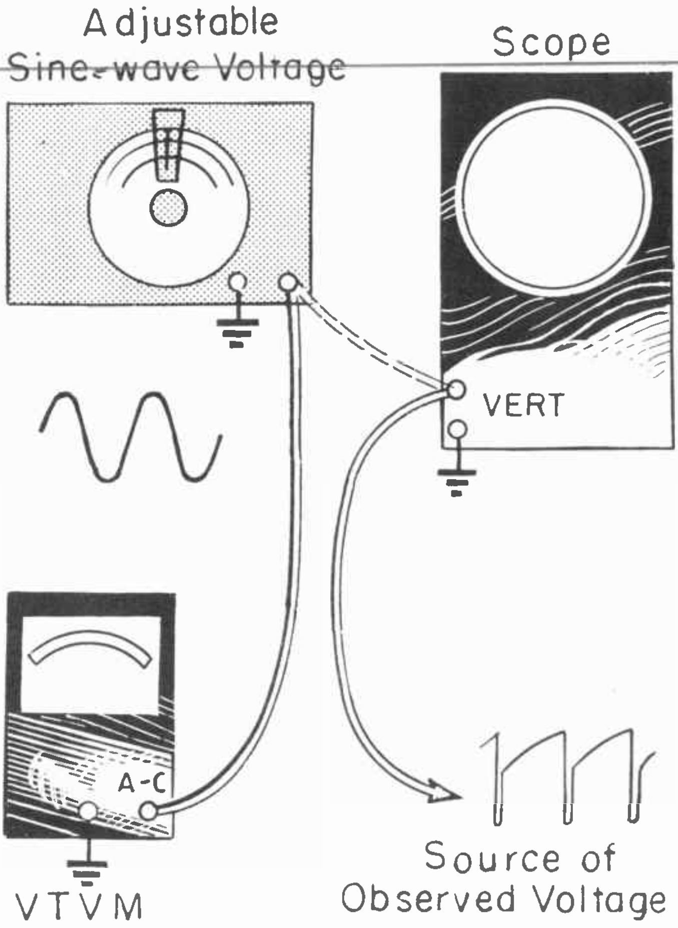

Fig. 11. Measurement of peak-to-peak voltage by a comparison method.

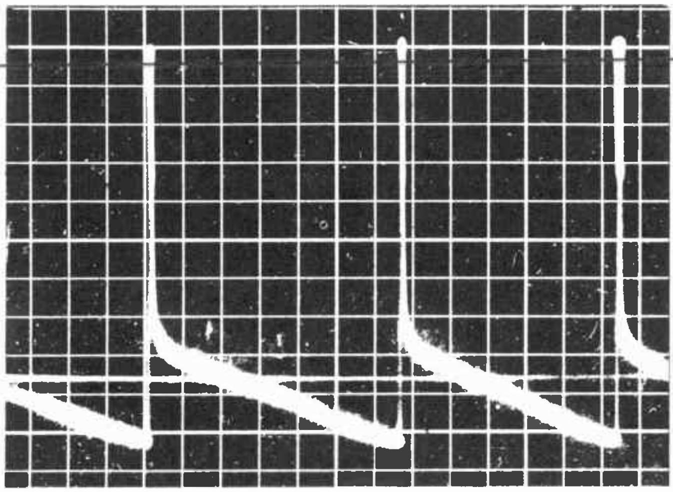

Fig. 12-A.

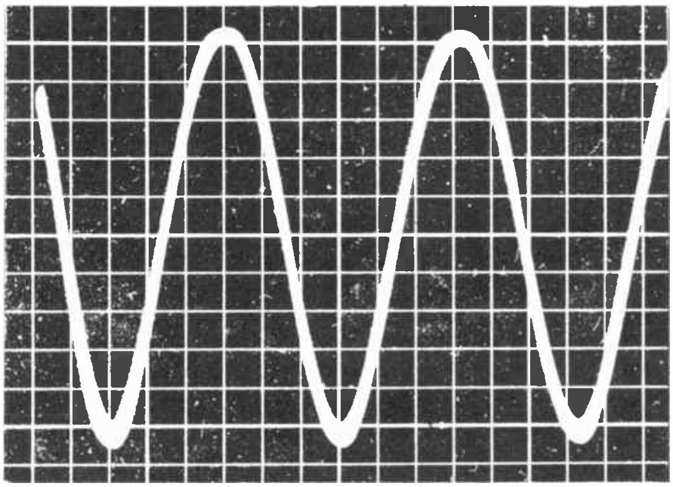

Fig. 12-B.

Fig. 12. Peak-to-peak height of a sine wave is made equal to peak-to-peak height of the measured waveform.

volts. Peak to peak then will be 2.8 times 5.0 volts, or 14.0 volts. Adjust the vertical gain of the scope for peak-to-peak trace height of 14 scale divisions. This calibrates the scope for one volt peak-to-peak per scale division. Any other values of adjusted voltage might be used similarly.

COMPARISON MEASUREMENTS. Fig. 11 shows the set up for peak-to-peak measurement by comparison when using a source of adjustable sine-wave voltage. The procedure is as follows:

1. On the screen of the oscilloscope set up a trace of the voltage whose waveform is to be observed and measured.

2. Adjust the vertical attenuator and gain to make the observed trace of any readily measured peak-to-peak height, usually 1, 2, or 3 inches. At A of Fig. 12 the peak-to-peak height is 2 inches.

3. Without altering vertical attenuator and gain adjustments, transfer the vertical input cable to the source of adjustable voltage, to which is connected the meter.

4. Set the adjustable voltage to produce a trace of the same peak-to-peak height as for the observed voltage in step 2 above. This is shown at B of Fig. 12.

5. Multiply the r-m-s reading of the meter by 2.8. This gives the approximate peak-to-peak voltage of the waveform observed in steps 1 and 2.

Peak-to-peak heights of observed waveforms and of those used for calibration or comparison are more easily adjusted and measured if you retard the horizontal gain

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control to leave only a vertical line on the screen. Intensity must be reduced at the same time, to prevent an excessively bright line.

It should be mentioned that extreme accuracy seldom is necessary when making peak-to-peak measurements of voltage. A variation of 10 per cent from a listed normal or average value hardly ever would mean more than the ordinary variation from one receiver to another of the same make and model. In view of the many variable factors which determine an observed voltage, a departure of as much as 20 per cent still may indicate no serious trouble in the measured circuit.

VOLTAGE CALIBRATORS. A voltage calibrator for oscilloscopes is a service instrument designed for convenient and rapid measurement of peak-to-peak voltages. Such an instrument furnishes an adjustable voltage which will produce a trace of any desired height on the oscilloscope screen. Dial pointers or a meter on the calibrator indicate directly the peak-to-peak voltage of the trace. A voltage whose waveform is to be observed and measured is connected to the calibrator, and from the calibrator there is another connection to the vertical input of the oscilloscope. A switch allows applying to the vertical input either the voltage to be measured or else the calibrator voltage, without changing any of the external connections.

One style of calibrator is pictured by Fig. 13. The source of measured voltage is connected to terminals at the left, and from terminals at the right a cable goes to the vertical input of the oscilloscope. At the bottom of the panel is a selector switch. With this switch in its "direct" position, voltage to be measured passes through the calibrator to the oscilloscope and forms a trace. With the switch in its "calibrate" position, voltage to be measured is disconnected from the scope, and on the screen appears a trace of voltage furnished by the calibrator.

By means of two knobs or pointers on the calibrator panel the trace of calibrator voltage is adjusted to the same height as the trace of measured voltage, and peak-to-peak voltage is determined from the positions or

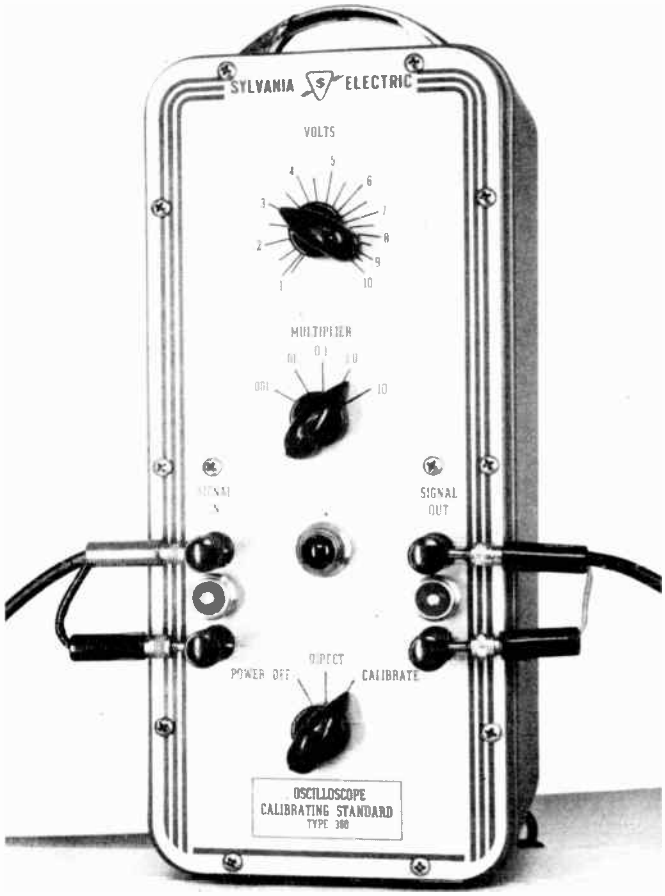

Fig. 13. A calibrator whose peak-to-peak voltages are determined by settings of two pointers.

readings of the pointers. In the picture the upper "volts" pointer is at 3 and the lower "multiplier" pointer is at 1. Multiplying 3 by 1 gives 3 as the peak-to-peak voltage of the calibrator trace, and also of the observed voltage whose trace height is the same as that of calibrator voltsge.

For the multiplier pointer on this particular instrument there are five positions, marked for 1/1000, for 1/100, for 1/10, for 1, and for 10. The dial for the volts pointer is graduated from 1 to 10. Were a desired trace height to be secured with the volts pointer at 6 and the multiplier at 1/10, peak-to-peak voltage would be 6/10. Were the volts pointer at 2 and the multiplier at 10, peak-to-peak voltage would be 2 times 10, or 20 volts. Other calibrators having graduated dials and multiplier switches operate in essentially the same manner.

Calibrators of another general type have a voltmeter on their panels. This meter has

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a scale or scales graduated in peak-to-peak volts, and sometimes also in equivalent r-m-s volts for a sine wave. There is a selector switch for various voltage ranges, also a control knob for adjustment of voltage within any selected range. Thus it is possible to produce a trace of any desired height on the oscilloscope screen and to determine the peak-to-peak voltage from the meter reading and position of the range selector switch. Connections for the measured voltage, and between calibrator and oscilloscope vertical input, are like those described in connection with Fig. 13, and there is a similar switch providing either "direct" or "calibrate" connections.

Most calibrators furnish a voltage whose waveform is flat at the top and at the bottom. This waveform may be a square wave as at A of Fig. 14 or may be a clipped sine wave as at B. These two photographs were made with the internal sweep of the scope adjusted for the output frequency of the calibrators, only for the purpose of showing typical calibrator waveforms. This adjustment of internal sweep rate is not made during voltage measurements.

For actual peak-to-peak voltage measurements the internal sweep of the scope is adjusted to bring any desired number of observed-voltage cycles onto the screen, and remains so for the calibrating voltage. Upon switching from the observed-voltage waveform to the calibration voltage, you will see on the screen only two horizontal lines as at C of Fig. 14. These lines are formed by the flat tops and bottoms of the calibrating waveform. The calibrator is adjusted to make the vertical separation between these lines equal to the peak-to-peak height of the voltage to be observed and measured.

Any voltage calibrator may be used for either comparison or for calibration of the screen. The procedure for comparison is as follows.

1. Set the calibrator switch for direct feed-through from the source of observed voltage to the oscilloscope.

2. Adjust the vertical gain of the scope for some peak-to-peak trace height easily

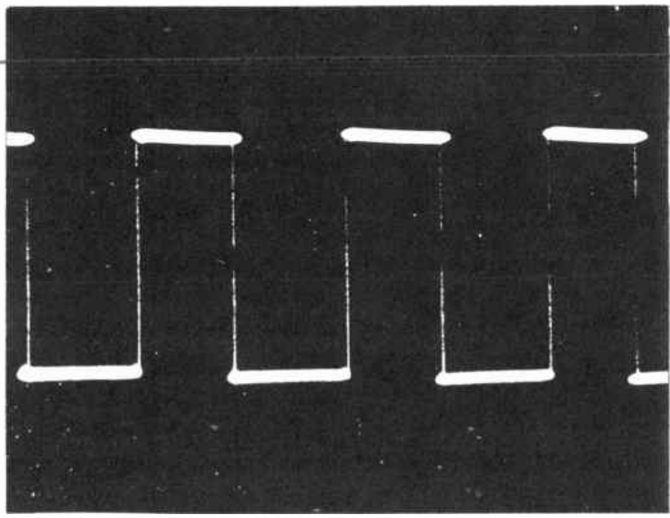

Fig. 14-A.

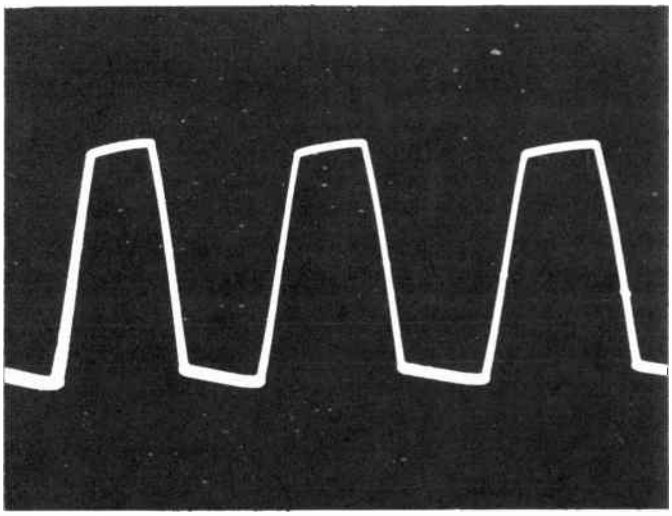

Fig. 14-B.

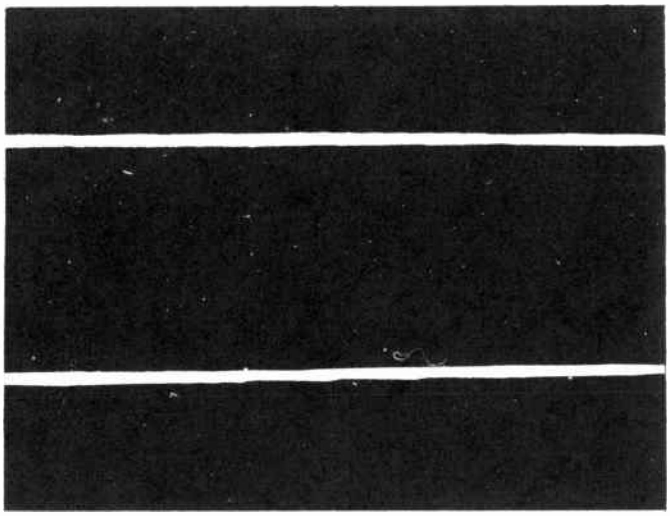

Fig. 14-C.

Fig. 14. Flat tops and bottoms of calibrator waveforms, and the lines they produce on the screen of the scope.

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identified on the graduated scale, usually to some simple number of inches. Do not alter the gain during the remainder of this process.

3. Shift the calibrator switch to its calibrate position.

4. Adjust the calibrator voltage for trace lines separated by the peak-to-peak height of the previously observed waveform. The calibrator dials or meter now indicate peak-to-peak voltage of the previously observed waveform.

To calibrate an oscilloscope screen in peak-to-peak volts per inch of trace height proceed thus:

1. Place the calibrator switch in its calibrate position.

2. Adjust the calibrator for some simple number of volts or simple fraction of a volt, as indicated by dial settings or meter reading.

3. Adjust the vertical gain of the scope to separate the calibrating trace lines by some simple number of inches.

4. The scope now is calibrated for the number of volts in step 2, per inches of height in step 3. For example, were the calibrator adjusted for 20 peak-to-peak volts, and the trace height to 1 inch, the calibration would be 20 peak-to-peak volts per inch of trace height. The calibration holds good only so long as vertical gain is not altered.

5. Set the calibrator switch to its direct feed-through position.

6. Peak-to-peak voltage of any observed waveform now is proportional to the "volts per inch" determined in step 4. For example, were peak-to-peak height of a signal waveform to be 1.4 inches, and were the scale calibrated for 20 volts per inch, peak-to-peak voltage of the signal would be 1.4 times 20, or would be 28 volts.

Many calibrators furnish a maximum of only 100 peak-to-peak volts, although some go to 200 volts or more. When peak-to-peak voltage of an observed waveform exceeds the maximum calibrator voltage proceed as follows.

1. Set the calibrator switch to its calibrate position and adjust the calibrator output for 100 peak-to-peak volts.

2. Adjust vertical gain of the oscilloscope to separate the calibration trace lines by some simple number of inches or a simple fraction of an inch.

3. The scope now is calibrated for 100 peak-to-peak volts per number of inches or fraction of an inch used in step 2. Examples: Were vertical gain adjusted for 1-inch separation of calibration lines, the calibration would be 100 peak-to-peak volts per inch. Were gain adjusted for 1/2-inch separation, the calibration would be 100 volts per 1/2 inch, or 200 volts per inch.

4. Set the calibrator switch to its direct feed-through position. Peak-to-peak voltage of any observed waveform now is proportional to volts per inch determined in step 3.

This method is illustrated by Fig. 15. The oscilloscope screen is calibrated for 100 volts per 1/2 inch, or 200 volts per inch, or 20 volts per scale division, of which there are 10 per inch. This calibration was performed by adjusting the height of a 100-volt calibration trace to occupy 1/2 inch or 5 scale divisions on the screen. The observed signal waveform occupies 9 scale divisions

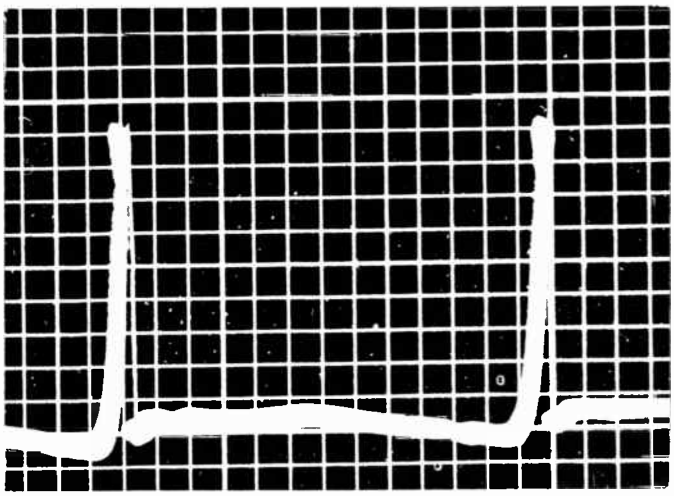

Fig. 15. When screen calibration is for 200 volts per inch, this signal measures 180 peak-to-peak volts.

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or 9/10 inch. Accordingly, this signal measures 180 peak-to-peak volts.

ment for the other waveform taken from the same point.

A voltage calibrator and the additional connections between this instrument and the oscilloscope introduce appreciable extra capacitance between the signal source and the oscilloscope. This added capacitance causes frequency discrimination. Well constructed calibrators add about 20 mmf of capacitance, and connections from calibrator and scope will add at least another 20 mmf. As a consequence, a low-capacitance frequency-compensating probe connected to a calibrator input will not serve its purpose unless the probe capacitor or resistor were readjusted.

When frequency discrimination is to be avoided, the calibrator may be used only as a source of comparison voltage. The method follows.

1. With any type of vertical input cable from the scope directly to the signal source, in the usual manner, bring the desired waveform onto the screen.

2. Adjust vertical gain to make peak-to-peak height of the trace some easily identified number of inches or scale divisions.

3. Transfer the same vertical input cable used in step 1 from the signal source to the output terminals of the calibrator. Set the calibrator switch to its calibrate position. Leave the calibrator input terminals disconnected, or short them together with a piece of bare wire to avoid pickup of unwanted voltages.

4. Adjust the calibrator for trace lines separated by the same vertical distance as peak-to-peak height of the waveform observed in step 2. The calibrator now reads peak-to-peak voltage of the signal waveform.

During many service operations you will wish to observe both vertical and horizontal waveforms taken from the same point in a circuit. Peak-to-peak voltage will remain or should remain the same for both observations. If you measure peak-to-peak of either the vertical or horizontal waveform, it should not be necessary to make another measurement for the other waveform taken from the same point.

If your oscilloscope has uniform vertical gain to only moderately high frequencies, and is used for waveforms containing much higher frequencies, measurements with a calibrator may indicate peak-to-peak voltages lower than actually existing.

As an example, assume that scope sensitivity drops noticeably about 50 kc. Peak-to-peak waveforms involving higher frequencies then will be less than they should be. But because most calibrators furnish voltages at 60 cycles or at only a few hundred cycles in any case, the calibration voltage is fully amplified in the scope. When you adjust the calibration trace to the reduced height of signal waveform, the calibrator will be adjusted for less than the true value of signal.

In a number of television receiver circuits it is desirable to measure the voltage in certain portions of a signal waveform. As an example, with the voltage of Fig. 16 it is desirable to know the voltage of the negative peaks, which extend to about four scale divisions below the central horizontal line, also the voltage of the sawtooth rises which extend three divisions above the line. Were the calibration adjusted for 10 volts per scale division, the negative peaks would measure 40 volts (for 4 divisions), the sawtooth rises would measure 30 volts (3 divisions) and signal strength would be 70 peak-to-peak volts overall.

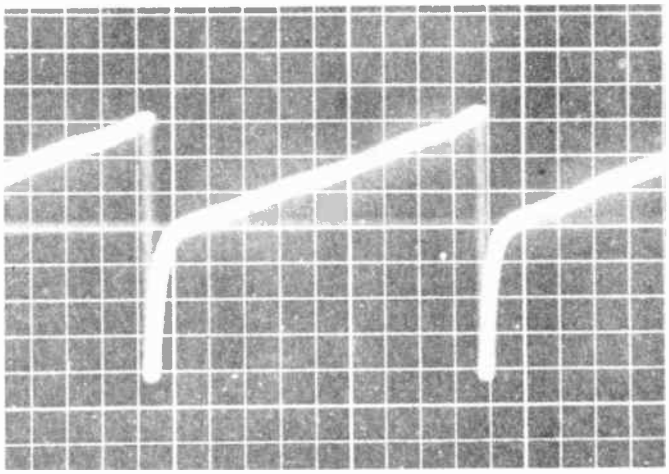

Fig. 16. On a calibrated screen it is possible to measure voltages in any portions of a complex waveform.

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In a video signal it is only the height of sync pulses that remains proportional to signal strength. The picture variations change in height with tone or shading of pictures transmitted at any one instant, not with signal strength. In Fig. 17 the sync pulses extend through two scale divisions. This height might be compared with that of sync pulses from a preceding or following stage, to determine stage gain without confusion which might arise when attempting to measure overall peak-to-peak heights, including picture variations.

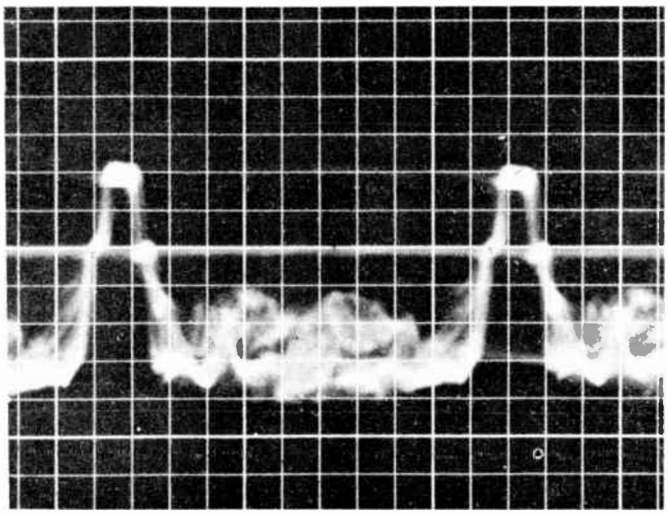

Fig. 17. The height of sync pulses is proportional to strength of a video signal.

In a number of service oscilloscopes are built-in peak-to-peak voltage calibrators. The action is similar to that of separate calibrators having graduated dial scales. One of the selector switches on the panel of such scopes will have positions for direct and for calibrate. One or more dials and pointers will allow adjusting the calibrating voltage for trace lines separated by peak-to-peak heights of signal waveforms. The manner of using a built-in calibrator is essentially the same as for separate calibrators described in this lesson. No additional cable connections are needed, since the "direct" connection is through the cable or leads regularly employed for the vertical input, and "calibrate" connections are within the oscilloscope.

PEAK-TO-PEAK VOLTAGES ON VTVM. It is possible to measure peak-to-peak voltages with a vacuum tube voltmeter by connecting between the meter and the voltage source a circuit in which capacitors are charged by rectified currents. Some VTVM's have built-in provisions for measuring peak-to-peak voltages.

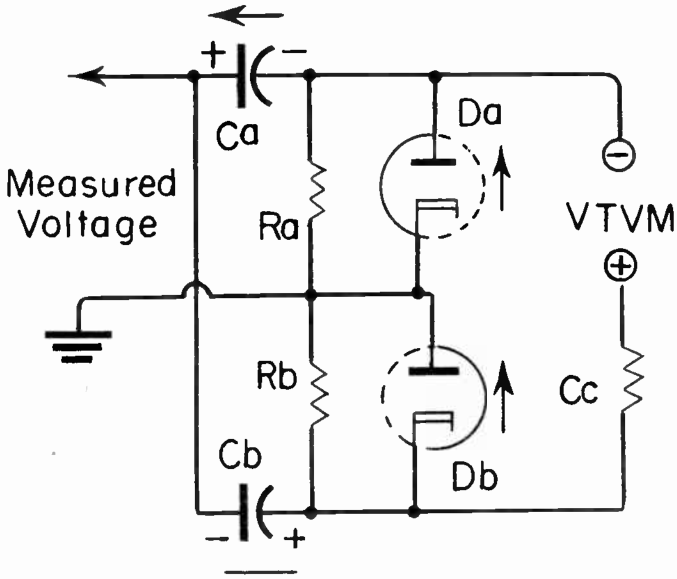

Fig. 18. A circuit for peak-to-peak voltage measurements on a vacuum tube voltmeter.

One of several circuits used for this purpose is shown by Fig. 18. Two paper capacitors, Ca and Cb, are of 0.1 mf or greater capacitance and of 600 volt d-c rating, or higher in order to minimize leakage. Resistors Ra and Rb usually are of 10 megohms each. Two rectifiers, Da and Db, may be two sections of a twin diode, such as a 6AL5, or may be two crystal diodes of a type having high back resistance. The output of the rectifier circuit is connected to the d-c input terminals of the VTVM, as shown.

Positive alternations of measured voltage cause current to flow as shown by arrows in Ca and Da, thus charging Ca in the marked polarity. Negative alternations similarly charge capacitor Cb in the marked polarity, by causing current to flow in rectifier Db. The capacitors discharge so slowly through high resistances at Ra and Rb that charge voltage becomes very nearly equal to peaks of positive and negative alternations.

The capacitors are so connected to the VTVM that the meter is subjected to the sum of the charge voltages. This sum is practically equal to the peak-to-peak of measured voltage. The value of calibrating resistance

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at Cc depends on characteristics of the VTVM, but usually is between 5 and 10 megohms.

Correct calibration allows reading peak-to-peak voltages on the d-c voltage scales of the meter for all values higher than about five volts. Lower peak-to-peak voltages may require special calibration or interpretation of meter readings. Since neither terminal of the VTVM may connect to ground, the meter case must be insulated from metal benches and such parts. With some instruments a zero measured voltage will not cause a zero reading with the power cord plug inserted one way in a receptacle, but readings will be correct with the plug turned around. The rectifier circuit some times is built into a probe by using crystal diodes and miniature capacitors.

GAIN MEASUREMENTS. Signal voltage gain in one or any number of amplifier stages or other circuits is easily measured with the oscilloscope. Peak-to-peak voltage at the output of any system, divided by peak-to-peak voltage at the input, gives the number of times the voltage is increased or amplified between points at which measurements are made. It is advisable to employ a low-capacitance probe on the vertical input, thus lessening the loading of measured circuits.

A separate voltage calibrator used with feed-through connection to the oscilloscope may cause serious loading and frequency discrimination in some circuits. A peak-to-peak measuring attachment for a vaccum tube voltmeter, such as shown by Fig. 18, will cause enough loading to make gain computations unreliable for circuits in there are high frequencies.

WAVEFORMS OF CURRENT. There are a number of television circuits in which variations of current are decidedly different from variations of voltage which cause the current to flow. One such condition exists in magnetic deflecting coils. At A in Fig. 19 is the voltage waveform across a deflecting coil, and at B is the waveform of current in the same coil at the same tmie. Reasons for the difference will be considered later on. Now we are interested only in observing current waveforms.

Test connections are shown by Fig. 20 The parts within the broken line represent any kind of circuit whose current is to be observed. In all circuits there is a high side to which operating voltages are applied, and a low side which connects more or less directly to ground, to the B-supply voltage, to bypass or filter capacitors, and at which there are minimum variations of operating voltage. The low side of the circuit is temporarily opened and in series with it is connected a resistor marked R in the diagram.

The inserted resistor will carry current flowing in the tested circuit, and across the resistor will be changes of voltage corres-

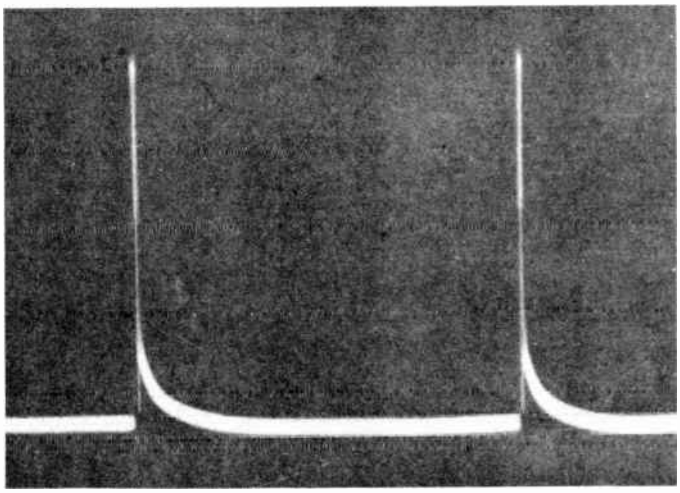

Fig. 19-A.

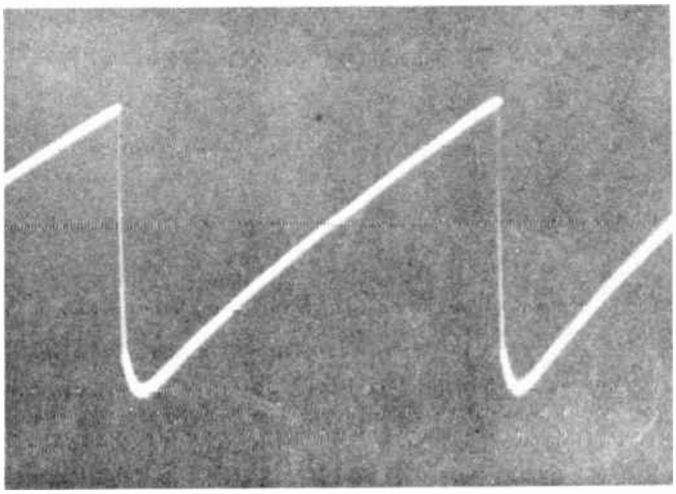

Fig. 19-B.

Fig. 19. The voltage at A causes the current at B.

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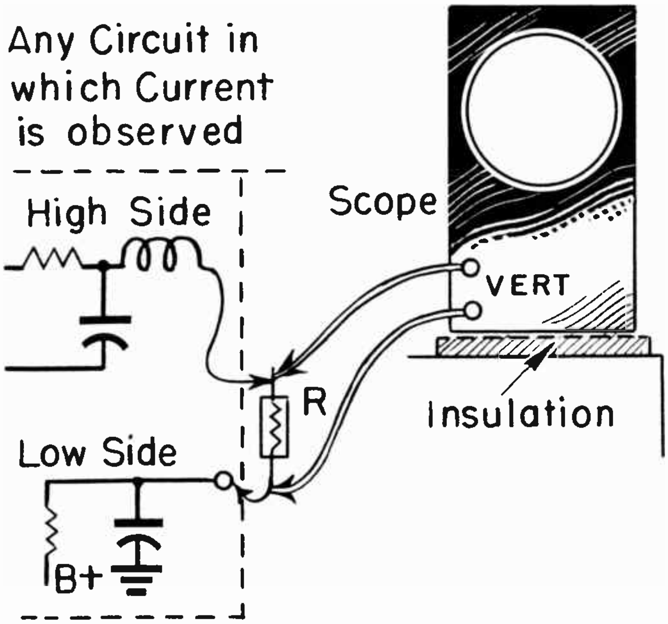

Fig. 20. Connections for observing current variations on the oscilloscope.

ponding to changes of current in the circuit. With the vertical input of the oscilloscope connected across the inserted resistor the scope will be actuated by changes of resistor voltage, and since these changes correspond to circuit current the trace will show changes of current.

Use the smallest inserted resistance in which the measured current will produce voltages sufficient to actuate the oscilloscope. The greater the current and the more sensitive the scope, the smaller may be the inserted resistance. The trace at B of Fig. 19 was taken from a 1-ohm resistor. Unless the tested circuit is opened at a direct connection to ground, do not ground any of the scope terminals or the case of the instrument. Connect the normally grounded terminal of the vertical input only to one side of the inserted resistor, as in the diagram.

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Terminate 15

TELEVISION

• RADIO

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LESSON 55 — SWEEP GENERATORS FOR ALIGNMENT

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Lesson 55

SWEEP GENERATORS FOR ALIGNMENT

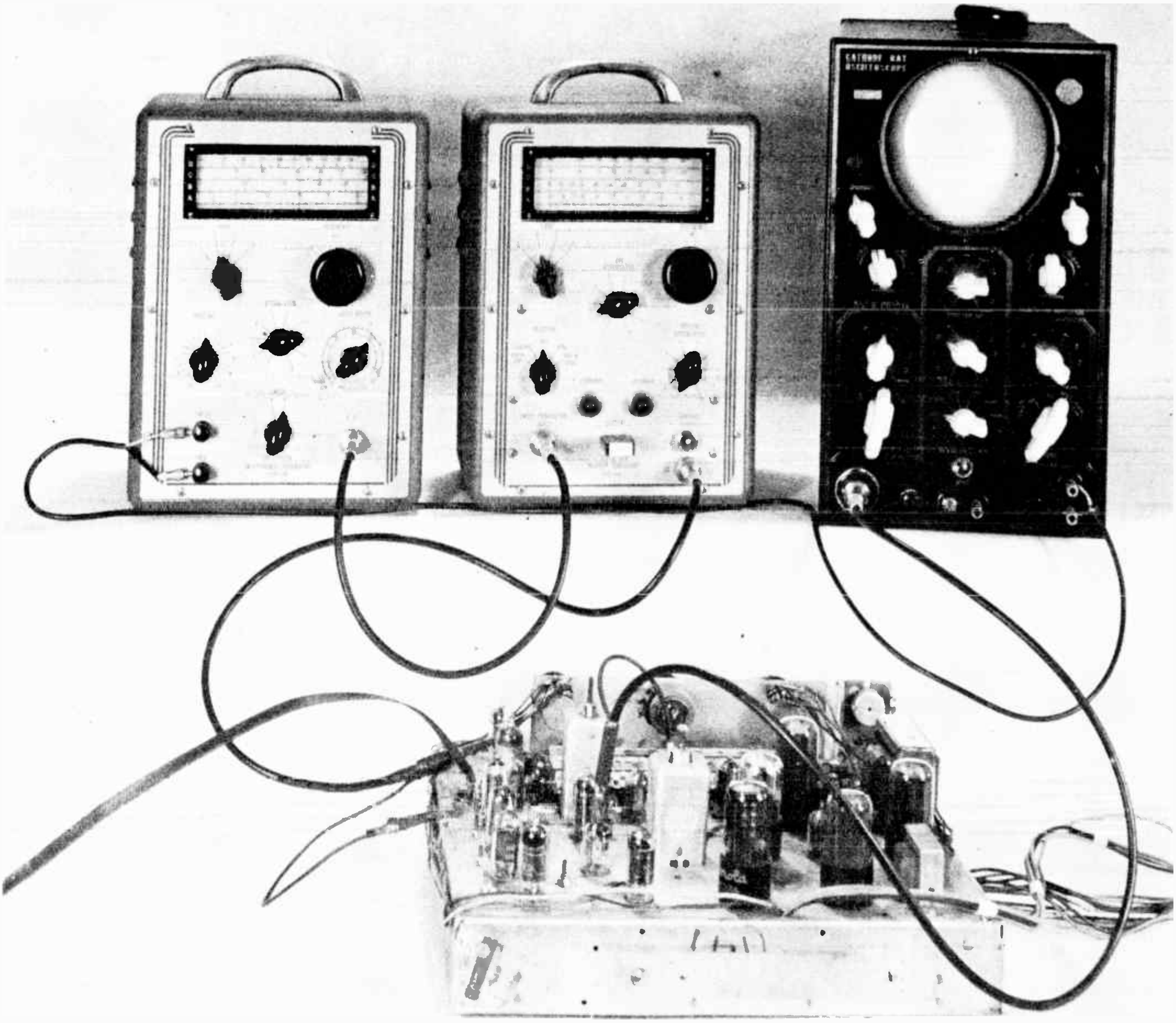

Fig. 1. A sweep generator, a marker generator, and an oscilloscope connected to a receiver for alignment of the i-f amplifier stages.

R-f amplifiers, i-f amplifiers, video amplifiers, and sound amplifiers are designed to provide voltage gains within limited frequency bands, and zero gains at other frequencies. In many cases we require certain percentages of maximum gain at particular frequencies. For instance, in an i-f amplifier the gain should be 50 to 60 per cent at the video intermediate frequency, should be down to about 5 per cent at the sound intermediate, should have dips or valleys of limited depth, and so on.

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All of the relations between frequency and gain which are designed into amplifiers, and which you endeavor to retain or restore during service work, can be shown only by frequency response curves such as we looked at when studying television i-f amplifiers. The only satisfactory way of checking frequency responses is to observe them on the oscilloscope. The frequency response curve on the oscilloscope screen will change instantly every time you make any adjustment which affects the gain, and thus show whether or not there has been an improvement in performance. It is easy to identify frequencies and relative gains anywhere along the response curve while adjusting the circuits of an amplifier being aligned.

The oscilloscope will display a frequency response curve only when the amplifier being tested is furnished with a special kind of signal voltage at its input. Frequencies at various points along the response curve can be identified by adding to the special kind of signal voltage another voltage which is effective only at some one selected frequency.

Fig. 1 shows an instrument setup for observing frequency responses. At the upper left is a sweep generator which supplies a signal voltage whose strength remains constant but whose frequency varies continually back and forth through the band in which an amplifier is designed to operate. Next to the sweep generator is a marker generator which allows identifying any particular frequency or sometimes two or more frequencies on a response curve.

The combined voltages from the sweep and marker generators go to the input of the amplifier on test. The picture shows a television amplifier chassis of a type used with separate picture tube, power supplies, and deflection system. The output of the amplifier goes to the vertical input of the oscilloscope, at the upper right.

The test connections may be seen more clearly in Fig. 2 than in the photograph. The continually varying frequency from the sweep generator goes through the marker generator, which adds the voltage for frequency identification. The signal voltage goes into the amplifier, where all the frequencies are amplified proportionately to the frequency response of the amplifier. The amplified signal voltage goes to the vertical input of the scope. An additional connection from the sweep generator to the horizontal input of the scope synchronizes the horizontal deflection of the CRT beam with variations of frequency in the signal going to the amplifier.

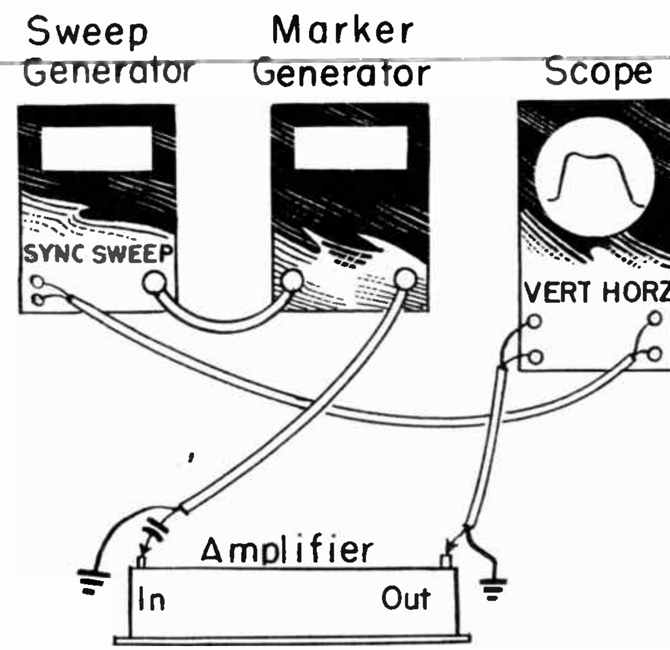

Fig. 2. Connections between the instruments and receiver for alignment.

The beam in the CRT deflects vertically in proportion to voltage gain at any applied frequency. At the same time the beam is swept horizontally, starting from one side of the screen at the instant in which the sweep generator is furnishing its lowest frequency. This is illustrated by Fig. 3. While frequency is increasing, the beam moves across the screen. By the time the beam gets to the far side of the screen, frequency from the sweep generator has become maximum.

When the CRT beam is at any one position across the screen, the sweep generator is furnishing signal voltage at one certain frequency. This voltage is amplified proportionately to gain of the amplifier at that particular frequency, and the CRT beam rises vertically a distance proportional to amplifier gain. Consequently, the height of the trace at any one point indicates relative gain

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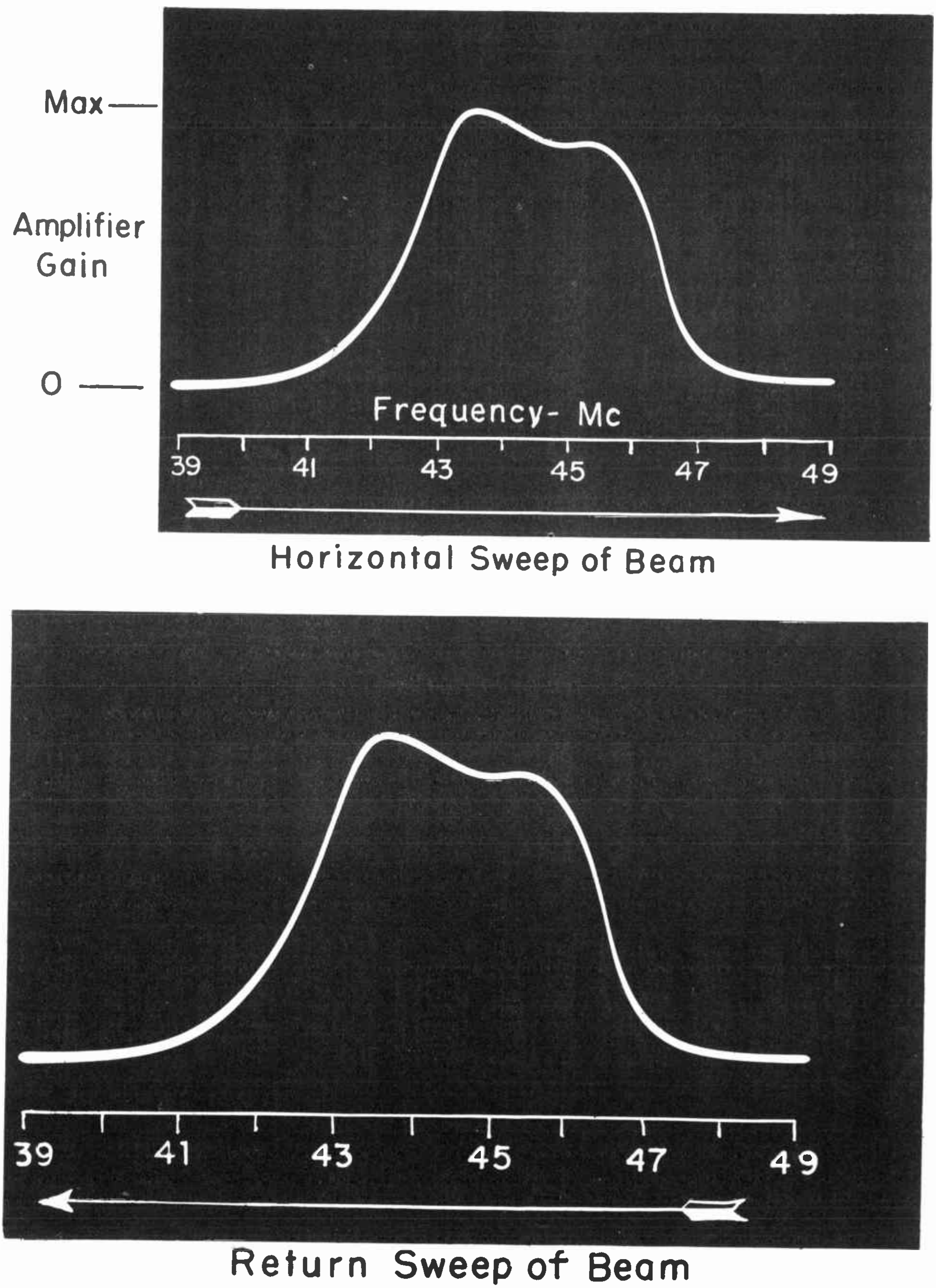

Fig. 3. The CRT beam is swept one direction while frequency is increasing, and in the opposite direction while frequency is decreasing.

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of the amplifier at the corresponding frequency. Variations of trace height correspond to variations of amplifier gain throughout the entire frequency band, and we have a frequency response curve.

As soon as the CRT beam reaches the far side of the screen it is swept at the same speed in the opposite direction, back to the starting point. During this return trace the sweep generator is decreasing its output frequency at the same rate in which frequency formerly increased, and at the same rate in which the beam is making its return trace. If amplifier gains during decrease of frequency are the same as during increase, beam height and trace height will be the same at every point along the return trace as on the forward trace.

It is common practice to vary the swept frequency and the sweep of the CRT beam at the rate of 60 cycles per second, for this allows everything to be timed or synchronized from any 60-cycle power line. If, as in Fig. 3, frequency varies between 39 and 49 mc, there will be a change from 39 mc up to 49 mc during 1/120 second, the time for one alternation at 60 cycles per second. In the following 1/120 second, the opposite alternation, frequency will change from 49 mc back down to 39 mc. Frequency goes through one complete cycle, from 39 to 49 and back to 39 mc, during 1/60 second.

During the first alternation or first 1/120 second the beam in the CRT is swept from left to right. During the opposite alternation, and following 1/120 second, the beam

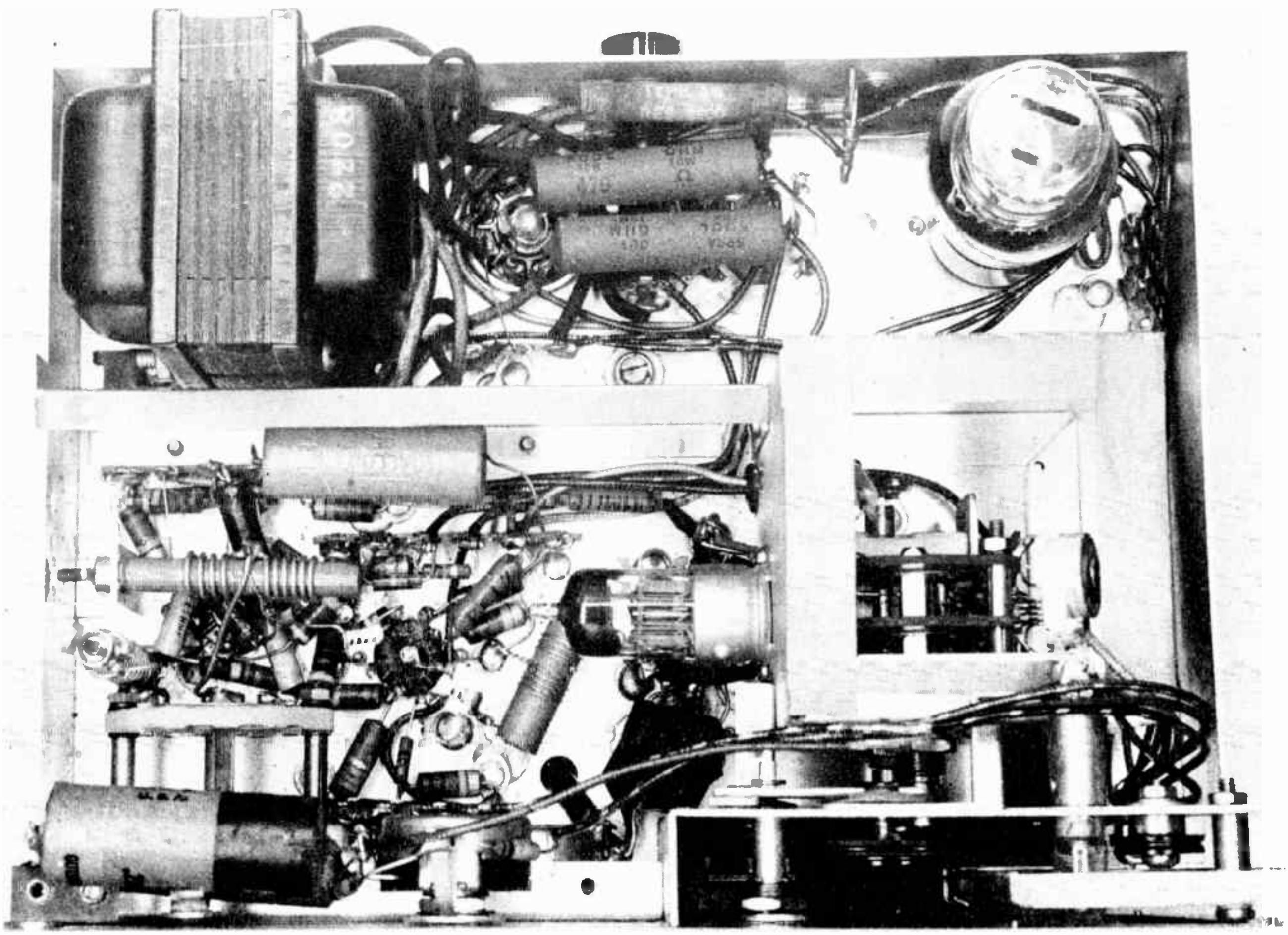

Fig. 4. The interior of a sweep generator. Portions of the shielding have been removed to expose the circuit elements.

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is swept back from right to left. This completes one horizontal sweep cycle in 1/60 second.

SWEEP WIDTHS AND CENTER FREQUENCIES. In Fig. 3 the swept frequency varies between 39 and 49 mc, a change of 10 mc in all. This total change is called the sweep width, or sometimes the deviation. A width of 10 mc would be about right for covering the frequency band of a television i-f amplifier operating with video intermediate frequency of 45.75 mc and sound intermediate of 41.24 mc, because gains extend both above and below the intermediates.

In the case of television r-f amplifiers or tuners, there may be measurable gain over a band of 15 mc or even more, and to display the frequency response would call for a sweep of at least 15 mc. On the other hand, i-f amplifiers for television sound and for f-m broadcast receivers have relatively narrow frequency response, and sweep width of 2 to 3 mc is ample. Sweep generators have adjustments for varying their sweep width from zero or thereabouts up to the maximum of which the generator is capable.

Again looking at Fig. 3, the center frequency is 44 mc because swept frequencies extend equally (5 mc) below and above 44 mc. This center frequency would be suitable for alignment of television i-f amplifiers having sound and video intermediates of 41.25 and 45.75 mc. But for alignment of an i-f amplifier having intermediates such as 21.6 and 26.1 mc we would need a center frequency of about 24 mc. This center frequency, with a sweep width of 10 mc, would cover a band from 19 to 29 mc.

Were we aligning an r-f amplifier with the tuner set for channel 4, as an example, a suitable center frequency would be that at the middle of the channel. Channel 4 extends from 66 to 72 mc, and centers at 69 mc. For complete alignment of v-h-f television receivers and f-m broadcast receivers we need the following center frequencies and ranges of center frequency.

Tv intercarrier sound	4.5 mc
F-m broadcast intermediate	10.7 mc
TV intermediates	20 to 50 mc
TV carriers, low band	55 to 85 mc
F-m broadcast carriers	88 to 108 mc
TV carriers, high band	175 to 215 mc

Sweep generators have range selector switches for the various bands of center frequencies, and adjustments for tuning within any one range. Accurate dial calibration of center frequencies or swept frequencies is not necessary. When using a sweep generator we tune it for the approximate center frequency required, then adjust the tuning to bring the response curve to the center of the oscilloscope screen -- regardless of frequency then indicated by the tuning dial of the sweep generator.

SWEEPING THE FREQUENCY. The usual manner of varying or sweeping the signal frequency with reference to a center frequency is illustrated in principle at A of Fig.

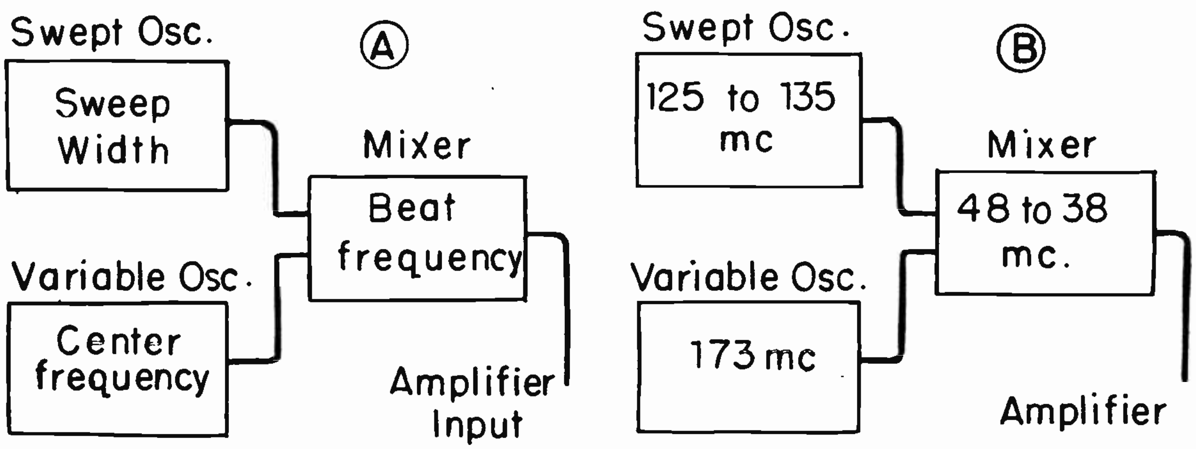

Fig. 5. The continually shifting frequency from one oscillator beats with a steady frequency from a second oscillator to produce a swept output voltage at any center frequency.

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5. The outputs from two oscillators are combined in a mixer. Output of the mixer consists of beat frequencies equal to differences between frequencies of the two oscillators. In another lesson we learned how beat frequencies are produced.

As an example, we may assume that inductance and capacitance in the tuned circuit of the swept oscillator are such that operation is at 130 mc when there is no sweep and no variation of frequency. By methods to be described in following paragraphs the oscillation frequency might be made to vary through a sweep width of 10 mc, from 125 mc up to 135 mc. Were sweep width to be only 4 mc, the variation would be from 128 to 132 mc. Other sweep widths would call for varying the oscillation frequency below and above 130 mc.

At B of Fig. 5 the swept oscillator frequency is indicated as being from 125 to 135 mc. It is assumed that the variable oscillator is tuned for a constant frequency of 173 mc. Resulting beat frequencies produced by the mixer will be the differences between the fixed frequency from the variable oscillator, 173 mc, and the continually varying frequency from the swept oscillator, as follows.

Variable osc. (constant)	173 mc	173 mc
Swept osc. (sweeping)	125 mc to	135 mc
Beat frequencies (differences)	48 mc to	38 mc

Beat frequencies from the mixer output will sweep through the same band width as frequencies from the swept oscillator. Any width for which the swept oscillator is adjusted will be retained at the mixer output, but the sweep frequencies will be at a center frequency determined by tuning of the variable oscillator.

In addition to the desired beat frequencies at the mixer output there will be also the higher frequencies of the two oscillators and the sum of the oscillator frequencies. These higher frequencies are eliminated by filtering or bypassing at the mixer output. There have been sweep generators in which all of these frequencies are applied to the amplifier being serviced, on the assumption that only those to which the amplifier responds will be effective. This method leads to production of numerous troublesome harmonic frequencies.

SWEEP METHODS. Of several commonly employed methods for continually varying the frequency of the swept oscillator, one is shown in circuit form at A of Fig. 6. The inductor in the tuned circuit of the oscillator is a spiral conductor mounted on a sheet of insulation. Such an inductor may be seen at the right in Fig. 7. Attached to the sheet of insulation are parts similar to those in a PM type loud speaker, as seen at the left in Fig. 7.

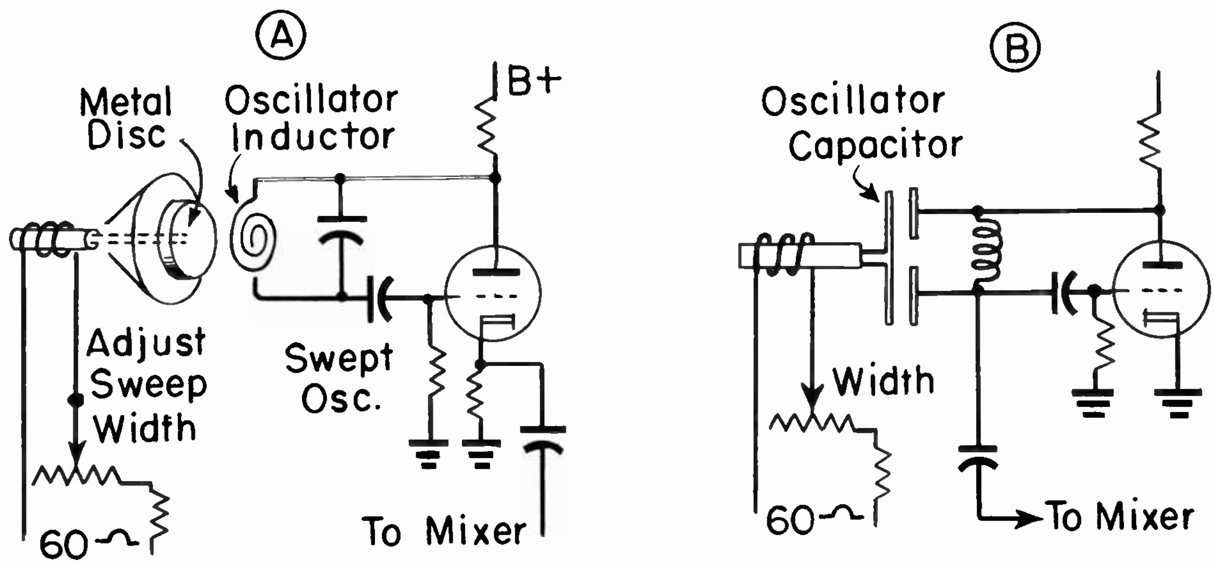

Fig. 6. Frequency may be swept by a vibrating mechanism which varies either the inductance or capacitance in an oscillator tank circuit.

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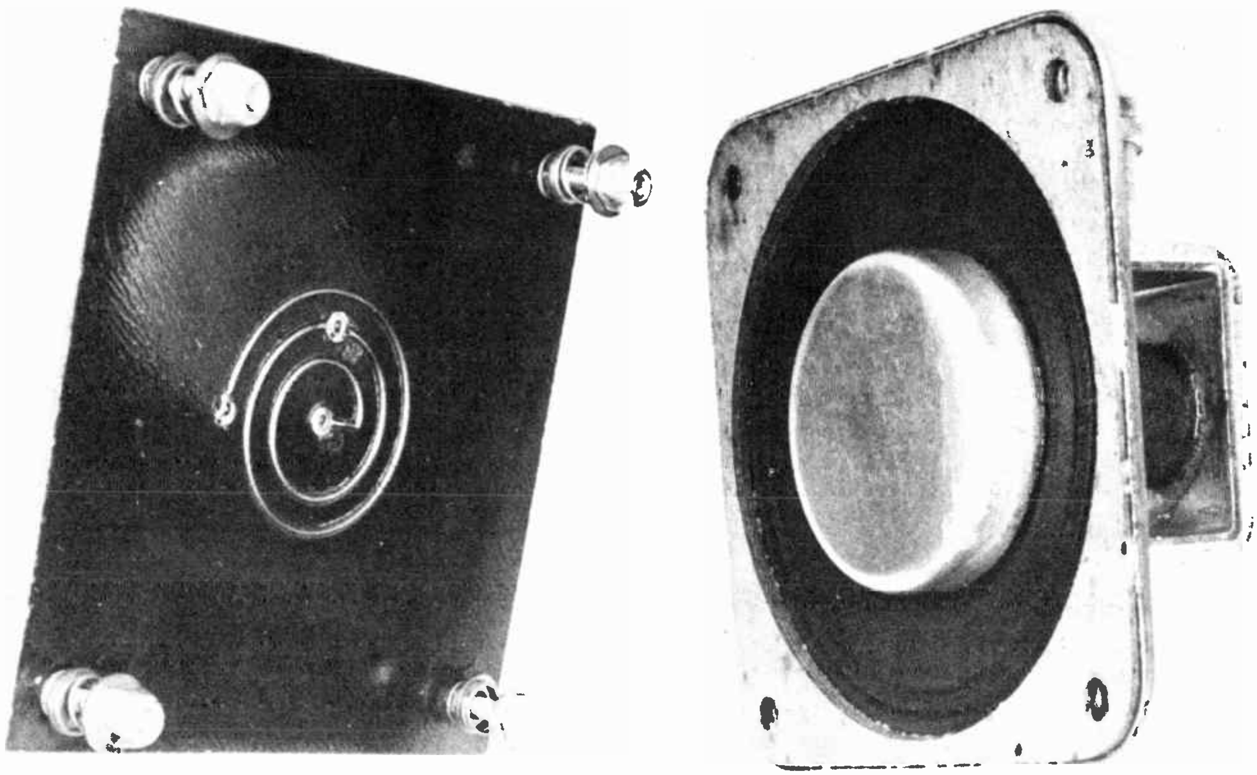

Fig. 7. A vibrator mechanism, similar to a small speaker, and an oscillator circuit inductor.

A light-weight metal cup or disc on the "speaker" element is attached to a sleeve carrying a coil of wire. Inside the sleeve is a strong permanent magnet. When 60-cycle sine wave current acts in the coil, reaction between the alternating magnetic field of the coil and the field of the permanent magnet vibrates the coil and attached metal disc. Then the disc moves toward and away from the spiral inductor 60 times per second.

Effective inductance of the spiral inductor is decreased as it is approached by the vibrating disc, and increases as the disc recedes. This change of effective inductance changes the oscillator frequency from minimum to maximum and back again 60 times per second.

Sweep width depends on change of effective inductance. This, in turn, depends on how far the metal disc moves toward and away from the spiral inductor. The extent of disc movement depends on strength of 60-cycle current in the coil attached to the disc. A rheostat alters the coil current, and thus provides adjustment for width of sweep.

Instead of varying the inductance of the oscillator circuit it is possible to sweep the frequency by varying the capacitance in this circuit, as at B of Fig. 6. A metal plate vibrated by 60-cycle current forms one capacitor plate. The opposite plate consists of two pieces of metal mounted rigidly just far enough from the vibrating plate to leave an air gap for capacitor dielectric. As the vibrating plate moves toward the fixed plates, capacitance increases and oscillator frequency drops. Opposite movement of the vibrating plate decreases capacitance, and causes oscillator frequency to increase.

REACTANCE TUBE. An entirely different method of sweeping the frequency employs what is called a reactance tube. There is

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nothing unusual about the tube itself, it may be almost any type of amplifier triode or pentode. But the reactance circuit does things which are hard to believe, even though you know they are happening. The reactance tube is of special interest because it is used also for automatic control of frequency in horizontal deflection oscillators and for other purposes in television receivers.

One style of reactance tube circuit is illustrated by Fig. 8. The oscillator shown here is a Hartley type with tuned circuit or tank circuit consisting of inductor L and capacitor Co. Any other kinds of oscillator and tuned circuit might be used. The important thing to be noted is this: The tuned circuit of the oscillator is paralleled by capacitor Cr and resistor Rr. These two elements

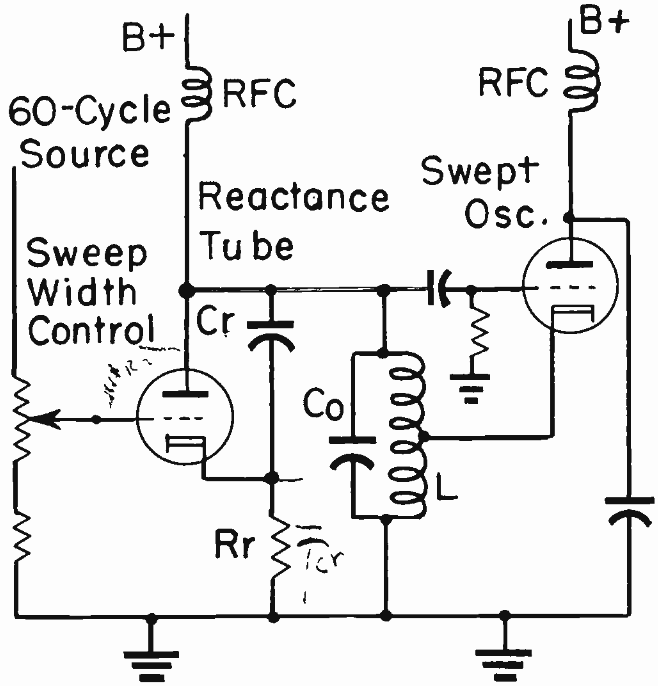

Fig. 8. Connections of a reactance tube which sweeps the frequency of an oscillator.

really are parts of the oscillator tuned circuit, while being connected also to the reactance tube.

If we can cause Cr to act like a continually changing capacitance in the tuned circuit of the oscillator, total tuning capacitance will change at the same rate. Oscillator frequency will be swept accordingly. This is how it is done.

Capacitance at Cr is of such value that its reactance, at the oscillator frequency, is 10 or more times the resistance at Rr. Because capacitive reactance is so great, and resistance so relatively small, Cr and Rr behave in the oscillator circuit much like a capacitance without any resistance. Oscillator voltage causes current at the oscillating frequency to flow in Cr and Rr. Because these elements are effectively a capacitance, and because current in any capacitance leads the voltage by nearly 90 degrees, current in Cr and Rr leads oscillator voltage by nearly 90 degrees.

Alternating current at oscillator frequency in Rr causes alternating voltage to appear across this resistance. Since voltage and current in any resistance are in phase with each other, and since current in Rr is leading the oscillator voltage by nearly 90 degrees, voltage across Rr also leads oscillator voltage similarly.

Rr is between cathode and grid of the reactance tube. Consequently, voltage across Rr, which is leading the oscillator voltage, becomes an alternating grid voltage for the reactance tube. Alternating plate current in any tube is in phase with the alternating grid voltage on the same tube, and so plate current in the reactance tube leads oscillator voltage by nearly 90 degrees. This leading alternating plate current flows in capacitor Cr, between plate and cathode of the reactance tube, and adds itself to alternating current already flowing in Cr due to oscillator voltage.

The combined current in Cr now leads oscillator voltage to an extent depending on how great is the leading current from the plate circuit of the reactance tube. We have the same effect as would be caused by increasing the capacitance of Cr, because we can increase the lead of current in the oscillator tuned circuit, and this is precisely what would happen were the tuning capacitance increased.

Every increase of plate current in the reactance tube, and in Cr, increases effective capacitance in the oscillator tuned circuit, and lowers the oscillating frequency. Every decrease of plate current in the re-

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actance tube lessens the effective capacitance and raises the oscillating frequency. It remains only to vary the plate current of the reactance tube to vary the oscillator frequency proportionately.

To vary the plate current in the reactance tube, its grid is connected to a source of 60-cycle voltage. The 60-cycle grid voltage causes plate current and oscillator frequency to vary or sweep at a 60-cycle rate. How great are the changes of plate current and oscillator frequency depends on the strength of 60-cycle voltage at the grid of the reactance tube. This grid voltage is varied by a potentiometer in the 60-cycle supply circuit. The potentiometer is the control for sweep width.

There are still other ways of sweeping the oscillator frequency. With what is called a variable permeability method, 60-cycle current is cause to vary the effective inductance in the tuned circuit of the swept oscillator. Another method employed in some earlier sweep generators utilizes an oscillator tuning capacitor of a special rotary type, driven at 1,800 or 3,600 revolutions per minute by an electric motor built into the sweep generator.

SYNCHRONIZED SWEEP. When changes of frequency in the swept oscillator are brought about by a 60-cycle sine wave voltage, as nearly always is the case, the changes occur as shown by Fig. 9. Referring to diagram 1, if the swept frequency increases in the portion of the control cycle between a and b, it will decrease in the portion between b and c, again will increase between c and d, and will so continue to vary.

As indicated in the lower part of this diagram, the oscilloscope beam must sweep from one side to the other of its trace during exactly the same time that the frequency is making one change between maximum and minimum. This synchronization of beam motion and frequency change will be realized if the 60-cycle voltage causing changes of

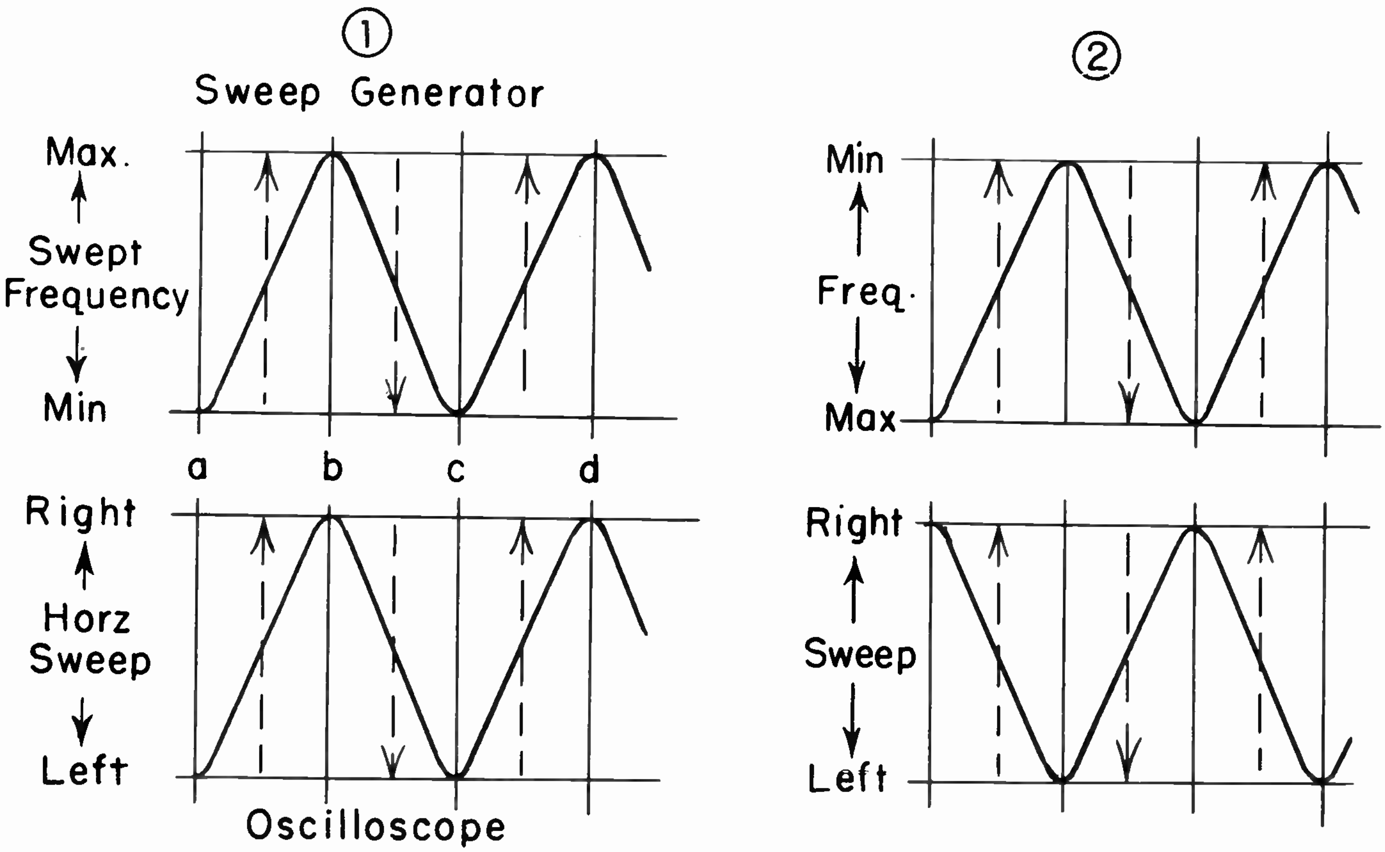

Fig. 9. The sweep of frequency from the generator must be synchronized with horizontal deflection of the beam in the oscilloscope.

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frequency is exactly in phase with the 60-cycle voltage causing horizontal sweep of the CRT beam.

Diagram 2 shows that results would be just as good were the two 60-cycle control voltages to be of opposite phase, or were frequency to increase during an opposite change of polarity in its control voltage, or were the CRT beam to be swept in a reverse direction by a given polarity of its 60-cycle control voltage. Satisfactory synchronization of frequency changes and beam travel will be had when the two control voltages are in phase or are of opposite phase, but not with any other phase relations. Also, the two control voltages must be at the same frequency, a condition easily satisfied by taking both of them directly or indirectly from the same a-c power line.

Unless the two 60-cycle control voltages are synchronized, either in phase or of opposite phase, the forward and return traces will be separated on the oscilloscope screen. Such separation is illustrated at A in Fig. 10. When the two control voltages are correctly phased or synchronized, the forward and return traces will come together, as at B, and appear very nearly as a single trace or a single frequency response curve. It would be possible to perform alignment adjustments with the traces separated, but it is easier and less confusing with what amounts to a single trace or single curve.

It might seem that the control voltages would be synchronized and remain so with both derived from the same power line voltage. It does not work out this way because, in the various circuits through which the voltages must pass before reaching the swept oscillator and the oscilloscope, there are many capacitances and inductances. These circuit elements cause many leads and lags in phase relations of currents and voltages.

Superimposed or single response traces could be secured by altering the phase of voltage controlling sweep frequencies or of voltage controlling deflection of the CRT beam. In practice it always is much simpler to alter the phase of horizontal deflection voltage which is applied to the horizontal input terminal of the scope.

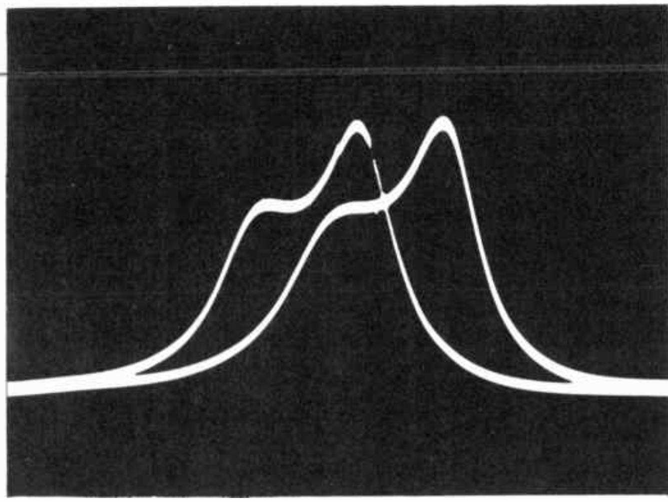

Fig. 10-A.

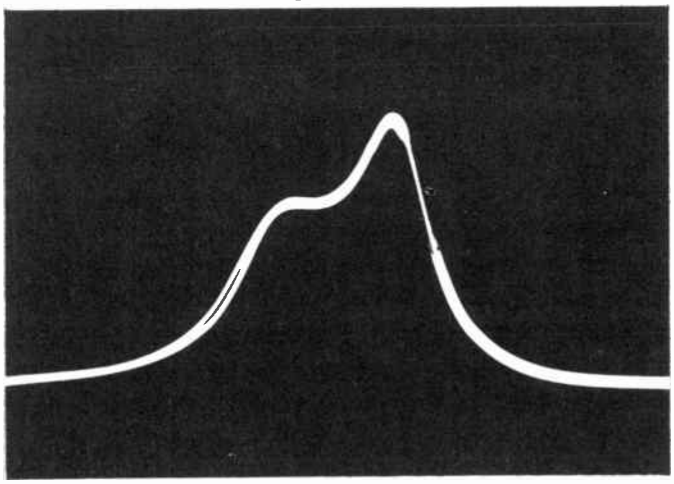

Fig. 10-B.

Fig. 10. Response traces which are out of phase or not synchronized at A, have been synchronized at B.

The great majority of phasing or synchronizing controls make use of the fact that alternating current in a capacitor leads the alternating voltage across the same capacitor, and, accordingly, voltage across the capacitor lags the capacitor current. Several phasing circuits utilizing this general principle are shown by Fig. 11.

The transformers in the phasing circuits may be the regular power transformer of the sweep generator or a small unit used only for phasing. Transformer primaries are connected either to the a-c power line or to a tube heater circuit in the sweep generator. Alternating voltage for controlling the swept oscillator may be taken from either side of the transformer used for phasing. When phasing voltage or a voltage for control of

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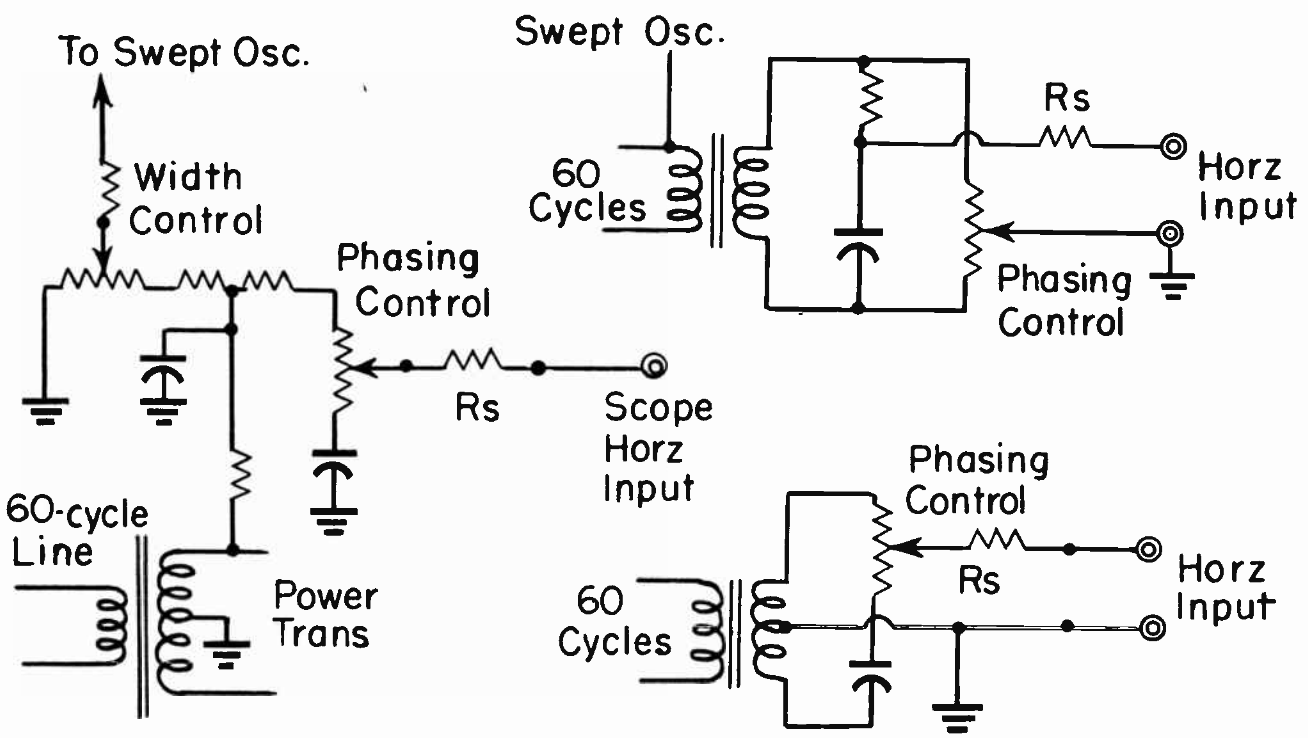

Fig. 11. These circuits and others similar in principle are employed for "synchronized sweep".

sweep width is taken from a power line connection or from the high-voltage secondary of a power transformer it is necessary to use dropping resistors to bring the voltage down to a value suitable for the controls. Resistors Rs in the phasing circuits limit the extent to which response curves may be shifted by operating the phasing control.

Most television sweep generators provide not only the swept signal voltage for amplifiers but also a 60-cycle phased voltage for horizontal sweep in the oscilloscope. Phasing or synchronizing terminals on the sweep generator are connected to the horizontal input and ground on the scope as in Fig. 12. The sweep selector switch of the scope is turned to the position for horizontal input, thus connecting the phased sweep voltage to the horizontal amplifier and gain control. The phasing control is on the sweep generator.

Since all phasing controls act on the horizontal sweep of the oscilloscope these controls sometimes are built into the scope. With such designs there is one position of the sweep selector or sync selector switch for applying the internally produced phasing voltage to the horizontal amplifier and gain control. On the panel of the scope is a pointer or knob for adjustment of phasing. No external connections are made to the horizontal input terminals.

Any of the phasing circuits may be constructed as a separate unit. Transformers are of a step-down type. The primary is connected through an off-on switch to the

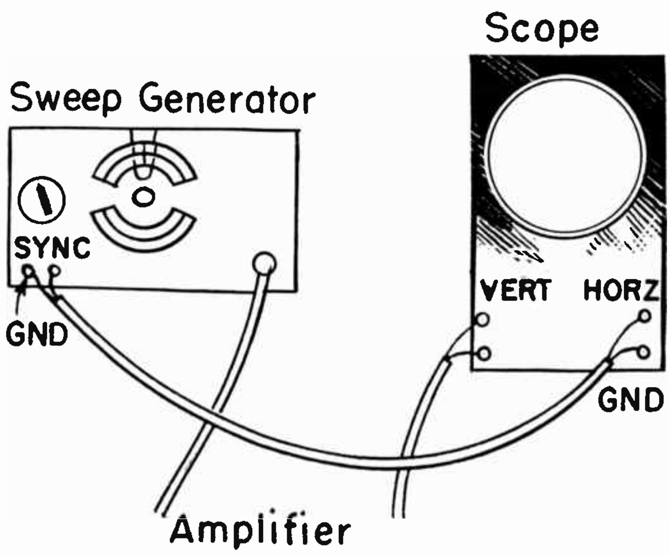

Fig. 12. A phased 60-cycle voltage from the sweep generator is applied to the horizontal input of the scope for timing the sweep of the CRT beam.

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110-120 volt 60-cycle a-c power line. The secondary, which may be tapped, usually furnishes 6.3 a-c volts. Small transformers of this kind are made primarily for supplying heater voltage and current to a few tubes in any kind of apparatus. The output of the separate phasing unit is connected to the horizontal input of the scope.

When a horizontal phasing voltage from any source is applied to the horizontal input and horizontal amplifier of the oscilloscope, frequencies on response curves may increase from left to right or else from right to left. That is, the lowest swept frequency may be at either the left or the right, with the highest swept frequency at the other side of the response.

The direction in which frequency increases depends on phase relations of these two voltages: (1) The 60-cycle voltage that causes sweeps of frequency in the swept oscillator of the sweep generator. (2) The 60-cycle phased voltage applied to the horizontal input and amplifier of the scope for sweeping the CRT beam.

When these two voltages are in phase with each other, frequencies will increase in one direction across the screen. When the two voltages are of opposite phase, frequencies will increase in the opposite direction. Your particular combination of instruments may give frequency increase in either direction. When using a separate phasing unit, reversing its power cord plug in the line receptacle will reverse the direction in which frequencies increase.

When using a sweep generator for alignment work it is common practice to apply a phased or synchronized sweep voltage to the horizontal input and amplifier of the oscilloscope, in any of the ways which have been described. It is, however, entirely possible to use the regular internal sweep of the scope, adjusted for 60 cycles, and to omit the usual phased sweep voltage.

For such operation the swept signal voltage from the sweep generator is applied to the input of the amplifier being aligned, and the output of the amplifier is connected to the vertical input of the oscilloscope, just as though you were going to employ a phased horizontal sweep voltage.

The selector switch on the scope is set for internal sweep, the coarse frequency and the fine frequency are adjusted to bring two response curves onto the screen, as at A of Fig. 13. Now the beam is crossing the screen from left to right in 1/60 second. During this time the signal voltage from the sweep generator is increasing in frequency from minimum to maximum and is decreasing from maximum to minimum. Consequently, one of the response curves on the oscilloscope screen results from frequency increase and the other from frequency decrease.

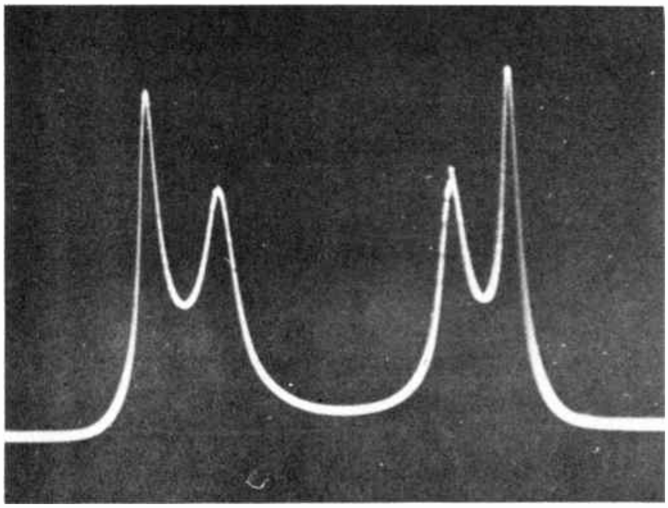

Fig. 13-A.

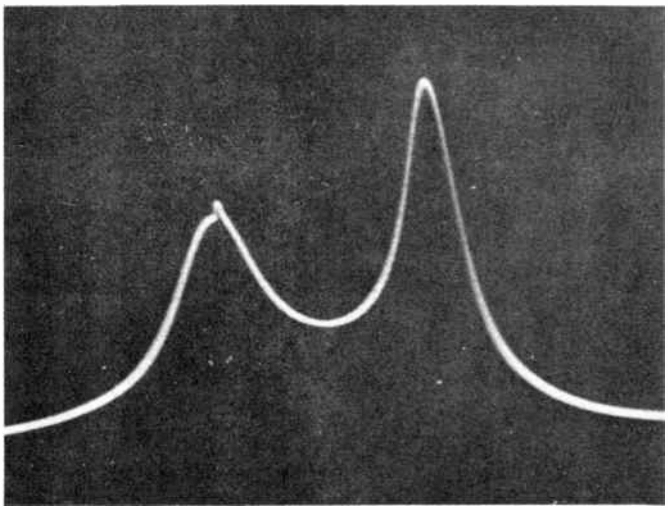

Fig. 13-B.

Fig. 13. The internal sweep of the oscilloscope may be used for timing and displaying of frequency response curves.

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It might be mentioned that the curves of Fig. 13 do not show satisfactory frequency response. The response has purposely been made bad in order to clearly distinguish the curve for frequency increase from the curve for frequency decrease.

The horizontal gain control of the scope is now advanced to make the curves wide enough to show effects of alignment adjustment, and the horizontal positioning control is adjusted to bring either curve to the screen center while putting the other curve off the screen. The result is shown at B of Fig. 13. Here we have enlarged and centered the response which is toward the right at A. Either of the two response curves may be used for alignment, since either may be brought to the center of the screen by suitable adjustment of horizontal positioning.

UNSYMMETRICAL TRACES. Occasionally you may find that the response curve with swept frequency increasing is not of the same shape as the curve with frequency decreasing. When using synchronized sweep the result on the oscilloscope screen may be as at A of Fig. 14, and often is very much worse. By adjustment of the phasing control the two curves have been matched at the right-hand peaks, but the two peaks at the left are not alike and cannot match. Were the right-hand peaks brought as nearly as possible together, the peaks at the left would be separated.

At B the phasing control has been adjusted to completely separate the two curves, so that characteristics of each may be examined separately. You might proceed with alignment by using either of the curves, or you might try to use both together as at A of Fig. 14. However, unsymmetrical response traces indicate that something is wrong, and it would be well to make a correction, if possible, before proceeding with receiver or amplifier adjustments.

The most probable cause for unsymmetrical response traces is overloading of the amplifier on test by applying too strong a sweep signal voltage from the sweep generator. How to recognize and avoid overloading will be considered a little later.

Another possible cause for unsymmetrical traces is poor low-frequency responses in the vertical amplifying system of the oscilloscope. When observing frequency responses we are working at 60 cycles so far as the vertical amplifier is concerned, even though the vertical rise of the CRT beam results from much higher frequencies which are being amplified in the tested receiver. To correctly reproduce response curves the range of uniform vertical gain in the scope should go below 10 cycles, and there should be little or no phase shift between input and output of the vertical amplifier at the very low frequencies.

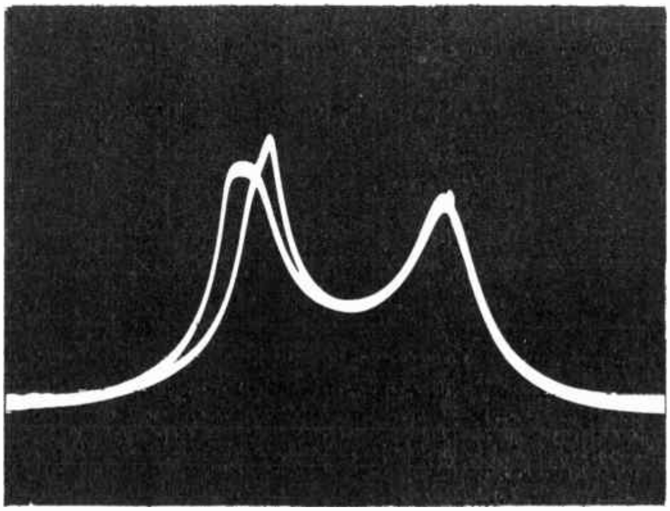

Fig. 14-A.

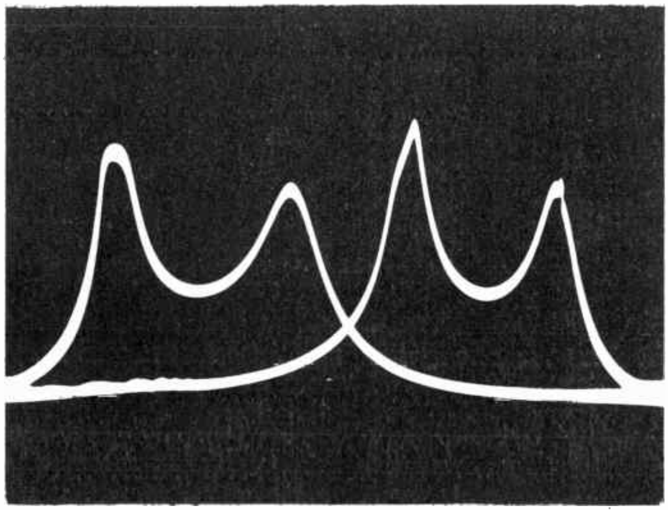

Fig. 14-B.

Fig. 14. Sometimes the response with frequency increasing is not like the response with frequency decreasing.

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Most of the examples of frequency responses which have been examined are taken from the outputs of multi-stage i-f amplifiers with which gains of separate stages combine to produce a wide-band response. In most sound amplifiers the conditions are different, with all stages tuned to a fairly narrow peak at the same frequency.

The response of a sound amplifier or of any simple resonant circuit may appear somewhat as in Fig. 15 when employing synchronized sweep. Here there actually is greater gain while frequency is increasing than when frequency is decreasing. This is due to reactances being chiefly capacitive above resonance and chiefly inductive below

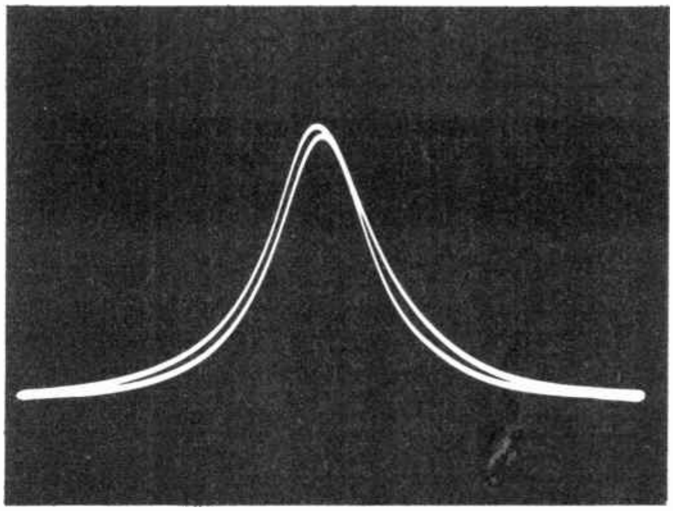

Fig. 15. Response of a single resonant circuit may show greater gain with frequency changing in one direction than in the opposite direction.

resonance, with greater gain where there is more inductive reactance. The fact that such response traces do not match does not indicate faults in the instruments nor in how you use them. Lack of curve symmetry is not great enough to cause any difficulty in alignment.

SWEEP GENERATOR CONNECTIONS. When observing frequency responses it is highly important that no alternating potentials other than signal voltage from the sweep generator shall reach the input of the amplifier being tested. For this reason, the connection from generator output to amplifier input should be made only through a shielded cable, with one end of the shield grounded at the generator and the other end grounded to chassis or B-minus of the receiver.

The next requirement usually is stated thus: The cable must be terminated in its characteristic impedance in order to provide a signal voltage which is constant through the band of swept frequencies. The characteristic impedance of a cable is of a value, in ohms, which depends on the capacitance, inductance, and resistance per unit of cable length. Capacitive and inductive reactances compensate in such manner that the impedance is the same regardless of the actual length of cable in inches or feet. Characteristic impedances of coaxial cables commonly used for instrument connections most often are between 52 and 73 ohms, but are greater for a few types.

To terminate a cable in its characteristic impedance means simply to connect from the receiver end of the central conductor to the shield and ground at this end a non-inductive (carbon) resistor whose resistance in ohms is equal to the characteristic impedance of the cable. A precise match is not essential. Resistances of 56 to 68 ohms are in general use.

At A in Fig. 16 is a response trace from an i-f amplifier with connection from sweep generator to amplifier input through a shielded but unterminated cable. The amplifier has been aligned for nearly equal peaks, for only a moderately deep valley, and, in general, to make the response look very satisfactory. Changing to a correctly terminated cable showed the response to be actually as at B. The amplifier had been misaligned to compensate for a fault in the connecting cable.

If the output of a sweep generator is fed to the antenna terminals, for tuner alignment, rather than to the mixer for i-f alignment, the sweep generator cable should terminate in the input impedance of the tuner. In nearly all receivers this input impedance is 300 ohms, with 150 ohms each side of ground. A termination of this kind may be built into a probe at the receiver end of the generator cable, but to avoid the need for too many kinds of cables and probes a matching network made of resistors may be connected to

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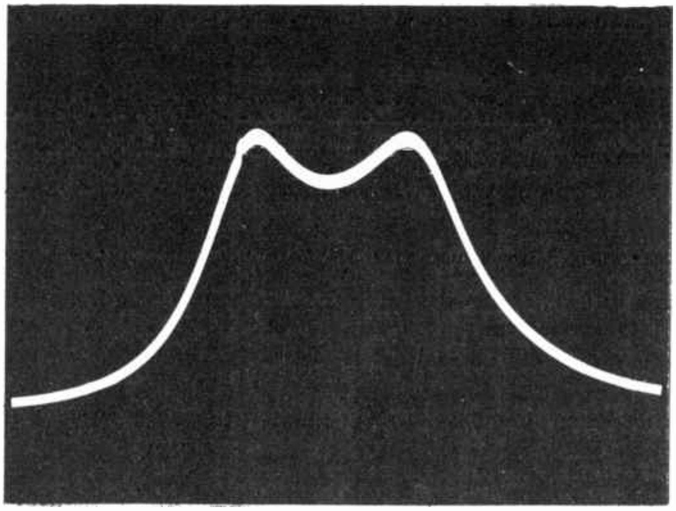
Fig. 16-A.

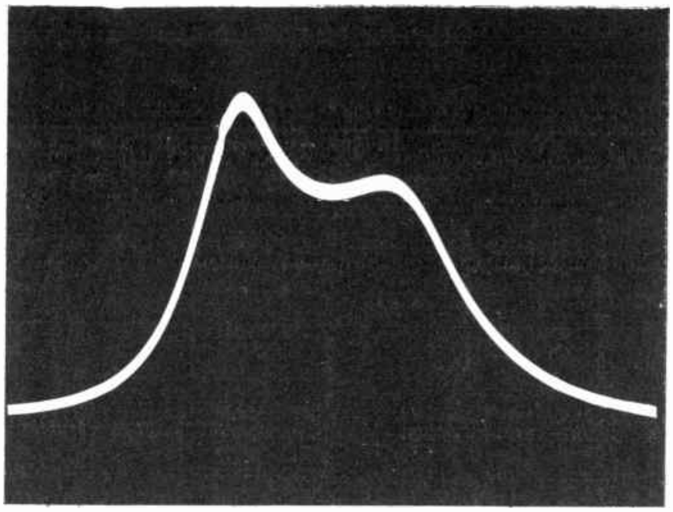
Fig. 16-B.

Fig. 16. Swept frequencies should be fed to amplifiers through a correctly terminated cable.

the receiver antenna terminals during tuner alignment.

Diagram A of Fig. 17 shows the receiver end of a shielded cable fitted with a probe in which is a terminating resistor Ra. One side of Ra is connected to the central conductor of the cable, and the other side is connected to the shield of the cable. The probe tip and its attached ground lead are connected through resistors Rb to the antenna terminals of the receiver or tuner. The connection scheme is shown by symbols at B. When resistor values are as in the accompanying list, the resistance or impedance across the central conductor and shield of the cable will be approximately equal to the characteristic impedance of the cable. At the same time the

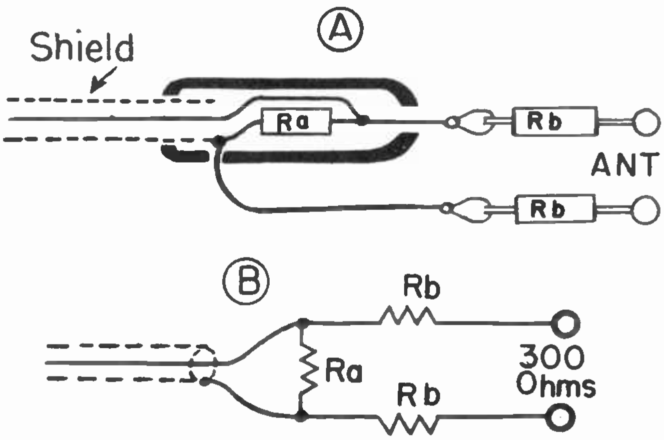

Fig. 17. Matching of the cable from a sweep generator to the antenna terminals of a receiver or tuner.

resistance or impedance connected across the antenna terminals will be approximately 300 ohms, which is the same as input impedance of the receiver.

Cable impedance	Resistor Ra	Resistors Rb and Rb
50 ohms	56 ohms	130 ohms
75 ohms	91 ohms	130 ohms
100 ohms	130 ohms	120 ohms

If a separate probe or separate cable and probe are to be used only for alignment connections to antenna terminals, all three resistors will be inside the probe. If an unterminated cable has to be used for antenna terminal connection, attach a 150-ohm carbon resistor to each antenna terminal, and to these resistors attach the central conductor and shield of the unterminated cable.

Terminated cables and antenna matching networks of the types described should be used on all signal generators as well as on sweep generators. Unless this is done, the cables are certain to distort signal voltages being fed to amplifiers and other circuits in spite of the fact that the generator itself may be developing a uniform or constant voltage.

OSCILLOSCOPE CONNECTIONS. At the output of any amplifier or other circuit whose frequency response is to be observed are many high frequencies, such as those of

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carriers, oscillators, intermediates, picture signals, and so on. If these frequencies reach the vertical input of the oscilloscope they will be amplified and will blur the traces. It is only the variations of a demodulated signal, and the varying strength of a demodulated signal which should reach the oscilloscope for vertical deflection of the beam as it forms response traces.

The unwanted high frequencies are kept out of the cable leading to the vertical input by connecting a bypass capacitor across the output of the amplifier or other circuit whose response is to be observed. The capacitance of the bypass as well as capacitance of the connecting cable would then be across the amplifier output, and would have an undesirable effect on performance. To isolate the bypass and cable capacitance from the amplifier circuit it is necessary to insert a resistance in series with the capacitances at the amplifier end.

All this may be accomplished by fitting the amplifier end of the shielded oscilloscope cable with a probe illustrated by Fig. 18. The 10,000-ohm (10K) series resistor prevents the cable and bypass capacitances from seriously affecting the amplifier. The 1,000-mmf capacitor bypasses unwanted high frequencies to ground before they enter the vertical input cable. These values of 10,000 ohms and 1,000 mmf will be satisfactory for practically all alignment work with any type of oscilloscope. Greater series resistance will weaken the voltages going to the scope, and require higher gain. Greater bypass

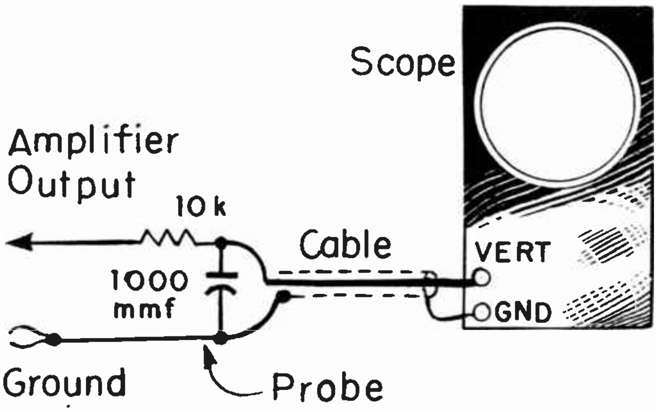

Fig. 18. A probe that isolates cable and scope input capacitance from the amplifier while keeping unwanted high frequencies from the vertical input of the scope.

capacitance may affect performance and output of the amplifier. The probe of Fig. 18 is suitable only for alignment with a sweep generator. Do not use it for waveform observation, it would cause much distortion.

BLANKING THE RETRACE. Unless the response traces with frequency increasing and decreasing can be perfectly superimposed or matched by adjustment of a phasing control, the combined trace cannot be as sharp and clearly defined as either of the separate traces alone. It is for this reason that some oscilloscopes have means for blanking or removing one of the traces, which may be either the one during which frequency increases or the one during which frequency decreases.

Blanking usually is accomplished by cutting off the variable oscillator of the sweep generator during half of every 60-cycle period. When this is done, the generator furnishes no signal voltage to the amplifier on test during the time for one sweep. Then there is no output voltage from amplifier to scope, and during this blanked period the CRT beam travels straight across the screen without vertical deflection. During the other halves of each 60-cycle period the variable oscillator, the amplifier, and the oscilloscope vertical deflection act as usual, and form a trace of frequency response on the screen. The variable oscillator in the sweep generator is put out of action during half of each 60-cycle period by making its grid so highly negative that oscillation ceases.

A negative blanking voltage for the oscillator grid may be obtained in various ways. One of the simplest methods applies a sine-wave voltage to a half-wave rectifier in such manner as to pass only the negative alternations, which are used for blanking. Another method employs a separate multivibrator oscillator designed to produce negative pulses of square waveform.

Instead of cutting off an oscillator in the sweep generator, return trace blanking may be obtained in the oscilloscope. During the portion of each sweep cycle to be blanked, a strong negative pulse is applied to the grid of the CRT, thus actually blanking the beam. The blanking pulse may be obtained by the

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same methods used for blanking the sweep oscillator. The pulse is applied to the CRT grid through connections such as used for intensity modulation.

SWEEP GENERATOR REQUIREMENTS. In addition to features discussed earlier in this lesson a satisfactory sweep generator should meet certain requirements with reference to its output signal voltage. A maximum signal output of 0.1 volt, often specified as 100,000 microvolts, is satisfactory for use in connection with an oscilloscope of good sensitivity, say 20 to 30 millivolts per inch. Signal output should not change appreciably with fluctuations of power line voltage. This usually means that the sweep generator must include a voltage regular tube or tubes.

The sweep generator must be well shielded, so that its signals go out only through the shielded cable to the amplifier or receiver and cannot reach sensitive receiver circuits by any other path. The attenuator or output voltage control of the sweep generator should be capable of reducing the signal to a low value, something like 20 microvolts, for alignment of amplifiers having high gain without overloading the tubes near the input of such amplifiers by applying too strong a sweep signal.

What probably is the most important requirement for a sweep generator is that its output voltage shall remain very nearly of constant value throughout any band of swept frequencies which may be used. If there are variations of signal voltage they will be amplified in the receiver being aligned and at the receiver output and oscilloscope vertical input these changes of voltage will be added to the frequency response curve. Obviously, any response in which there are peaks and valleys and slopes not put there by characteristics of the receiver is quite worthless for alignment purposes. If the receiver is adjusted to get rid of the false parts of the observed response, the alignment will be exceedingly poor for operation on regularly transmitted television signals.

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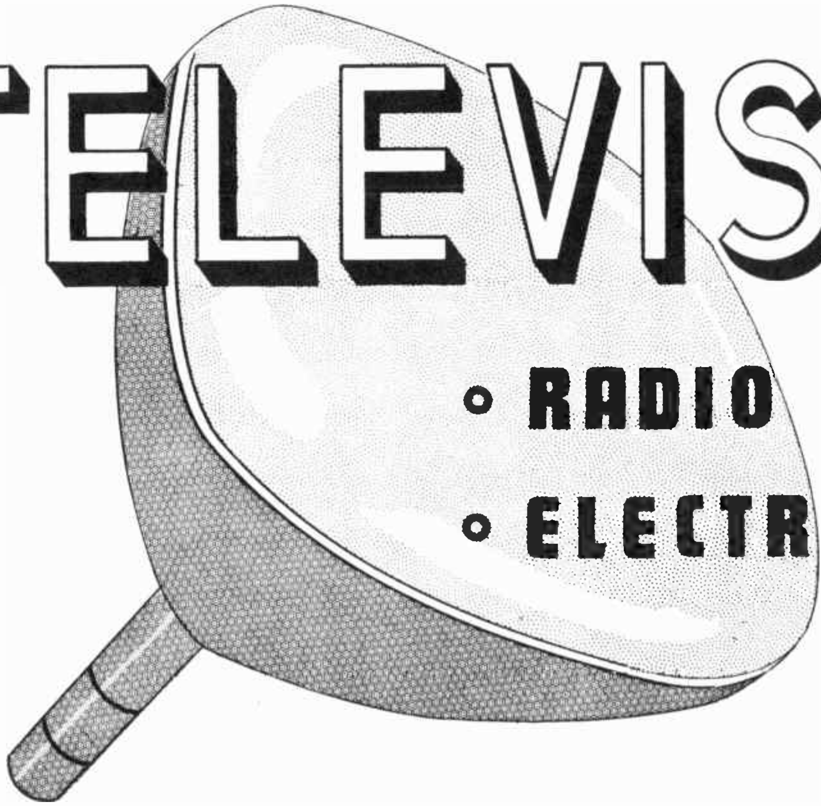

• RADIO

• ELECTRONICS

LESSON 56 — MARKER GENERATORS AND CRYSTAL CONTROLS

Coyne School

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Chicago, Illinois

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Lesson 56

MARKER GENERATORS AND CRYSTAL CONTROLS

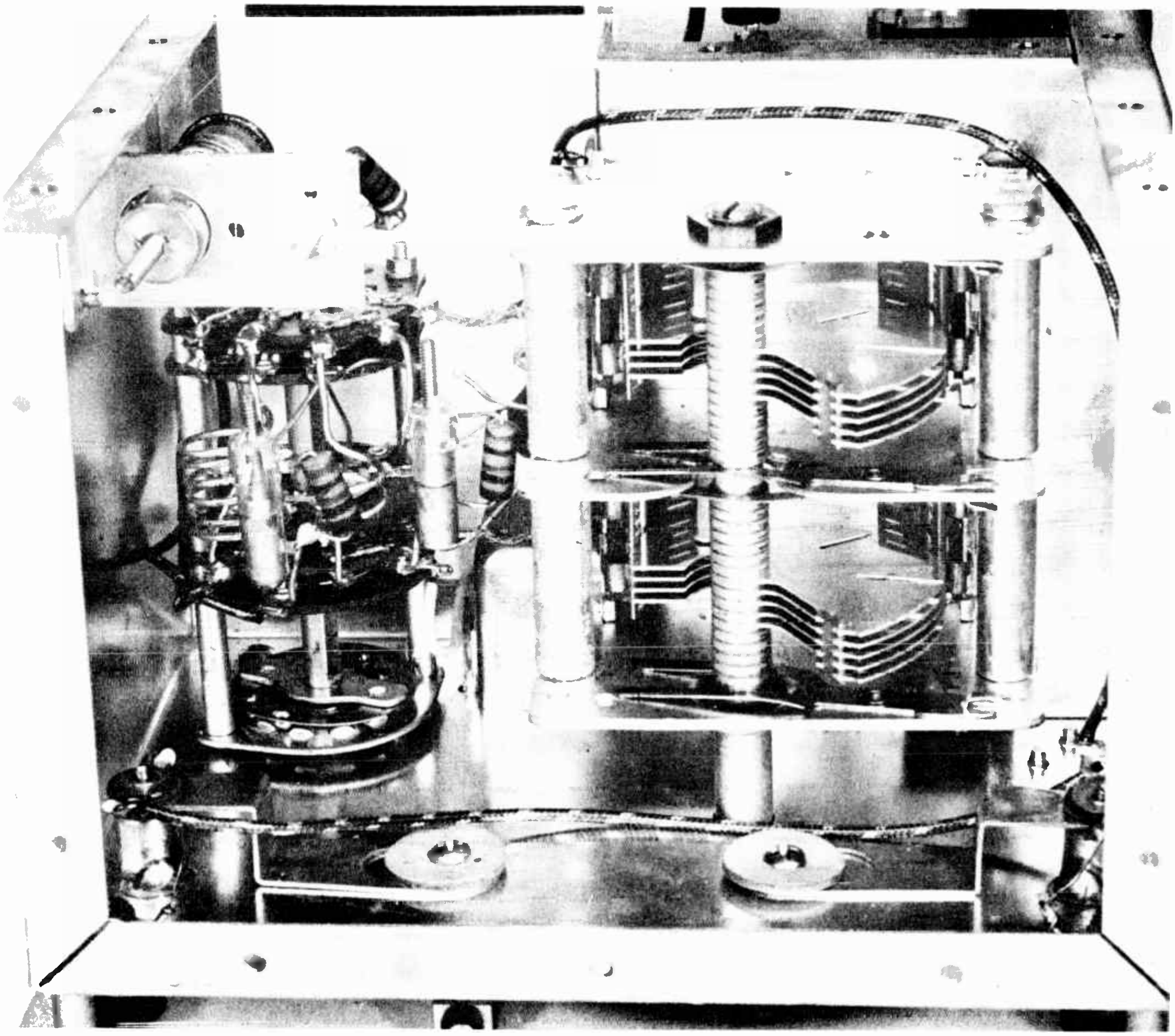

Fig. 1. The tuning and range switching section of a marker generator.

The sweep generator allows bringing a trace of frequency response onto the screen of the oscilloscope, but the response curve is of little use without knowing exact frequencies at various points. It might seem that frequencies could be identified on a graduated scale, assuming that frequencies extend uniformly below and above a center frequency indicated by the sweep generator dial, and assuming a sweep width indicated by the generator setting. This method does not work out in practice. The sweep usually is not equal on both sides of an indicated center frequency, the trace may not be perfectly linear, and there are various other inaccuracies.

For frequency identification we need a marker generator. The marker generator is merely a highly accurate signal generator

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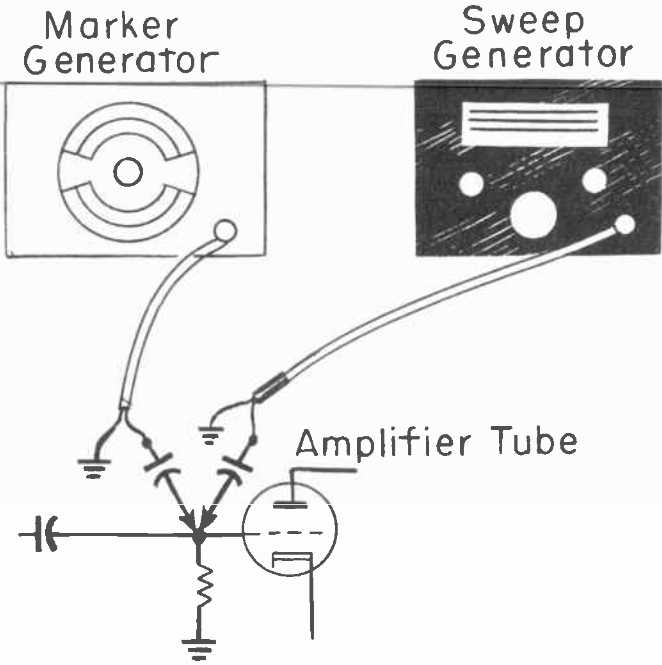

Fig. 2. Marker and sweep generators are connected to the input of an amplifier being aligned.

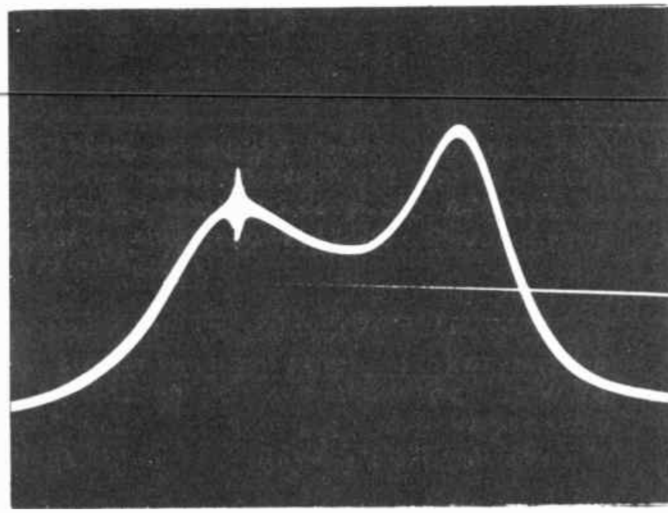

Fig. 3-A.

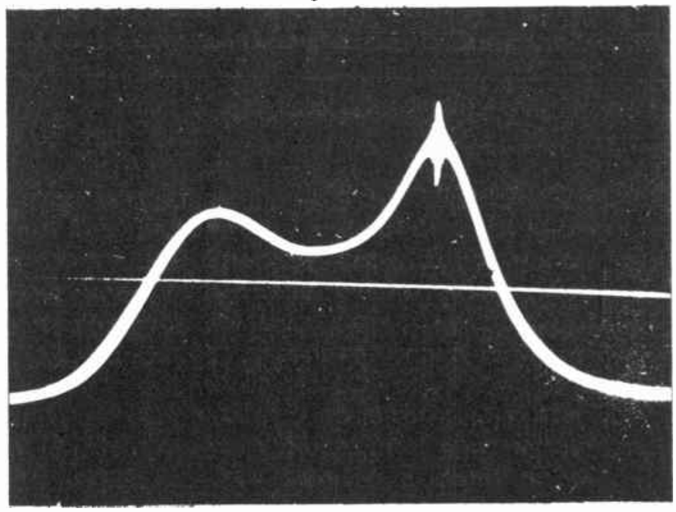

Fig. 3-B.

Fig. 3. A marker may be placed at any point on the response where frequency is to be identified.

which produces one or more constant or steady frequencies. As in Fig. 2, the swept frequency output of the sweep generator and the steady frequency output of the marker generator are fed together to the amplifier being tested. Both connections are through small capacitances, to prevent short circuiting a grid bias voltage through the generators.

When the marker frequency is adjusted to fall within the band of swept frequencies, there will be one point along the response curve at which the swept frequency becomes the same as the marker frequency. Here, in effect, the outputs of the two generators combine and produce on the response trace a marker such as illustrated at A in Fig. 3. Marker indications may be called pips, birdies, or other names.

The center of the marker on the response trace is at the frequency being furnished by the marker generator, and to learn the value of this frequency we read the dial of the marker generator. Changing the frequency from the marker generator will move the pip to another point along the trace, as at B of Fig. 3. The frequency of this new point may be read from the tuning dial of the marker generator. In this manner it is possible to identify frequencies all the way along the response. On the two traces illustrated, we are identifying the frequencies at two peaks of a response.

Having identified the frequencies at various points along a response, the next step might be that of making alignment adjustments to bring the video intermediate to about 50 per cent of maximum gain. This would require tuning the marker generator to the video intermediate frequency, thus placing a marker at this frequency on the response curve. By suitable alignment adjustments the i-f marker could be brought about half way up on the higher-frequency slope of the trace, as at A of Fig. 4.

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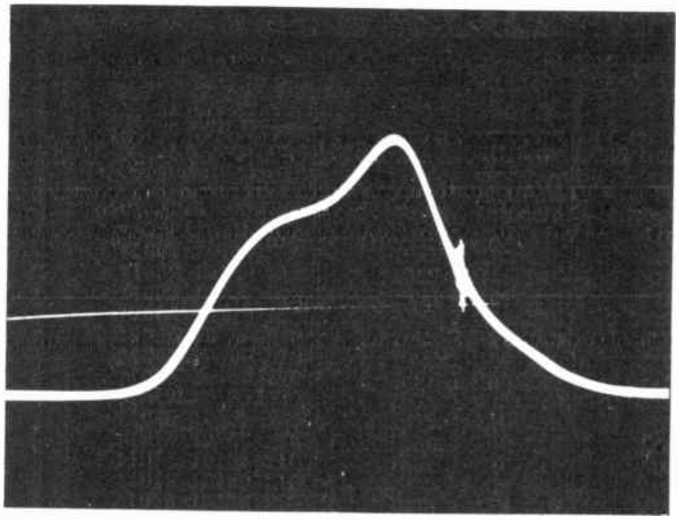

Fig. 4-A.

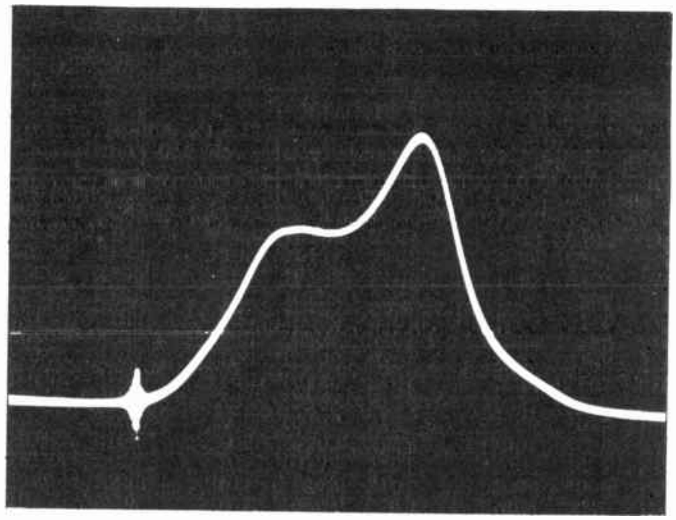

Fig. 4-B.

Fig. 4. A marker may be shifted from the video intermediate frequency (A) to the sound intermediate (B).

Now the marker generator could be returned to the sound intermediate frequency, and, as at B of Fig. 4, a marker would appear at this frequency on the response curve. Finally, alignment adjustments could be altered to improve the shape of the response curve while keeping video and sound intermediate frequencies where they belong.

Inasmuch as the principal requirement for a marker generator is that it be a first class r-f signal generator, the instrument may be used for any and all purposes requiring an r-f signal generator as well as for identifying frequencies on response curves. There are many single instruments combining the functions of sweep and marker generators in one. External connections for alignment work then are somewhat simpler than with separate generators, but the built-in marker may or may not be usable for other service operations.

Not all markers are pips, like those illustrated by Figs. 3 and 4. Some are dips, like the one you can see in Fig. 5 identifying the frequency at one of the peaks on a response curve. In the type of marker generator that produces the, pip or birdie type of marker there is an oscillator producing the frequency which causes a marker. A pip results from combination of instantaneous r-f powers from sweep generator and marker generator. No oscillator is needed for producing a dip type of marker.

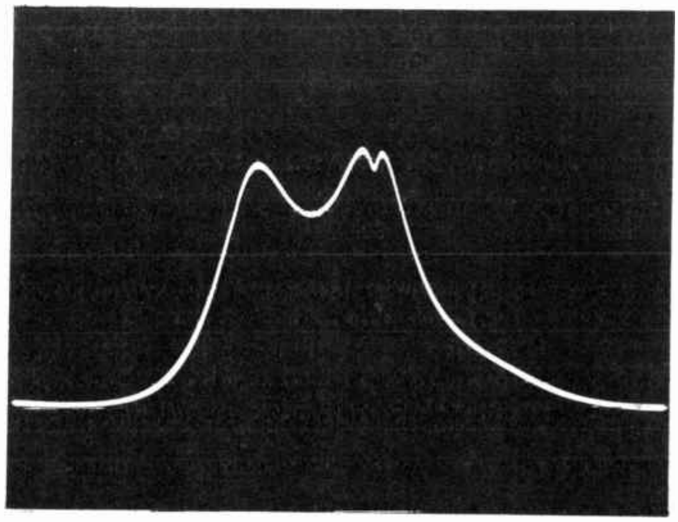

Fig. 5. A dip or absorption marker at one of the peaks on a response curve.

A dip marker is caused by absorption of r-f power from the output of the sweep generator. A high-Q resonant circuit with adjustable tuning capacitor, and sometimes with a range switch for various bands, is loosely coupled to the output of the sweep generator or to the input of the amplifier being tested. Every time the swept frequency becomes equal to the tuned frequency of the marker circuit, the marker circuit absorbs some r-f power from the output of the sweep generator. This reduces the sweep signal power going to the amplifier at the marker fre-

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quency, and causes a sharp dip in the curve of frequency response. The dip marker circuit usually is built into the sweep generator, although it may be a separate unit.

MARKER GENERATOR CONNECTIONS. The output of a marker generator must be taken through a shielded cable with one end of the shield grounded in the generator and the other end grounded at the amplifier being tested. Preferably the cable is terminated in its characteristic impedance, as is the cable from a sweep generator.

The output of the marker generator is connected to the same point on the amplifier as the output of the sweep generator, as shown by Fig. 2. It is preferable, as illustrated in that figure, to connect the two generators through separate small capacitances to the amplifier. Generally similar results are obtained when the capacitor in series with the marker output is connected to the high side (central conductor) of the sweep generator. Then the outputs of both generators go to the amplifier through the small capacitance on the high side of the sweep generator. Under no conditions should the high-side connection from the marker be made directly to the high-side of the sweep generator, without an intervening capacitance.

Capacitors for connection of the two generators to the amplifier may be of values between 2 and about 20 mmf. The smaller capacitances are used when the amplifier has high gain, when the oscilloscope has high vertical sensitivity, or when the signal voltages from the generators cannot be sufficiently reduced by their attenuators. Often it is sufficient merely to lay the high-side cable connector of the marker close to the output clip of the sweep generator. Connection of the marker may be through a gimmick; two or three turns of wire wound on the high-side connection of the sweep generator, with the marker cable clipped to one end of this wire.

The marker generator is used without modulation of its r-f output when employed as a marker. Many generators designed for general use, as well as for markers, have provision for internal or external modulation at audio and other frequencies. In this case the modulation is turned off while using the generator as a marker.

USING THE MARKER GENERATOR. When preparing to use a marker generator it is a good idea to commence with only the sweep generator and oscilloscope connected to the amplifier, and to set up a trace of frequency response on the scope. Then connect the marker generator to the amplifier, with the marker generator turned off. There will be a slight lowering of the trace, but there should be no change of shape or of relative responses at various points. If there is a decided change of form in the curve it usually indicates one of three errors. (1) There are not enough ground connections or good enough ground connections between ground terminals or housings of the sweep generator, the marker generator, and the oscilloscope. Improve the grounding or bonding. (2) The highside leads and connections from sweep generator, marker generator, or both of them are too close to wiring and elements in the amplifier or receiver. (3) You are using excessively great capacitance from generator cables to the amplifier.

Now turn on the marker generator and tune it to a frequency to be checked. Retard the attenuator of the marker generator as far as leaves a visible pip or dip. At A in Fig. 6 is a response trace on which a marker adjusted for least intensity which leaves it clearly identifiable on the screen of the scope. This marker, hardly visible in the photograph, is at about the level of the faint horizontal line through the middle of the trace.

At B the marker has been made much too strong. The shape of the response is badly distorted. The marker does not even appear at the same height on the response slope as with correct conditions. The marker pips in Figs. 3 and 4 are much stronger than they need be, this having been done to more clearly show what happens during changes of marker frequency.

When frequencies from the sweep and marker generators pass together through the amplifier to the scope the two frequencies beat together. The resulting beat frequency is strongest at the marker frequency, but

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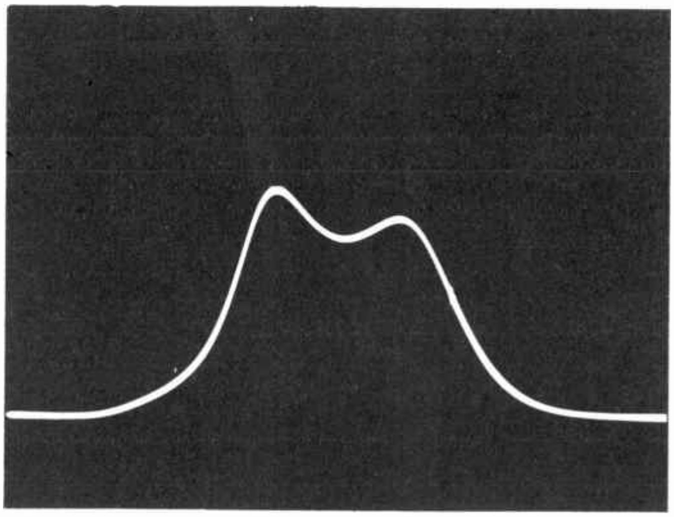

Fig. 6-A.

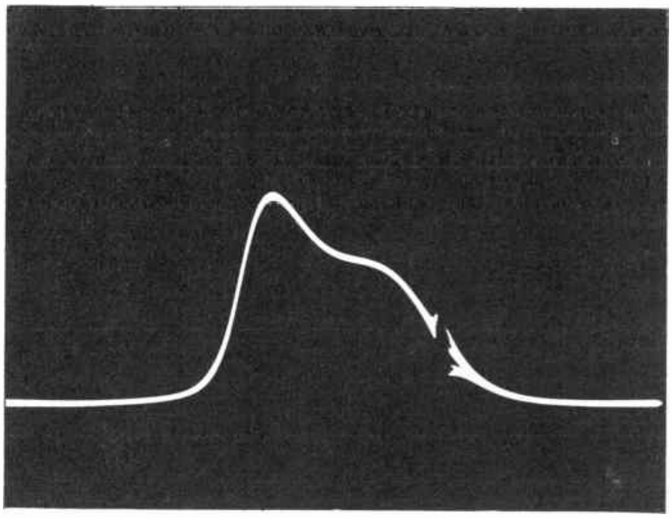

Fig. 6-B.

Fig. 6. A marker pip of too great intensity or strength causes serious distortion of the frequency response curve.

actually there are other beat frequencies extending to indefinite distances both ways, and becoming higher and higher in frequency at greater distances from the marker frequency.

If your oscilloscope has good response at high frequencies, the beats extending both ways from the marked frequency can be seen on the trace. The effect is an extended fuzziness, as at A in Fig. 7. The fact that the beat frequencies exist throughout the response band is shown by hazy broadening at both ends of the trace.

The higher beat frequencies are removed from the vertical input of the oscilloscope by connecting a capacitance from this input to ground. Then, as at B we have remaining only the strongest and lowest-frequency beats at the marked frequency, and have a clean, sharp marker. This is easily accomplished by using on the vertical input cable a filter probe described in a preceding lesson, the one including a 10,000-ohm series resistance and a 1,000-mmf bypass capacitor. If you do not have such a probe it is a simple matter to connect the resistor and capacitor to the points at which the vertical input cable

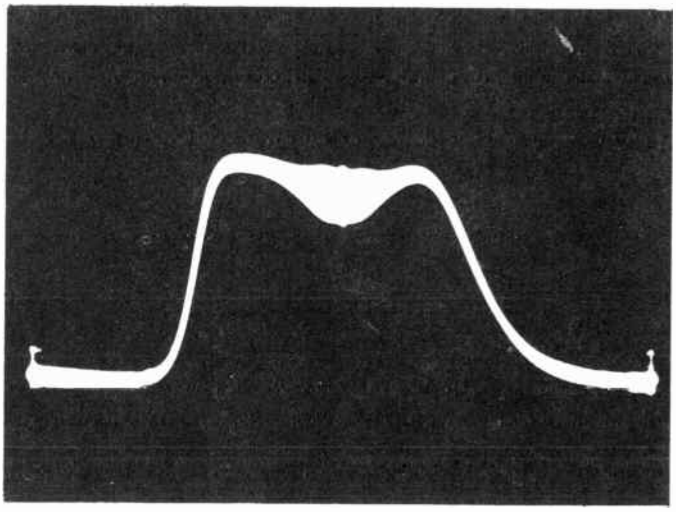

Fig. 7-A.

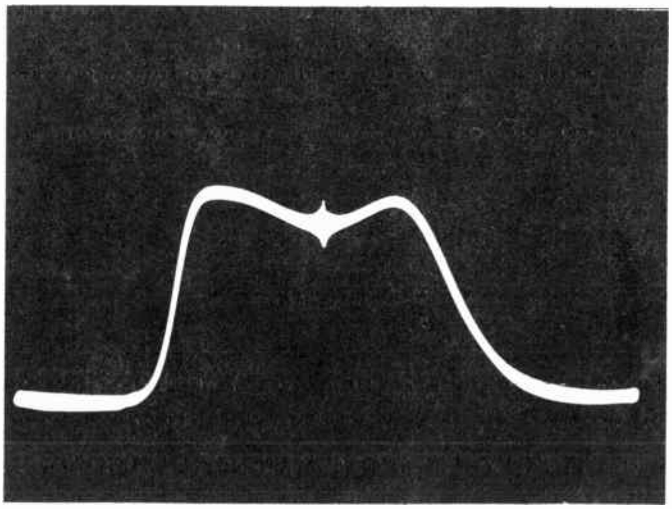

Fig. 7-B.

Fig. 7. Unless the higher beat frequencies are bypassed they cause fuzzy and indistinct marker pips.

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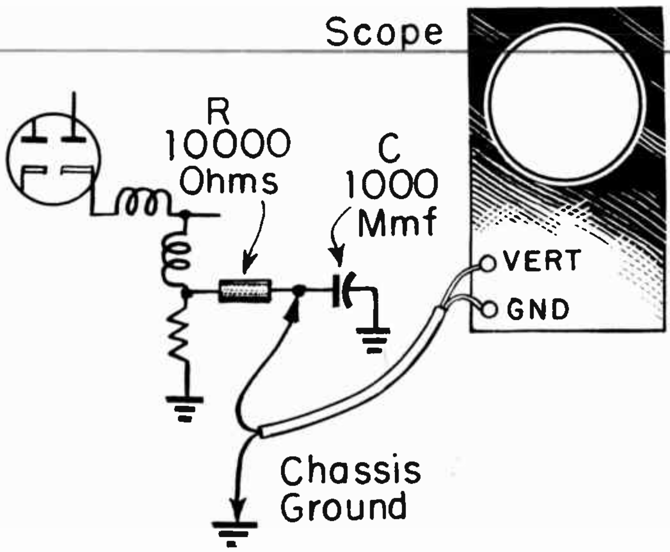

Fig. 8. The vertical input cable is connected to a resistor and capacitor for sharpening the marker pips.

is attached, as in Fig. 8 which shows a connection to the load of a video detector.

The beat frequency voltage which forms a marker pip is amplified before reaching the oscilloscope, just as are the swept frequencies. The greater the amplification the larger will be the pip on the response curve. Consequently, as you change the tuning of the marker generator to move the marker pip up on a response curve, the pip becomes larger and larger, and tends to distort the response to a greater and greater degree. It is necessary to readjust the output attenuator of the marker generator when shifting the marker pip up and down on the response trace.

It may be difficult to see a marker pip on the sloping sides of a response curve, because the marker itself extends up and down, and there is not much difference from the slope of the trace. It may help if you widen the trace by using the horizontal gain on the scope, or lower it by using the vertical gain, making the slopes less steep in either case. Oftentimes the markers are brought out more distinctly by using a phasing control to separate the forward and reverse traces of the response rather than leaving the two traces superimposed as in usual practice. Blanking of a return trace, either in the sweep generator or the oscilloscope, helps in making marker pips more distinct.

Increasing the output from the marker generator in an effort to make pips more distinct is quite likely to distort the response. The pips may be enlarged without distorting the response curve by reducing the signal output voltage from the sweep generator and increasing the vertical gain of the oscilloscope to make the response curve of satisfactory height on the screen. This allows using a moderate or low output from the marker generator.

MULTIPLE MARKERS. Alignment adjustments ordinarily are made to bring about a desired shape of the response curve while keeping the video intermediate at about half of maximum gain and the sound intermediate far down on the opposite side of the curve.

The process is not too easy, because every change of alignment adjustment in any amplifying stage alters the shape of the entire response. A given adjustment may have greatest effect at either end of the curve, or in the middle, but it will have some effect everywhere else. Consequently, with a single marker, you have to keep changing the tuning of the marker generator back and forth between video and sound intermediates. Otherwise, when you get the video intermediate just right, the sound will be too high or too low, and when the sound is right the video will be too high or too low.

The work of alignment is simplified and greatly speeded by the use of two markers at the same time, with one of them kept at each of the intermediate frequencies. Then you may proceed to shape the response in any way possible while retaining correct positions for both intermediate frequencies. The use of two simultaneous markers is illustrated by Fig. 9. The marker on one of the slopes is at the video intermediate, and the one far down on the other side of the curve is at the sound intermediate. Some sweep generators provide two independently tunable frequencies.

Some of the advantage of two independent markers may be had from a marker generator or a signal generator which furnishes strong harmonic frequencies. The method involves obtaining a harmonic frequency equal to the required video intermediate, and

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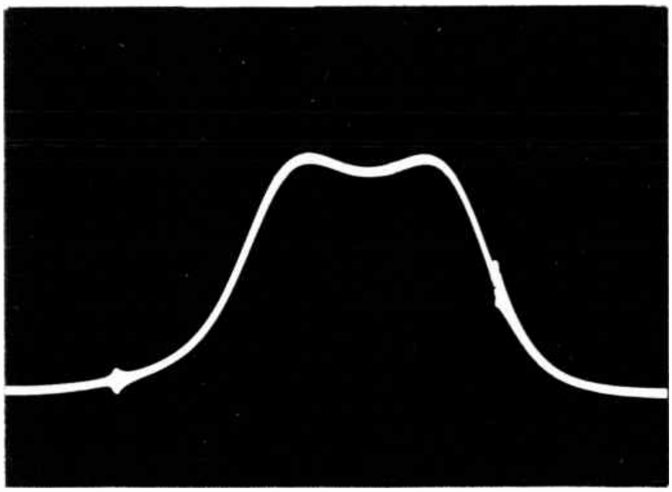

Fig. 9. Two separate markers kept at the two intermediate frequencies help to speed the process of alignment.

another harmonic having a close relation to the sound intermediate of the receiver. Procedure is as follows.

1. Set up a response trace as usual, tune the marker generator to the video intermediate frequency, and note just as closely as possible the position of the resulting marker pip on the response.

2. Tune the marker generator to the sound intermediate, and note the marker pip position.

3. Tune the signal generator to a frequency about 1/6 or 1/7 of a video intermediate which is in the 21 to 27 mc range, or to about 1/11 or 1/12 of a video intermediate in the range around 45 mc. Increase the output of the marker generator and tune it back and forth to obtain, if possible, a marker pip at exactly the same point occupied by the video intermediate marker in step 1. A second marker should be seen at a point somewhat higher than the original sound intermediate marker obtained in step 2.

Here is an example: Assume a video intermediate of 25.75 mc. With the generator tuned down to 3.68 mc the seventh harmonic will be 25.75 mc. Note that it is not necessary to tune the generator to any particular fractional frequency, such as 3.68 mc, but only to any dial position which gives a marker at the video intermediate on the response trace.

Continuing our example, the sixth harmonic of 3.68 mc will be at 22.08 mc. This is only 0.83 mc above the regular sound intermediate which, for the assumed video intermediate, would be 21.25 mc.

4. Note the approximate position of the second, lower frequency, harmonic marker on the response, and compare this position mentally or on a ruled screen with the correct position for a sound intermediate marker.

5. Proceed with alignment adjustments for correcting the shape of the response while keeping both the harmonic markers at their relative gains with respect to either maximum or zero response.

This method is a time saver for all preliminary alignment work. It will, of course, be necessary to make a final check with a marker at the true sound intermediate frequency.

MARKER GENERATOR REQUIREMENTS. The frequency ranges of a marker generator should be the same as the center frequency ranges mentioned earlier for sweep generators. The attenuator should be capable of bringing the output voltage down to only a few microvolts. Shielding and consequent freedom from signal leakage are highly important.

What we might class as good accuracy is enough for some service operations, while accuracies to within a few hundredths of one megacycle are needed for other operations. A maintained accuracy on this latter order would call for precision construction, for controlled temperatures and supply voltages, and for refinements which would raise the cost beyond that warranted for instruments to be used in a service shop. The economical way to secure high accuracy plus frequency stability is to employ crystal control of frequencies or crystal calibration for an ordinary marker generator.

CRYSTAL FREQUENCY CONTROL

A piezo-electric crystal, commonly called a quartz crystal, is a piece of the min-

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eral quartz about a half-inch or less square and something like 1/50 inch in thickness. This element, as used for frequency control, is not just an ordinary piece of quartz, but is cut in a special manner from a larger crystal so that the crystalline axes are in certain relative directions, and is ground to precise form and dimensions.

The style of quartz crystal most often used in radio and television instruments is shown by Fig. 10. At the center of the picture is a plastic insulating case with the crystal in position, but with the cover removed and placed at the left. Against the two flat faces of the crystal are pressure plates, one of which is shown at the right. Outside the pressure plates are contact plates attached to two projecting pins. These pins fit into a socket used for supporting the crystal and making external circuit connections. There are various other methods of assembly, such as silver plating on opposite faces of the crystal to do away with need for pressure and contact plates.

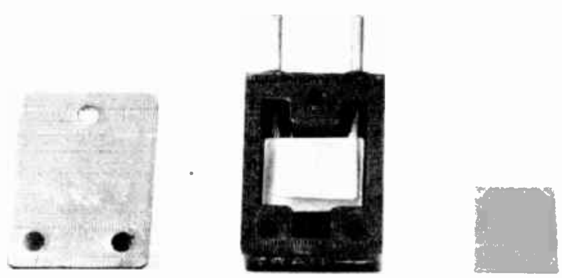

Fig. 10. A quartz crystal of a type in general use for production of highly accurate frequencies.

If an alternating voltage of suitable frequency is applied across the crystal faces, by means of the metal plates or silver plating, the crystal becomes alternately thicker and thinner by almost microscopic amounts. The crystal itself then produces an alternating electrostatic field and voltage at a frequency depending on the dimensions of the quartz and the manner in which it has been cut from the original mother crystal.

The alternating voltage which excites the crystal need not come from an external source or circuit, it may result from action of the crystal itself in any of several oscillator circuits employing the feedback principle. As with oscillators in general, the action may be started by application of any voltage in a circuit of a kind which encourages vibration of the crystal and which will furnish the small amount of power consumed by mechanical expansion and contraction of the quartz.

A circuit widely used for crystal frequency control in service instruments is called the Pierce oscillator. One of its many forms or modifications is shown at A in Fig. 11. The quartz crystal, represented by its

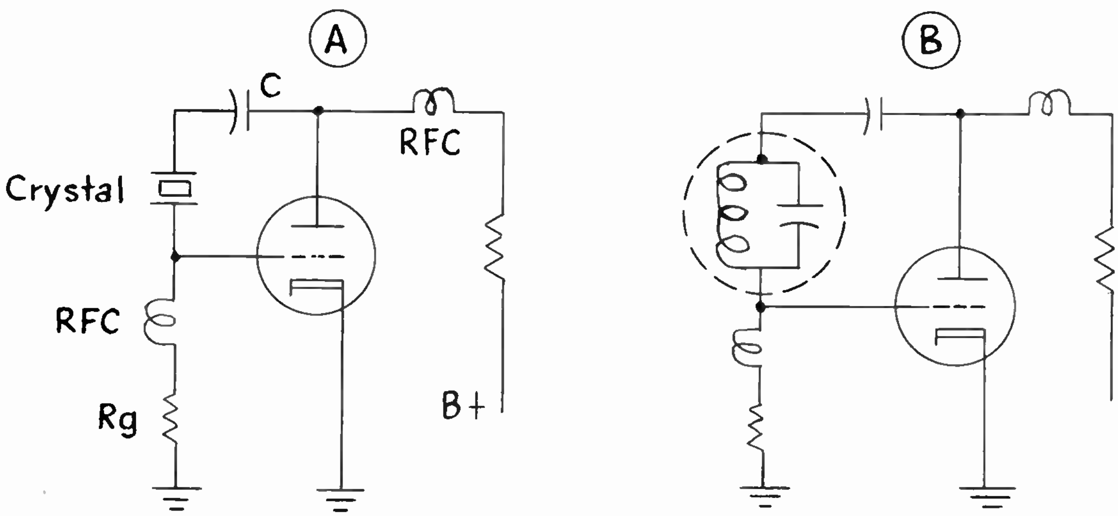

Fig. 11. A form of Pierce crystal oscillator circuit and its electrical equivalent when employing an ordinary L-C resonant circuit.

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usual symbol, is connected between plate and grid of the tube, with a series blocking capacitor C to prevent d-c plate voltage from reaching the crystal while completing the circuit for r-f currents.

Resistor Rg is a grid leak, as used with nearly all oscillators to provide grid bias. The capacitance required for grid bias action results from mechanical construction of the crystal. The crystal structure includes an excellent dielectric material (quartz) between two conductive plates, a combination which forms a capacitor. R-f chokes confine high-frequency currents and voltages to the circuit which consists of the tube plate, the grid, and the crystal.

As shown by diagram B, the crystal is the electrical equivalent of a resonant circuit, but it has a Q-factor many times greater than in any ordinary coil-capacitor circuit. Weak alternating voltage produced by the crystal is applied to the grid of the tube, and amplified. Part of the amplified voltage appearing at the tube plate feeds back to the crystal, where it furnishes power to maintain vibration. Remaining r-f output power may be taken from the circuit in any of the ways used for oscillators in general.

The Q-factor of the crystal is so great that its frequency of oscillation is almost wholly independent of characteristics of the connected circuit. Oscillation frequency is controlled by dimensions and method of cutting the quartz. In crystals ordinarily employed for service instruments the frequency maintains an accuracy of 1/50 of one per cent or of one part in 5000 with reference to the rated or specified frequency.

There may be slight change of crystal frequency with wide variations of temperature, but with temperature in and around the crystal remaining within a range of about 25° to 120° Fahrenheit, the accuracy will be as stated. Accuracies of 1/500 of one per cent are attained from suitable crystals operated at controlled temperature.

CRYSTAL HARMONICS. The oscillating frequency of quartz crystals is increased by reducing their thickness. To reach frequencies much higher than 10 to 11 mc the crystal has to be ground so thin that it becomes quite fragile, and subject to breakage when handled roughly or slightly overloaded with r-f current to cause excessive vibration. We are referring here to the fundamental frequency of oscillation.

A crystal is not tunable to different frequencies by any practicable methods, and by any methods at all it is possible to cause only slight changes of frequency. For each fundamental oscillating frequency it is necessary to have a different crystal except with certain dual-frequency types. A dual-frequency crystal used in a number of service signal generators may be made to oscillate at either 100 kc or at 1,000 kc by making changes in inductance or capacitance of a connected resonant circuit.

Crystal oscillators produce many harmonic frequencies in addition to the fundamental. From a simple circuit such as that of Fig. 11 we may secure harmonic frequencies up to at least the tenth, all with ample strength for marker service. With adjustable tuning in plate circuits, and with one or more amplifying stages following the oscillator, it is possible to obtain a range of harmonic frequencies up to several hundred times the fundamental. In general, the lower the fundamental frequency of a crystal the greater will be the number of useful harmonics, and the higher the fundamental the more limited is the number of harmonic frequencies.

CRYSTAL CONTROLLED MARKERS. Since any one crystal will produce only one fundamental frequency and harmonics or multiples of that fundamental, and since crystals cost several dollars each, they are used for direct control of only those marker frequencies required for alignment of practically every receiver. For example, we might have separate crystals for video carrier frequencies in each of the v-h-f television channels. It would be impractical, from the cost standpoint, for all of the intermediate frequencies used in all makes and models of receivers to be covered by separate crystals for each one. However, were you doing a great deal of work on one make or model of receiver it might pay to have a crystal for either the video or sound intermediate, or

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for both intermediates in that particular receiver.

It is desirable to have a crystal operating at a fundamental frequency of 4.5 mc, because this is the separation between video and sound in both carrier and intermediate frequencies, and because it is the intermediate frequency for sound sections of all television receivers employing the intercarrier sound system. Were you doing a great deal of work on f-m broadcast receivers it would be convenient to have a crystal for 10.7 mc, which is the standard intermediate frequency for such sets.

CRYSTAL CALIBRATORS. Marker frequencies other than those provided directly by crystal fundamentals or harmonics are secured from a continuously tunable marker generator or signal generator. To insure satisfactory accuracy of the generator frequency it may be compared with a frequency produced or controlled by a crystal.

A simple method of making a comparsion between generator frequencies and crystal harmonic frequencies may be illustrated by this example. Assume that you are aligning a receiver in which the video intermediate is 45.75 mc and the sound intermediate 41.25 mc. Assume also that you have a 4.5-mc crystal in an oscillator circuit whose output may be fed to the i-f amplifier, along with the output of your regular marker generator and the output of the sweep generator. Connections would be as in Fig. 12. Each generator and the crystal oscillator are connected through the usual small capacitances to the input of the amplifier being aligned. A crystal oscillator is built into some marker generators, and into some sweep generators. Then fewer external connections are needed to the amplifier. Proceed as follows:

1. With marker generator and crystal oscillator turned off, or with their attenuators at zero, use the sweep generator in the usual way to set up a response trace on the screen of the scope.

2. Turn on the crystal oscillator or advance its attenuator until you can see two marker pips on the trace. In our assumed example, one pip will be at 40.50 mc, which

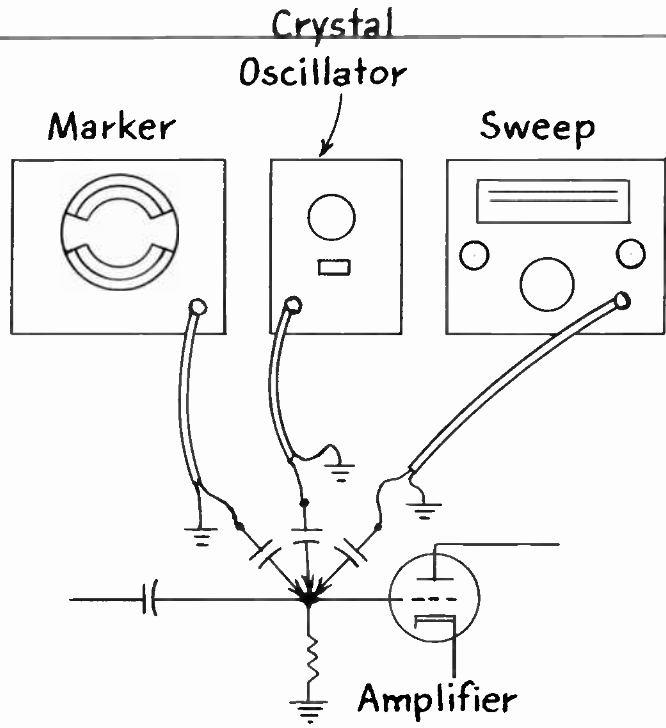

Fig. 12. One method of connecting a crystal oscillator for calibrating the tuning dial readings of a marker generator.

is the ninth harmonic from the 4.5-mc crystal, and which is only 0.75 mc below the sound intermediate frequency of the receiver. The other pip will be at 45.00 mc, which is the tenth harmonic from the crystal and is 0.75 mc below the video intermediate of the receiver. If necessary, a pip far down on the trace may be made more visible by methods explained earlier in this lesson. During this step of the process it makes no difference whether the trace becomes distorted, we now are going to use the scope only for comparing frequencies.

3. Leave the crystal oscillator turned on, and turn on or advance the attenuator of the regular marker generator. As you vary the marker tuning through the response band, a pip will move across the trace.

4. Vary the marker tuning to bring its pip to the same position as the 45.00-mc pip from the crystal. Tune the marker very slowly while watching the outer ends of the trace, the parts down near zero response. When frequency from the marker generator approaches the crystal harmonic frequency, these ends of the trace will break up into

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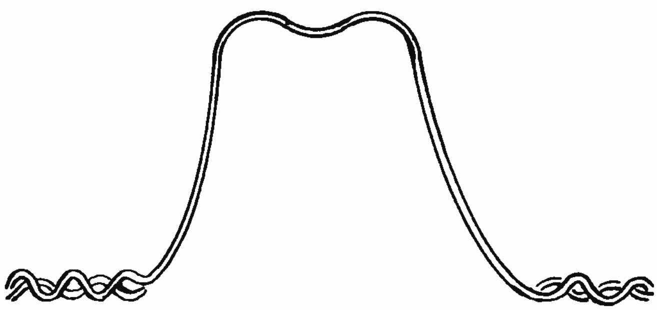

Fig. 13. Equality of frequencies from marker generator and crystal is most easily recognized by appearance of wavy lines at the outer ends of the response curve.

wavy lines, about as shown by Fig. 13. These waves are the result of strong beats from combining of generator and crystal frequencies.

By tuning the marker generator very carefully and very slowly, the waves will appear even when the individual pips are so weak as to be scarcely visible. The wavy lines become stronger or higher as the two frequencies come closer together. Were it possible to make a perfect match, and hold it, the wavy lines would flatten out at the condition of zero beat, and would be of maximum height on both sides of zero beat.

5. Now the marker generator is tuned to the harmonic frequency of the crystal. Examine the reading of the marker generator tuning dial and compare it with the known accurate frequency of the crystal harmonic. The plus or minus error, whatever it may be, will hold with the marker generator tuned a short ways either direction from this calibrated frequency. You can allow for this error when reading frequencies from the dial of the marker generator.

6. Make a similar beat-frequency check at the other harmonic frequency of the crystal. Note the marker generator tuning dial error and allow for it when using the generator to place markers near this frequency.

Similar calibrations of marker generator tuning may be made in other intermediate-frequency bands by using a crystal giving suitable harmonics. For instance, a 4-mc crystal would give a tenth harmonic of 40 mc and an eleventh of 44 mc. Were you working with intermediates in the 20- to 30-mc band, a 4-mc crystal would give fifth and sixth harmonics of 20 and 24 mc, while a 4.5-mc crystal would provide fifth and sixth harmonics of 22.5 and 27.0 mc. If a crystal oscillator and amplifier will furnish strong harmonics at high frequencies, similar calibrations may be made at carrier frequencies when working on r-f amplifiers and tuners.

When you have a setup suitable for calibrating, with one marker pip from a marker generator and another from a crystal oscillator, it is possible to use the combination to provide two simultaneous markers such as shown by Fig. 9. The generator is used to provide a pip at the video intermediate, and remains tuned to this frequency. A second pip, close enough to the sound intermediate frequency to be helpful, may be provided by a crystal harmonic.

As an example, with a marker generator furnishing a pip at a video intermediate of 45.75 mc, the ninth harmonic of a 4.5-mc crystal would provide a second pip at 40.50 mc, which is 0.75 mc lower than the sound intermediate. For another example, when working with a video intermediate of 25.75 mc, and setting the marker generator for this frequency, the fifth harmonic of a 4.5-mc crystal would provide a second pip at 22.50 mc, which is 1.25 mc above the sound intermediate which must accompany a 25.75 video intermediate. As when using other approximate sound intermediate pips, the final alignment must be made by tuning the marker generator to the true sound intermediate.

Crystal oscillators using the Pierce circuit of Fig. 11 or something generally similar are simple and quite inexpensive whether built into a signal generator or constructed as a separate unit. Fig. 14 shows the interior of an oscillator, three inches in overall width, in which a twin triode acts as two oscillators, each with its own crystal. Fundamentals and harmonics from either crystal may be fed to the output, or frequencies from both crystals may be used at the same time. Crystals of any two fundamental frequencies may be inserted in sockets on the front of the instrument.

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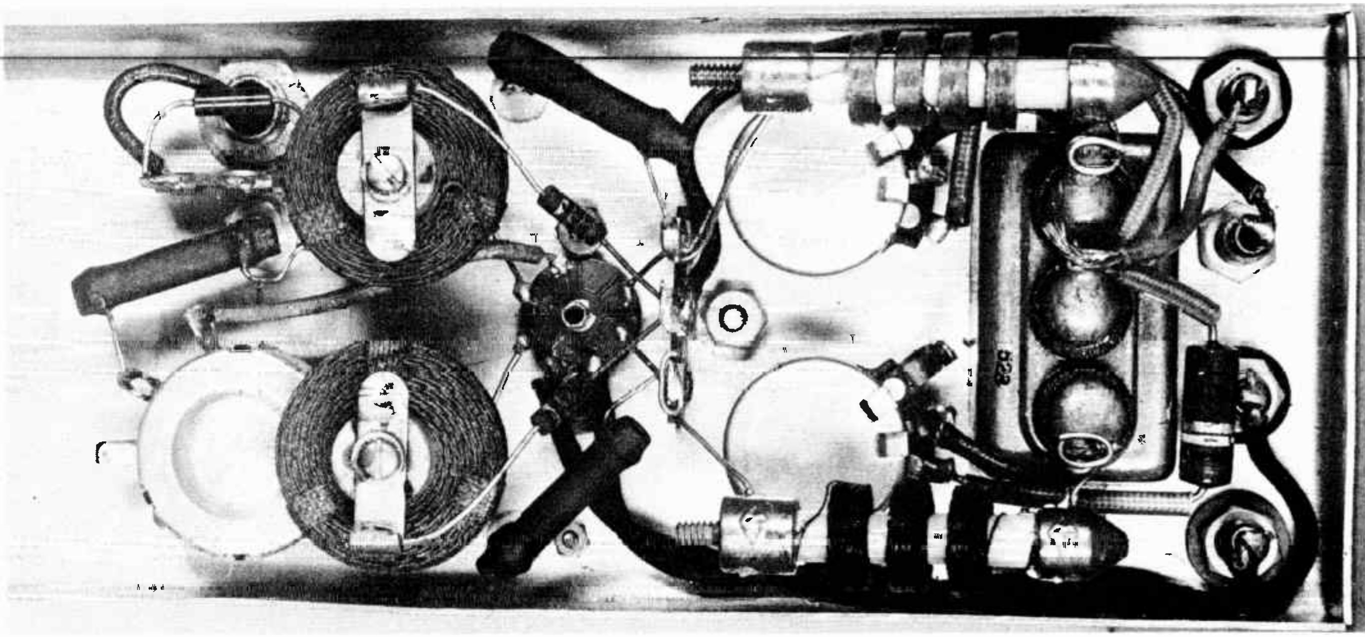

Fig. 14. The underside of the panel in a dual crystal oscillator which furnishes either of two fundamentals and two ranges of harmonic frequencies.

CRYSTAL MOUNTINGS AND CARE. The style of crystal most often used in television and radio service instruments, as pictured by Fig. 10, has pins separated by 0.486 inch center to center. This usually is referred to as half-inch pin spacing. The pins are 0.093 inch in diameter, which is within two thousandths of an inch of the standard diameter for pins on octal tube bases. Other styles of crystals have pins 1/8 inch in diameter, spaced 3/4 inch center to center. Still others are fitted with large (banana) plugs spaced 0.85 inch center to center. Some crystals are mounted on bases exactly like those of octal tubes, or on 5-pin tube bases, or there may be solder lugs in various arrangements for making circuit connections.

Crystal mounting sockets are made for all the standard pin arrangements. A crystal with certain pin spacing and diameter will fit directly only into a socket designed for it, but there are adapters having openings for one pin type and their own pins which will fit into a socket of some other type.

The care required by quartz crystals is quickly explained; handle them gently and never open the cases. Place crystals only in circuits correctly designed for the purpose. Excessively high plate voltage on the tube in a crystal oscillator, or excessive feedback from plate to crystal, may easily cause the crystal to vibrate so energetically that it cracks or punctures, and is useless thereafter. Various types of quartz crystals will safely carry maximum currents from somewhat less than 50 to as much as 200 milliamperes.

If a crystal refuses to oscillate in a suitable circuit, and you know that everything about the circuit and its voltages is right, and the crystal is useless until something is done, the case might as well be opened. A completely disassembled crystal is pictured by Fig. 15. The contact plates may be flat, but often have small "lands" at the four corners which rest on the crystal. If you replace such a plate with the lands away from the crystal, and the flat surfaces of the plate against the crystal faces, there will be no oscillation.

Unless a crystal is broken, failure to oscillate usually results from dirt or moisture which has entered the case. While holding the crystal and the contact plates only by their edges, they may be cleaned with a very mild soap solution in moderately warm water by using a soft brush. The parts should be rinsed free from soap, dried with a clean lintless cloth or a piece of optician's lens tissue, and immediately assembled into the

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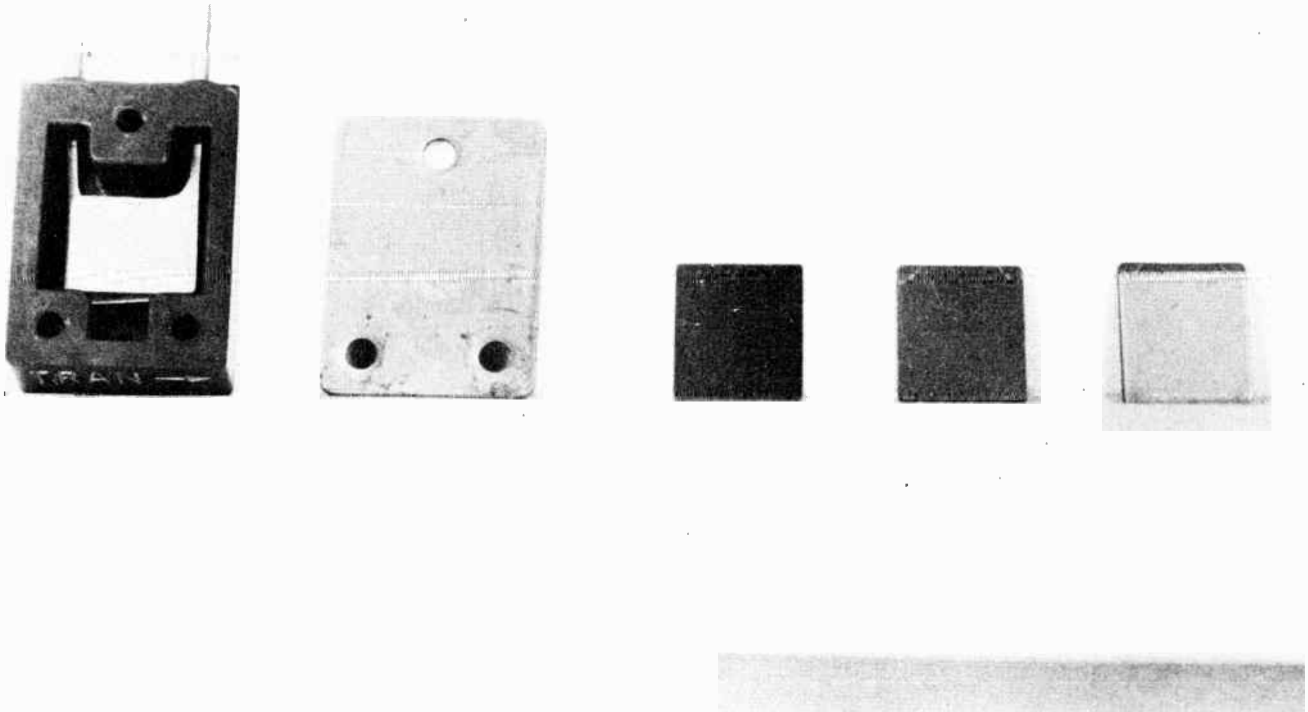

Fig. 15. From left to right: The case for a crystal, one of the outer covers, an insulator, a pressure plate with lands, the quartz crystal.

case, and the case closed. Be sure to replace the gaskets which are intended to exclude dirt and moisture.

<u>HETERODYNE FREQUENCY GENERATORS.</u> A service instrument variously called a heterodyne frequency meter, a heterodyne detector, or a heterodyne frequency generator consists of a signal generator with built-in means for calibrating its settings from a crystal or other source of highly accurate frequencies.

The elementary principle of the heterodyne frequency generator is illustrated by Fig. 16. The r-f outputs from any kind of crystal oscillator and any kind of tunable signal generator are fed together to a mixer. The mixer is sometimes called the heterodyne detector. A detector and mixer are essentially the same thing, inasmuch as both depend for their action on passage of voltages more freely in one polarity than in the opposite polarity. The word heterodyne refers is put through an audio amplifier to a loud speaker or possibly to headphones. As the two radio frequencies are brought closer and closer together, the beat note becomes of lower and lower frequency. Finally the note becomes a low growl, and, when the two radio frequencies are precisely equal there is silence, called the condition of zero beat. As the signal generator is tuned either way from the crystal frequency the beat note rises in frequency and when the difference becomes a few thousand cycles (not megacycles) the beat note becomes so high as to be inaudible.

The signal generator, the crystal oscillator, the mixer, and the audio amplifier often are built together as a single instrument. Then it is possible to calibrate or to note the error in generator dial readings for the oscillator fundamental and all harmonics up to at least the fiftieth when beat notes are strengthened in the audio amplifier. For

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to any element in which two frequencies beat together to produce a beat frequency or difference frequency.

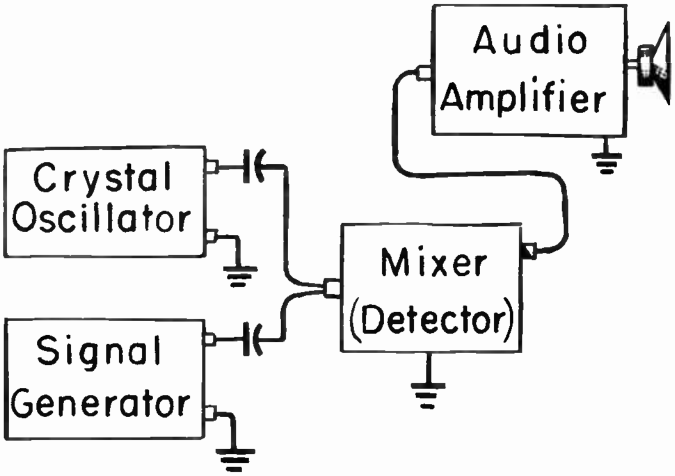

Fig. 16. Principal parts or sections of a heterodyne frequency generator.

When the signal generator is tuned to a frequency closely approaching any fundamental or harmonic frequency coming from the crystal oscillator the beat note is at a frequency low enough to be audible. The rather weak beat frequency from the mixer greater precision in identifying the condition of zero beat, and equality of radio frequencies, the speaker or phones may be replaced by an a-c voltmeter which is responsive at audio frequencies.

Heterodyne frequency generators have provision for connection of any externally produced frequency instead of the internal crystal oscillator. This allows measurement of any unknown frequency which is within the range of generator tuning. The source of unknown frequency is connected to the generator, beats in the mixer with the signal generator frequency, and at zero beat the unknown frequency may be read from the generator tuning dial.

Any external amplifier or other circuit which is to be tuned or resonated at a certain frequency may be connected to the heterodyne frequency generator. The generator tuning dial is set at the required frequency, and the external circuit is tuned to cause zero beat. The external circuit then is operating at the frequency indicated by the generator tuning dial.

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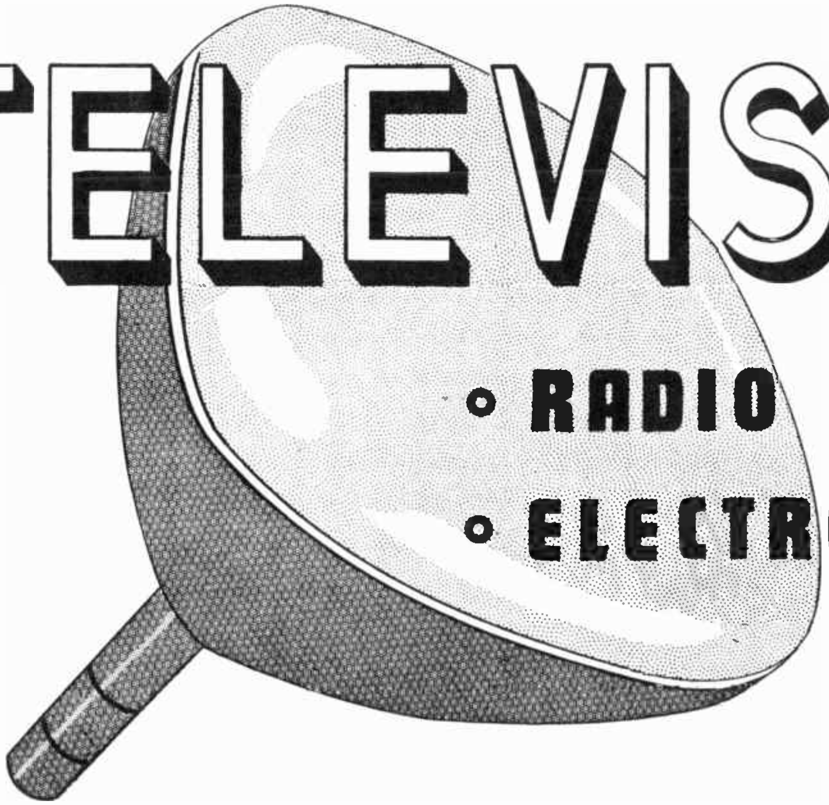
TELEVISION



- RADIO
- ELECTRONICS

LESSON 57 — ALIGNMENT WITH THE OSCILLOSCOPE

Coyne School

practical home training

Chicago, Illinois

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Lesson 57

ALIGNMENT WITH THE OSCILLOSCOPE

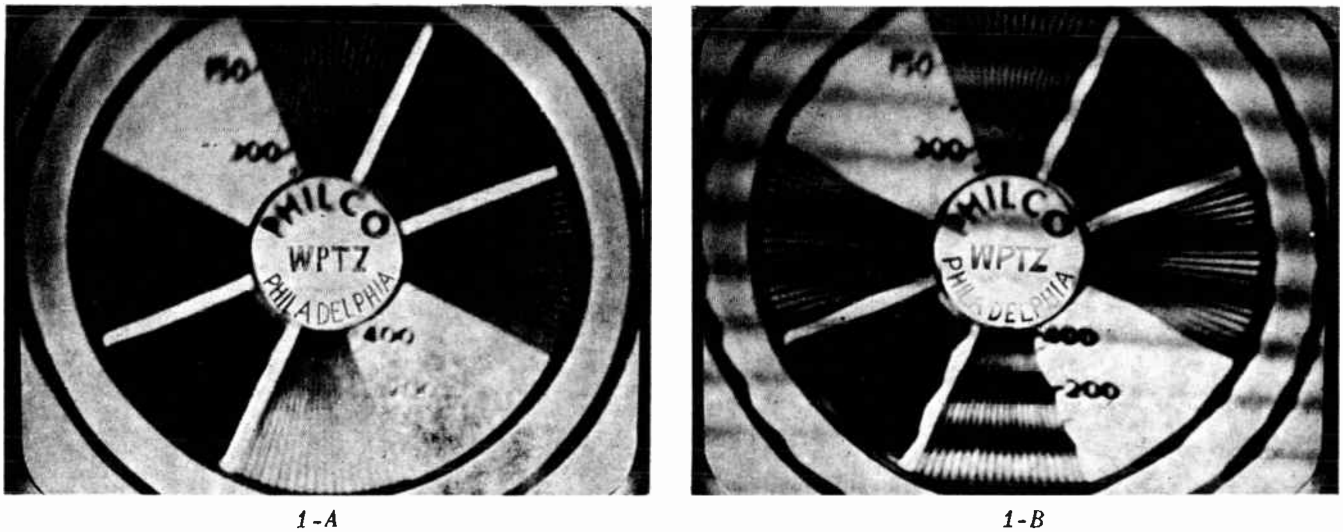
In earlier lessons we learned to align television i-f amplifiers by using an r-f signal generator and a vacuum tube voltmeter. That method is fast and simple, and usually gives acceptable results on stagger tuned amplifiers provided you know the frequency at which each interstage coupler should be peaked.

The other general method of alignment requires an oscilloscope, a sweep generator, and a marker generator. Obviously, it takes longer to make this kind of setup, and it may take a little longer to make the alignment adjustments. But with the oscilloscope you see the effect of every adjustment at the instant it is made, you can bring video and sound intermediate frequencies exactly where they belong on the response. Upon completion of the job you know that the response is correct - provided you are working with good instruments. If the scope, the sweep, and the marker do not meet requirements which have been outlined for alignment work, it would be much better to use an accurate r-f signal generator and a good VTVM.

Incorrect alignment may produce any or many of an imposing list of troubles. Pictures may be so weak that the contrast control cannot bring them up, or they may be fuzzy and lacking in "snap". There may be the appearance of snow in pictures, there may be various interference patterns, and on weak signals you may see many peaks or horizontal streaks. It may be difficult or impossible to hold vertical and horizontal synchronization. Sound may be weak, or poor quality, and there may be hum or disagreeable buzzing noise.

The whole process of trouble shooting, for the entire receiver, is greatly simplified by using an oscilloscope. It takes but a few minutes to examine the frequency response of the i-f section, or the overall response from antenna to video detector. Then, leaving the scope connected, disconnecting the sweep and marker generators, and tuning in a transmitted program, you can examine the video signal waveform at the detector output.

If response and waveform are satisfactory you know that the trouble is not between antenna and video detector, but must be further along in the receiver. If response or waveform are unsatisfactory, trouble is in the video detector or ahead of it. Either way, you have eliminated approximately half of the receiver circuits from the search.



1-A 1-B

Fig. 1. Faults such as these may result from incorrect i-f alignment.

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Because many procedures during alignment with an oscilloscope are the same as when using a VTVM, you should reread the lessons on "Television Alignment" and on "Alignment With the Vacuum Tube Voltmeter". Note especially precautions applying to transformerless receivers, to high voltages, to connection of a speaker which includes a power filter choke, and to disconnection of the transmission line. Positions for controls are the same with either method of alignment. The same adjustment tools are used. Shields must remain in place. And don't forget the importance of plenty of warmup time.

GROUNDING. Grounding or bonding of instruments and receiver is even more important with the scope than with the VTVM. The sweep and marker generators will be grounded to the receiver chassis through their shielded output cables. The scope calls for some special consideration.

For most observations the vertical input of the scope is connected to the high side of the video detector load, and the ground lead or the shield of a cable is connected to chassis ground, as at A of Fig. 2. This connection to chassis ground is correct when the low side of the video detector load goes to chassis ground, since the scope then is placed across the detector load.

There are, however, quite a few receivers in which the low side of the video detector load does not go to ground, but goes to some point which is negative with reference to ground. Such a condition, shown at B, exists in receivers having a conductive connection from detector output to video amplifier input, with the amplifier biased through the detector load. Then the ground lead from the scope must be connected only to the low side of the detector load, not to chassis ground. The housing of the scope must be insulated from common ground connections of the generators and receiver chassis, or, at least, not conductively connected to the common ground. Connection of the scope to a common ground would short circuit the video amplifier bias, and cause trouble also in other circuits of the receiver.

Unless you have a service diagram for the receiver, find the detector load resistor underneath the chassis and note whether there is a connection from this unit to chassis ground, either directly or through a peaker. If you cannot see such a ground, test by connecting a high-resistance d-c voltmeter or a VTVM between ground and the low side of the load resistor, while the receiver is turned on. If voltage is other than zero, do not connect the ground lead of the scope to chassis ground.

After making all connections between instruments and receiver it is in order to check the effectiveness of grounding, thus: Bring a

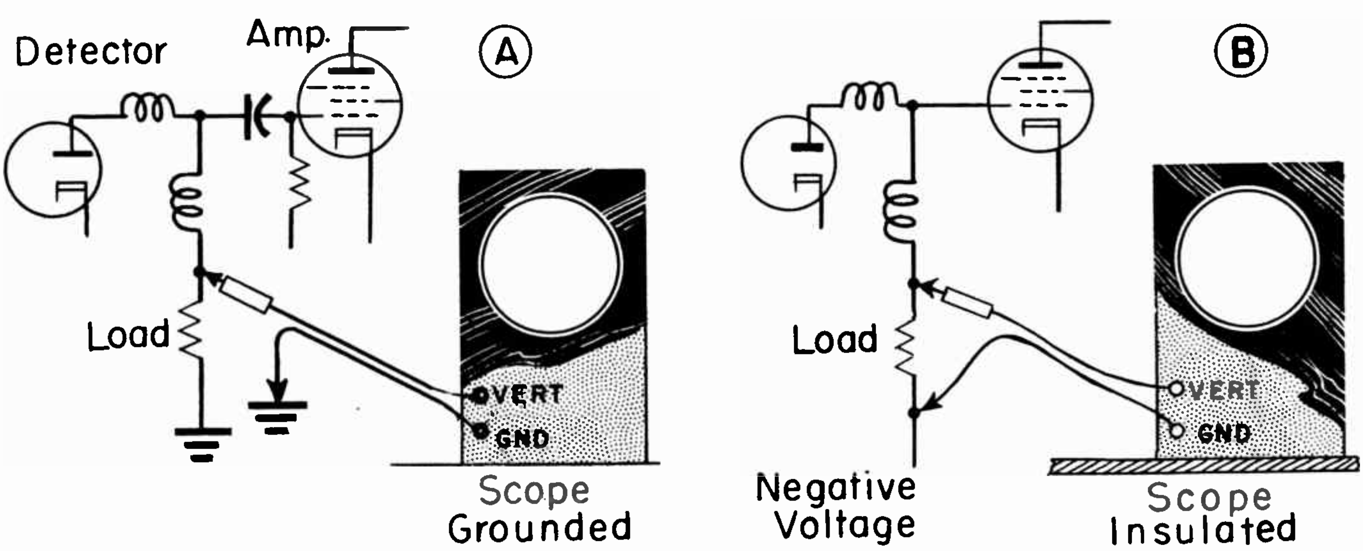

Fig. 2. The oscilloscope may or may not be grounded during alignment work.

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response trace onto the screen of the oscilloscope. Rest your hand successively on the case of each instrument and on the receiver chassis. If this causes any change in shape of the response, or any appreciable change in height, there is not sufficient grounding or bonding. Run additional grounding wires.

Automatic gain control should be overridden with a fixed negative bias of three to four volts. The method is the same as when using a VTVM for alignment.

The r-f oscillator of the tuner is preferably made inoperative during i-f alignment. Methods were explained in lessons dealing with the VTVM for alignment. Check oscillator action as follows: Alter the adjustment or setting of a fine tuning control. If this changes the shape of the response curve, or causes pips similar to those from a marker to move across the trace, the r-f oscillator has not been made inoperative.

SWEEP CONNECTIONS. For oscilloscope alignment of i-f amplifiers the sweep generator is connected to the grid or grid circuit of the mixer or to the grid of some following i-f amplifier tube in the same general way that the r-f signal generator is connected when using a VTVM. There may be top-chassis connection for the mixer grid. Otherwise the connection may be made from the top with a bared wire wound on a tube base pin, or underneath the chassis to a socket lug. With any of these connections it is necessary to have a small fixed capacitor in series with the high side of the generator lead in order to preserve grid bias.

If signal input to a mixer or other tube is through an ungrounded tube shield, or through a metal ring slipped over a tube, it is not necessary to use a series capacitor.

The importance of keeping signal input to a mixer at a low level cannot be overemphasized. Remember, the mixer is followed by all the i-f amplifiers, and excessive signal to the mixer is certain to overload some or all of the amplifiers and to distort the response. Sweep input to the mixer never may exceed a strength with which small variations of this strength cause the response trace to rise or fall with no change in form. Any change of form or shape indicates excessive signal.

The strength of signal to the mixer is affected by setting of the attenuator on the sweep generator, also by the value of series capacitance on the generator lead. (Input is reduced by using less series capacitance, or by sliding a metal ring or ungrounded tube shield farther up on the tube.)

At A in Fig. 3 is a true response taken with a series capacitor of 2 mmf to a mixer which is followed by a four-stage i-f amplifier. The trace at B shows what happens when using 5 mmf series capacitance, with no change in generator output. At C is a trace taken when using 50 mmf between generator and mixer grid. You might, by misaligning the i-f amplifier, change the traces at B or C to much the same shape as at A. Then, during normal reception, there would be very poor reproduction of all transmitted pictures.

If the output of the sweep generator can be sufficiently attenuated, if there is no appreciable signal leakage from the generator, and if the i-f amplifier has only the usual gain, a series capacitance up to 10 mmf usually is satisfactory.

MARKER GENERATOR CONNECTIONS. If the marker generator is separate from the sweep generator, the output of the marker is to be connected through a small series capacitance to the same point as the output of the sweep generator. Series capacitance should be no greater than for the sweep connection, and usually should be smaller. The capacitor in series with the marker lead may connect directly to the tube grid, as at A of Fig. 4, or it may connect to the cable side of the sweep capacitor, as at B. Do not, as at C, connect the high side of the marker cable directly to the high side of the sweep cable.

A marker voltage to the grid of a mixer or other tube must not be so strong as to distort the response trace. If there is excessive lowering or deformation of the response curve when moving the marker pip to points of high gain, retard the attenuator of the marker generator or use a smaller series capacitance.

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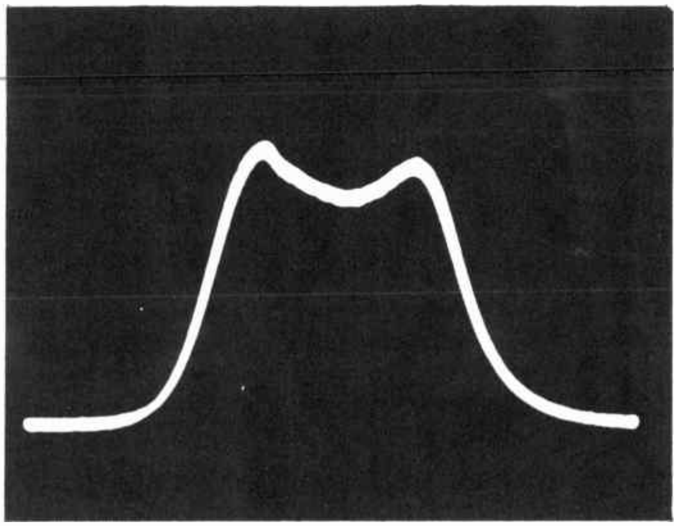
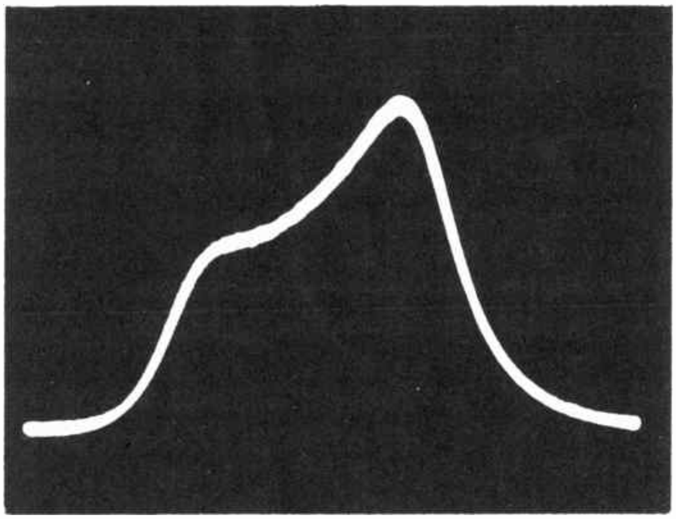
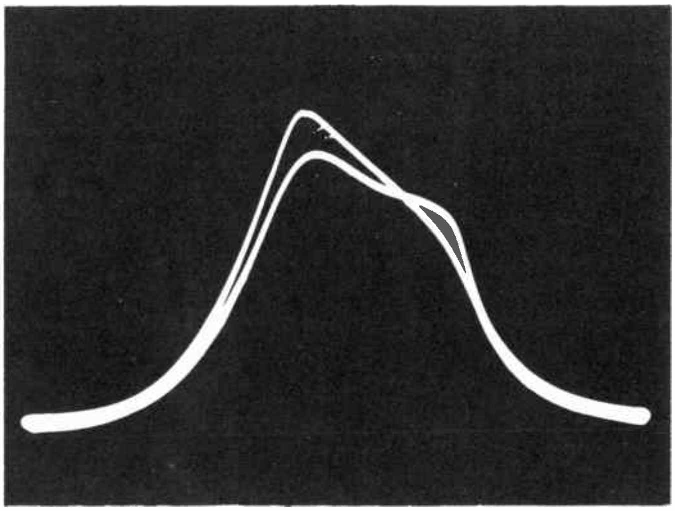


3-A



3-B



3-C

Fig. 3. Excessive voltage input to the i-f amplifier will seriously distort the frequency response.

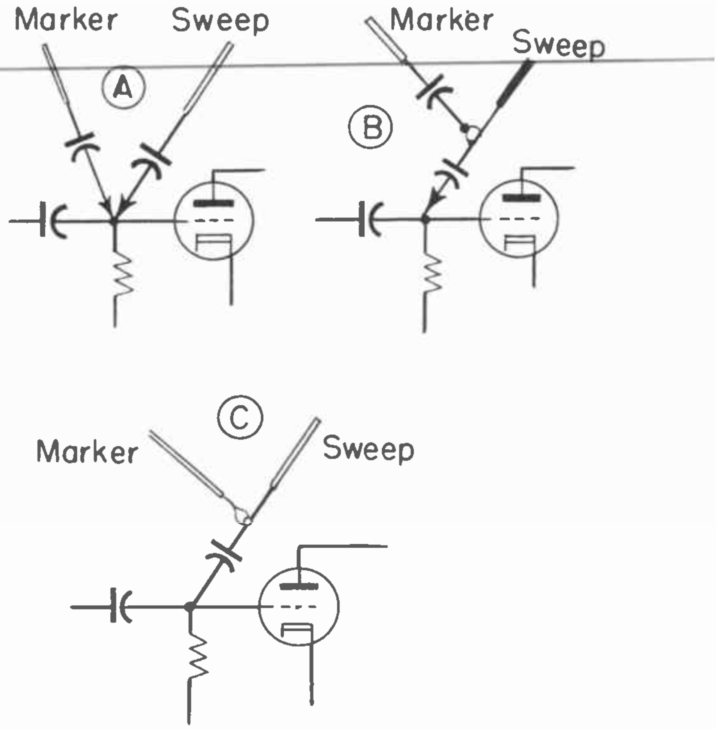


Fig. 4. Connections of marker and sweep generators. The connection at C is wrong.

OSCILLOSCOPE CONNECTIONS. The vertical input of the oscilloscope should be connected to receiver circuits only through a shielded cable. Use the type of probe having about 10,000 ohms series resistance and about 1,000 mmf bypass capacitance to ground. As you will recall, such a probe or any equivalent connections will isolate the capacitance of cable and scope from receiver circuits, will keep high video frequencies out of the cable, and will sharpen marker pips.

The vertical input may be connected to any of the points lettered in Fig. 5. The usual connection, at A, is to the high side of the video detector load resistor, or, at B, to the top of a peaker in series with the load resistor. Should it be impossible to secure response traces of satisfactory height from the detector load, scope connection may be made to the video amplifier.

Connection to the plate of a video amplifier tube, as at C, utilizes the gain of this amplifier between detector load and scope input. If there is a second video amplifier, a connection to its plate, at D, will add still

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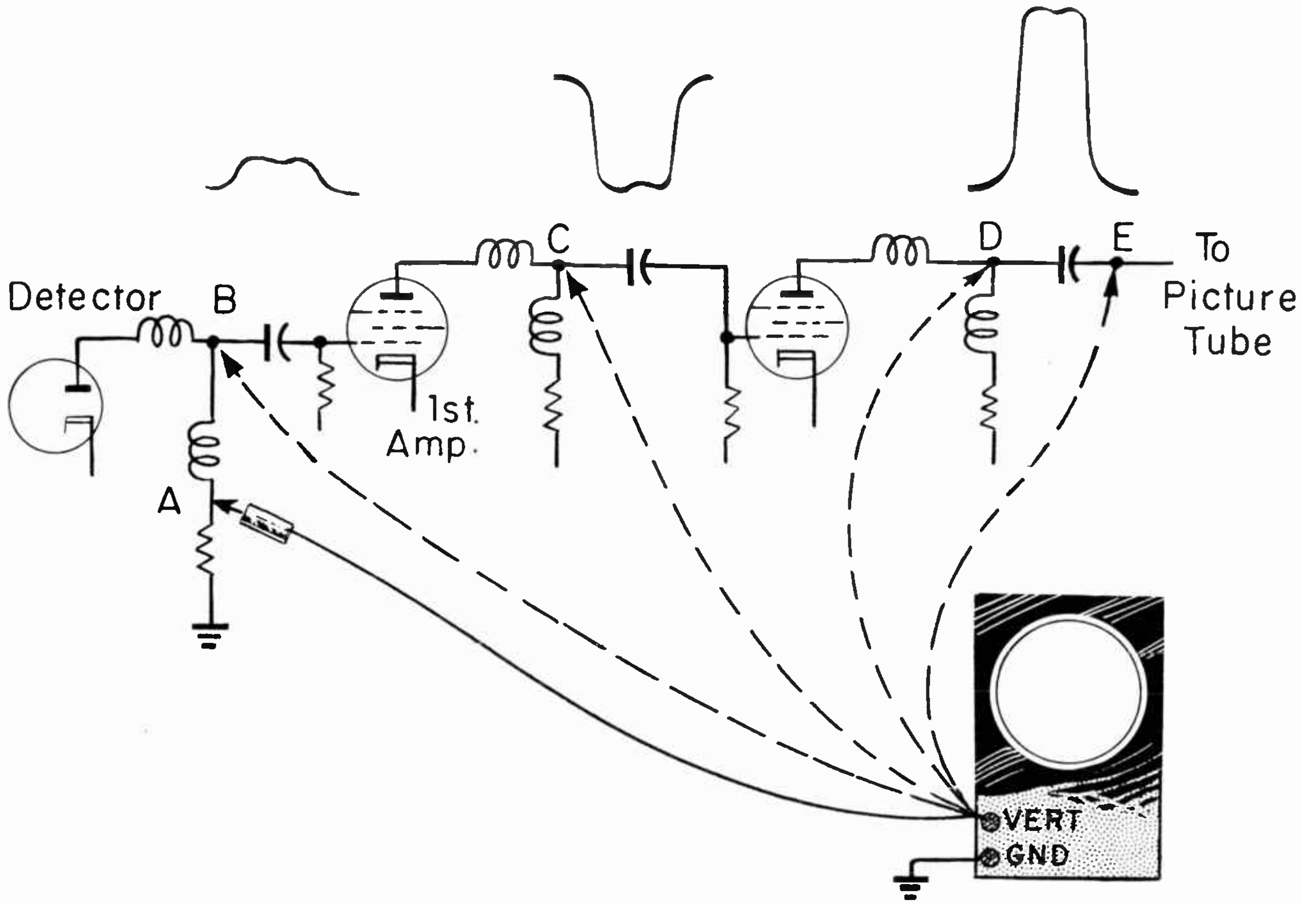

Fig. 5. The oscilloscope may be connected to the video detector load, or to various points in the video amplifier system.

more gain. The vertical input of the scope may be connected alternatively at E, to the lead which goes to grid or cathode of the picture tube. Gain at E is the same as at D. Provided the video amplifier is in reasonably good operating condition, traces will be of the same form or shape when taken from any of the lettered points. There will, of course, be inversion of trace polarity between grid and plate sides of any one amplifier, as indicated on the diagram.

The response trace may show up on the scope in any of the positions illustrated by Fig. 6. To allow identifying the positions, a marker pip has been placed at the video intermediate frequency. At A the gain increases in an upward direction, and frequency increases from left to right. At B the gain increases downward and frequency still increases as at A. Whether gain increases upward or downward depends on the point to which the vertical input is connected (shown by Fig. 5), on whether video signal input is to grid or cathode of the picture tube, and on the number of video amplifier stages.

At C of Fig. 6 the gain increases in an upward direction, while frequency increases from right to left. At D the frequency again increases from right to left, while gain increases downward. The direction of frequency increase depends on the design of the sweep generator and on phasing of a synchronized sweep voltage. If you are in doubt, it always is possible to determine the direction of frequency increase by watching the travel of a marker pip while frequency from the marker generator is increased or decreased.

When horizontal sweep of the oscilloscope beam is to be provided by synchronized sweep voltage from the sweep generator, connect the sync output of the generator to the horizontal input terminals of the scope

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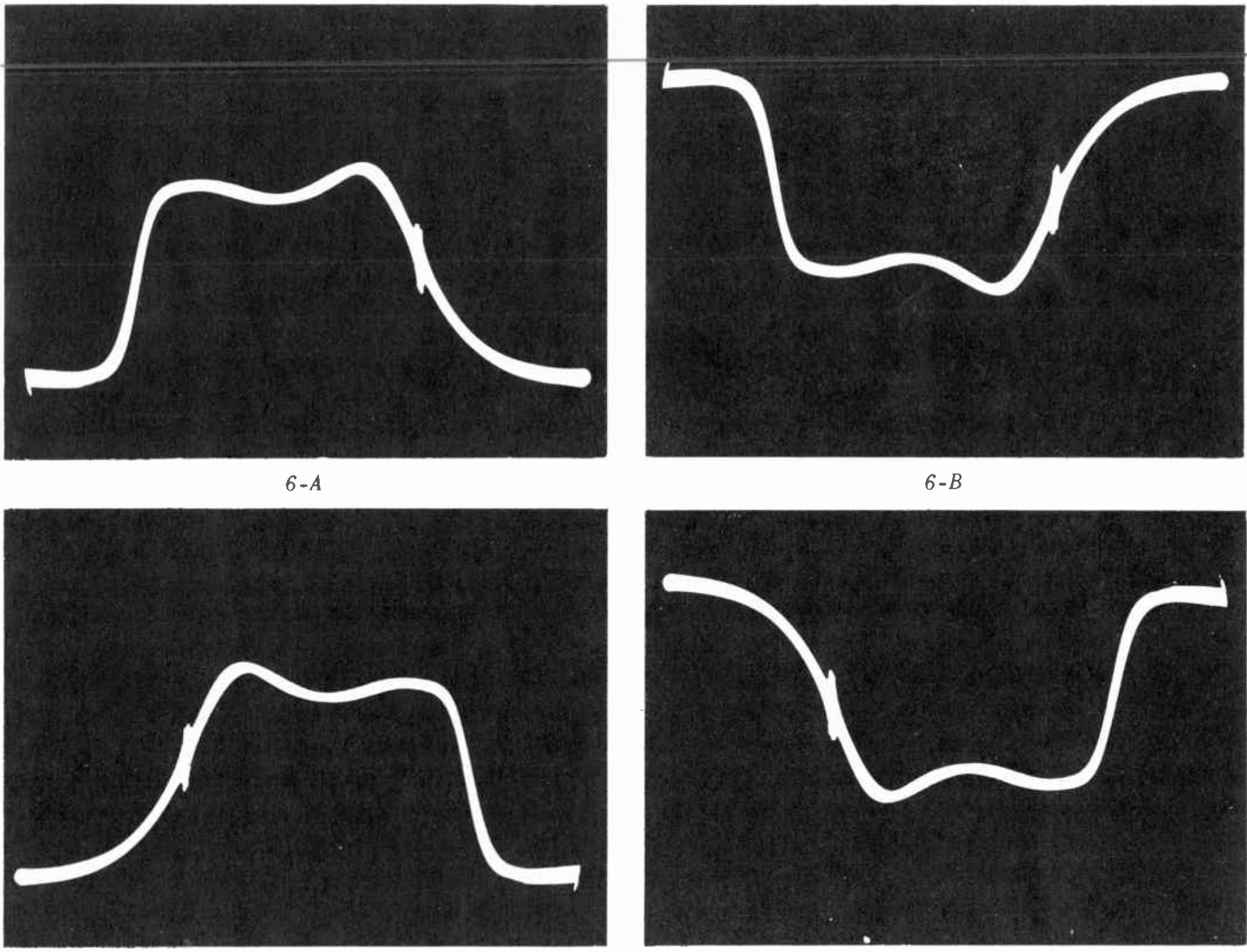

6-A 6-B 6-C 6-D

Fig. 6. A response curve on the oscilloscope screen may appear in any of these four positions.

and set the scope selector switch for external horizontal input. Should you now turn on the scope before turning on the sweep generator there would be no horizontal deflection of the beam. Were there also no vertical deflection, the undeflected beam would form a brilliant stationary spot on the screen, with probable damage. Therefore, when using synchronized sweep, form the habit of turning on the sweep generator before the scope or, at lease, before advancing the intensity control of the scope.

OBTAINING A RESPONSE CURVE. When all connections between instruments and receiver are complete, proceed as follows:

1. Preliminary settings.

a. Receiver.
   Brightness control at minimum.
   Contrast control for normal picture reception.

b. Marker generator.
   Attenuator at minimum. Set for "Standby" if there is such a selector position.

c. Sweep generator.
   Range or band selector to include intermediate frequencies of receiver.
   Sweep width control for about 10 megacycles.
   Attenuator advanced about half way.

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d. Oscilloscope.
For synchronized sweep set input selector for external horizontal input.
Vertical gain to half or more of maximum.
Horizontal gain to half or more of maximum.
If intensity control is not combined with power switch, set this control for minimum.

2. Turn on the generators, the oscilloscope, and the receiver. Let them warm up for at least 15 minutes.

3. Advance the intensity control of the scope until a trace appears.

4. Adjust horizontal gain and horizontal position of the scope to make the trace extend almost but not quite all the way from side to side of the screen. Adjust vertical position, if necessary, to bring trace to approximate center of screen.

5. If the trace is not already a curve, adjust the frequency control or center frequency control of the sweep generator until the trace (a) forms a curve, (b) rises and falls, or (c) changes to one or two approximately vertical lines.

6. Adjust center frequency and sweep width controls of the sweep generator until both sides of a curve or both vertical trace lines are approximately centered from left to right on the screen.

7. Retard the attenuator of the sweep generator while, if necessary, increasing vertical gain of the scope until the trace curve is an inch or more in height. The desirable height depends on the face diameter of the CRT in the scope.

8. Operate the phasing control on the sweep generator or oscilloscope to make the forward and return traces appear as nearly as possible a single curve.

9. Adjust the focus control of the scope for sharpest trace.

10. Use the least possible output signal from the sweep generator, and high vertical gain in the scope, to give a response curve of satisfactory height.

11. Readjust the sweep width control of the generator and horizontal positioning in the scope to make base lines of zero gain appear on both sides of the response. These base lines are essential, they must be there. If the i-f amplifier section is in good alignment, you now should have a response trace somewhat like the one of Fig. 7.

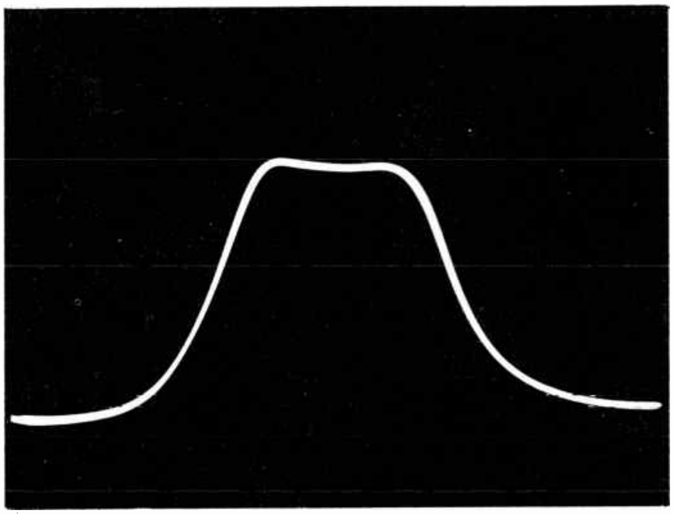

Fig. 7. A typical i-f response trace.

Fig. 8 shows some effects of wrong adjustments. At A the response curve is too far toward one side of the screen. This condition, when using synchronized sweep, is corrected by adjustment of the center frequency, at the sweep generator. When using internal sweep of the scope, the cause for an off-center curve may be wrong adjustment of the center frequency or it might be due to wrong adjustment of the horizontal positioning at the scope.

The curve at A is not only off center, it is too narrow. When brought to the center of the screen a narrow curve would appear as at B. When using synchronized sweep the narrowness is due to misadjustment of sweep width. Sweep width is too great in number of megacycles, meaning that the entire horizontal trace, from left to right on the screen, covers too many megacycles. For trace B of Fig. 8 the sweep width was adjusted for more than 15 mc. The i-f response curve, from

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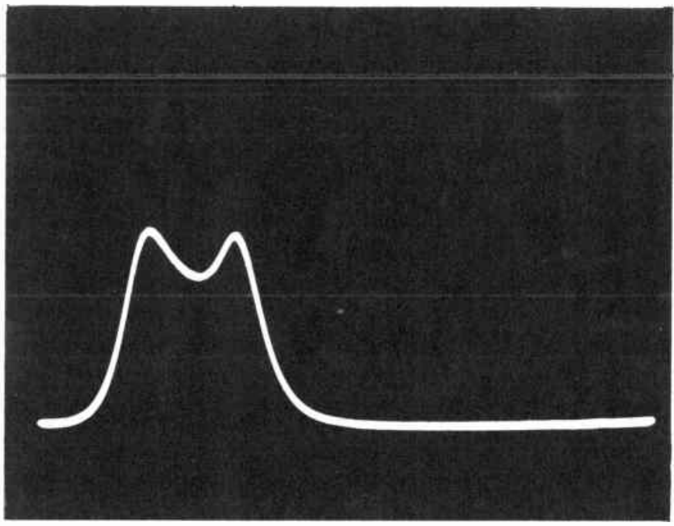
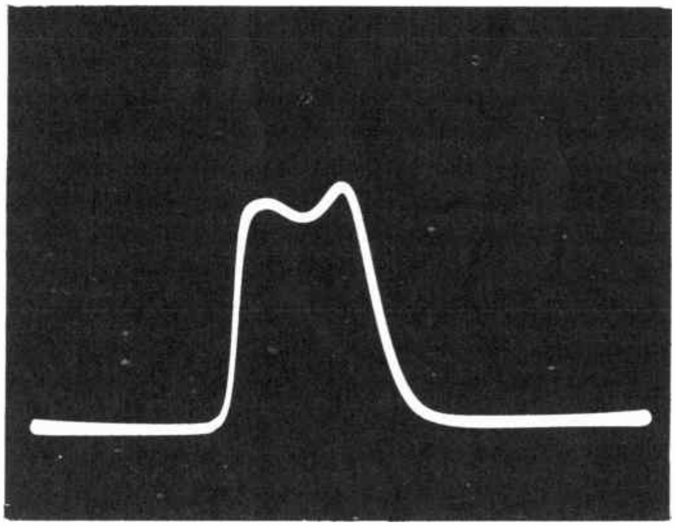
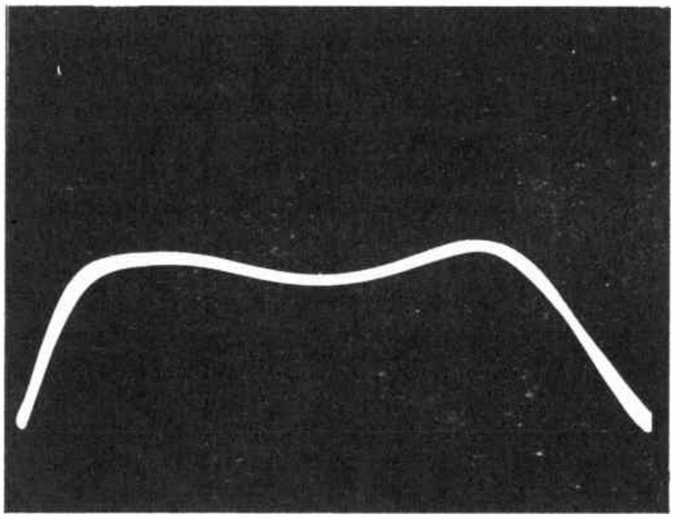


8-A



8-B



8-C

Fig. 8. Some effects of incorrect adjustments at the sweep generator.

zero gain on one side to zero gain on the other side, takes in only about 6 mc, consequently occupies only a small part of the entire frequency sweep. Reducing the sweep width, by means of the generator control, has the effect of spreading the response curve because then the curve takes in more of the total frequency sweep.

If sweep width is made too little in proportion to the range of frequencies included in the response we have the effect at C of Fig. 8. Here the sweep width has been reduced to about 4 mc, by adjustment at the sweep generator. The response still covers the same range of frequencies as before, about 6 mc. Only part of this 6-mc response can be traced with a sweep width of only 4 mc, and when the curve is centered on the screen we see only the top portion.

When using internal sweep of the scope, rather than synchronized sweep, a curve which is too narrow or too wide may be due to wrong adjustment of horizontal gain control on the scope. Of course, it may be due also to wrong adjustment of sweep width at the sweep generator.

Once you have a response curve correctly on the screen, as in Fig. 7, do not alter the sweep width during the process of alignment. A change of sweep width would vary the slopes of the sides of the response, and you might be misled while making adjustments in the i-f amplifier circuits.

Only after setting up a response curve in the manner described are we ready to use the marker generator for checking frequencies. Since the marker will have been thoroughly warmed up while setting up the response curve, we need take only the following additional steps.

Set the range selector to include the receiver intermediate frequencies.

Advance the attenuator about half way.

Vary the frequency control of the marker generator through the i-f range while watching the trace on the scope.

If no pip or dip appears, advance the attenuator more and try again.

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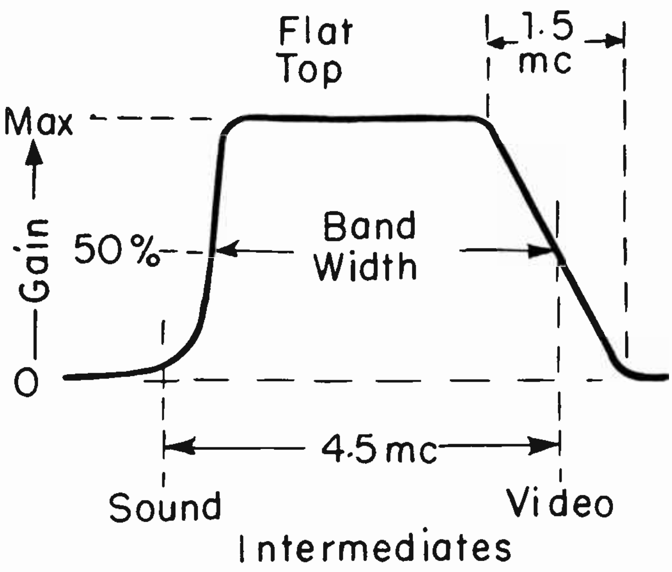

Fig. 9. Requirements of a good frequency response in an i-f amplifier system.

Should a marker pip unduly distort or flatten the trace, retard the attenuator.

RESPONSE REQUIREMENTS. Fig. 9 illustrates a nearly ideal curve of i-f amplifier response, the response we strive to attain by alignment adjustments, but almost never realize in practice. Here is a list of the requirements.

A. The top of the curve should be as nearly as possible flat all the way across. Usually there will be two peaks, in which case neither one should be more than 20 per cent lower than the other. The deepest dip of a valley between peaks should be no more than 30 per cent below the higher peak.

B. The video intermediate frequency should be no lower than 50 per cent of maximum gain,. and seldom should be allowed higher than 60 per cent of maximum. A video intermediate too low down weakens the low video frequencies for pictures and weakens all the sync pulses.

C. For receivers employing intercarrier sound systems, the sound intermediate frequency should be at least 95 per cent down from maximum gain, or should be at no more than 5 per cent of maximum.

D. The high-frequency slope of the response, near the center of which is the video intermediate, should have a total width of about 1.5 mc, extending about equally each way from the video intermediate.

E. Band width is measured from the point of video intermediate frequency on one side of the response straight across to a point on the other side, or is measured between points which are at 50 per cent of maximum gain on the opposite sides of the response. When preceding requirements are satisfied, band width should be as great as possible. In practice, a width of 3.5 to 3.6 mc would be very good. For many receivers the band width is no more than 2.5 mc.

F. With all preceding requirements satisfied, the maximum gain, to the higher peak or to a flat top, should be as great as possible.

For checking all except the first and last of the requirements outlined it is necessary to use the marker generator in identifying frequencies. The very first step in alignment, after setting up the response curve, consists of determining the actual frequencies at points shown by Fig. 9.

It should be noted that an excessively high and ragged peak which tends to vary irregularly in height and sharpness usually denotes improper feedback and regeneration, and possibly oscillation, in some portion of the i-f amplifier. The subject of regeneration was dealt with at length in lessons dealing with use of the VTVM for alignment.

IDENTIFYING THE INTERMEDIATES. When a receiver leaves its factory the alignment of the i-f amplifier is well within the limits explained in connection with Fig. 9. But tubes gradually deteriorate, capacitors and resistors may undergo slow changes of value, and by the time you get the receiver as a service job the alignment may have changed materially. Even so, if peaks are not too different in height, if a valley is not too deep, if the video intermediate is from 50 to as much as 70 per cent of maximum gain, and if the sound intermediate is down close to zero - if all these are true it should not be absolutely necessary to make a realignment.

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In service instructions issued by manufacturers for i-f alignment it is common to call first for peaking of the interstage couplings at listed frequencies, using an r-f signal generator and VTVM. The work is completed with a sweep generator, marker generator, and oscilloscope. While using the scope you can make slight readjustments as may be necessary to bring certain marker frequencies to specified points on the response, and to obtain a response curve of desired shape. Fig. 10 shows a typical service instruction response curve with various frequencies marked. Dips at the ends of the curve show attenuations due to several traps.

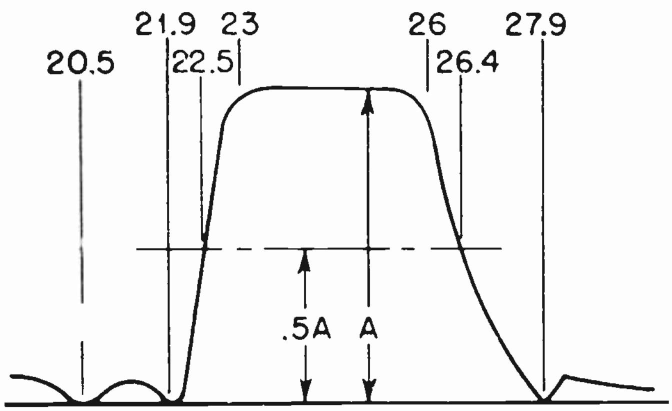

Fig. 10. A response curve with frequencies marked, as shown by service instructions.

Service instructions for many receivers are based on the use of sweep, marker, and scope for the entire process of alignment. Then it is usual practice to show response curves which should be obtained during successive steps of adjustment. Instructions specify which coupling unit is to be adjusted

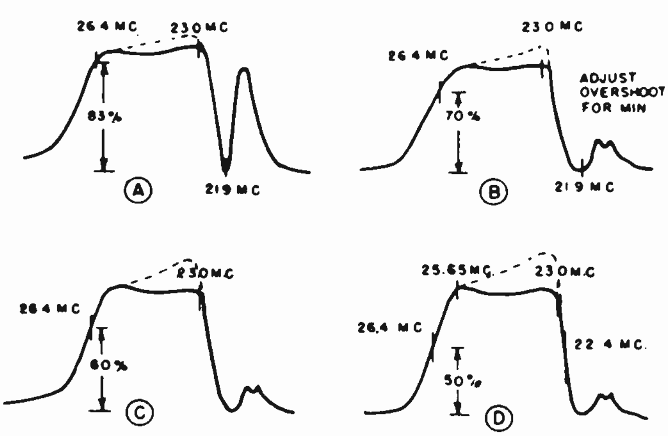

Fig. 11. Service instructions may show responses to be obtained at each step of alignment.

to bring each marker frequency to its correct position on the response, also which adjustments are to be used for shaping the curve in relation to flat-topping and band width. Typical curves of this kind are illustrated by Fig. 11.

When service instructions for a receiver are available, you should follow them to the letter. The manufacturer knows better than anyone else how to make an alignment for best possible receiver performance. Unfortunately, instructions for one particular receiver will not apply in detail to other receivers, and when you have no specific instructions it becomes necessary to proceed "on your own".

First of all, you should determine as nearly as possible the video and sound intermediate frequencies at which the receiver is supposed to operate. Do this by setting up an i-f response on the scope, running a marker pip across the curve, and noting frequencies at peaks, on the slopes, and near the bottoms of the slopes. The video intermediate should be about half way up on the high-frequency slope. The sound intermediate must be 4.5 mc lower than the video, and far down on the low-frequency slope. Look through the listing of intermediate frequencies in the lesson on "Television I-f Amplifiers" and pick a pair closest to those indicated by marker frequencies.

The selected intermediates may not be exactly the same as those for which the set originally is designed. But if the intermediates meet certain requirements, and if you make a proper alignment based on the selected frequencies, the receiver will perform well. The first requirement for the intermediates is that they be within the adjustment range of the i-f couplings. For example, if the full range of coupling adjustment allows resonating only from 30 to 27 mc, you couldn't possibly use intermediates in the 30 or the 40 mc ranges. Provided none of the coupling adjustments are at the limit of their travel in either direction when you check frequencies along the response, the couplings undoubtedly may be adjusted for the selected intermediates.

The second requirement is as follows:

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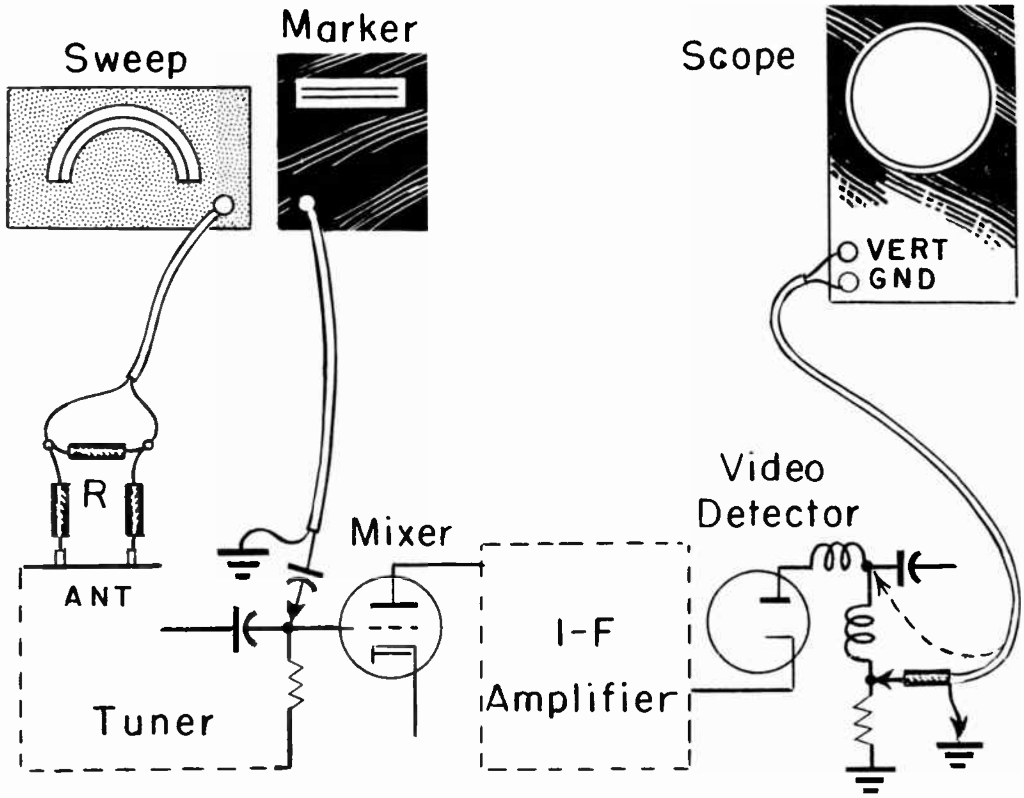

Fig. 12. Checking of tuner output frequencies in relation to response of the i-f amplifier.

The intermediates must be such as can be furnished from the tuner when there is beating of received carriers and the r-f oscillator frequency in the mixer tube. A check of this requirement or of tuner output frequencies is made in this manner.

1. Connect the sweep generator to the antenna terminals of receiver or tuner as in Fig. 12. Be sure to use a terminated cable and antenna matching resistor network as indicated at R.

2. Connect the marker generator through a small capacitance to the mixer grid.

3. Connect the scope to the video detector load or at a point further along in the video amplifier, as previously explained.

4. Set the receiver channel selector to any channel, preferably to one of those in the low band of the vhf range.

5. Set the contrast control as for normal picture reception, and the brightness control at minimum.

6. Adjust the fine tuning control to its mid-position; this is essential.

7. Tune the center frequency of the sweep generator through the carrier frequencies of the selected channel until a response trace appears on the screen of the scope, just as it appears when feeding the sweep voltage to the mixer grid.

8. Tune the marker generator to what you have assumed as the video intermediate frequency. This should place a pip somewhere along the response trace.

9. Vary the marker tuning one way and the other. It will be possible to produce two or more separate but simultaneous pips which sometimes move in the same direction and again in opposite directions across the response trace.

10. Vary the fine tuning control of the receiver. This will shift the response curve to one side or the other of the screen of the scope, as indicated by Fig. 13.

One or more of the pips will move with

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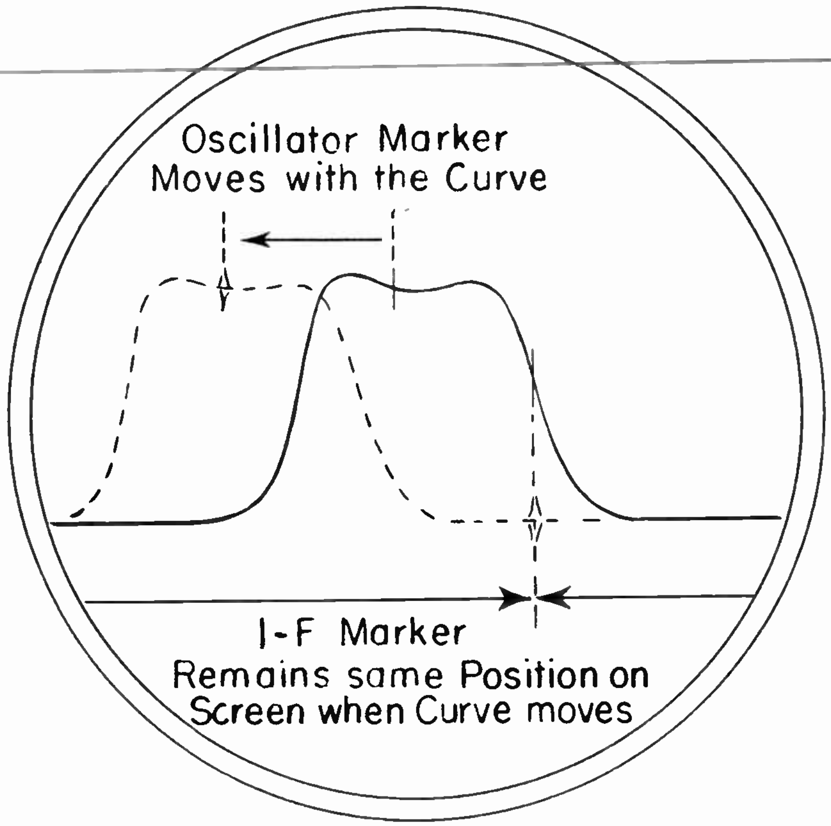

Fig. 13. Varying a fine tuning control should shift the response bodily across the screen of the scope.

the curve and will remain in the same position on the curve as the curve moves during variation of the fine tuning control. These pips that stay with the curve result from action of the r-f oscillator in the receiver. They do not identify the video intermediate frequency, and should be disregarded.

One pip will remain in the same position with reference to the sides of the screen of the scope regardless of fine tuning adjustment, this pip will not move with the response curve. This stationary pip is due solely to the intermediate frequency being furnished to the mixer tube by the marker generator, it is the one that identifies your selected video intermediate. Try to shift the response curve, by operating the fine tuning control, to bring this stationary pip about half way up on the low-frequency slope of the response. Note that here you watch the low-frequency slope because the response curve is being formed by sweep frequencies in the carrier range, not in the i-f range.

If the video i-f pip can be brought to the required position on the response, the selected video intermediate frequency can be used. As a final check, note the setting of the fine tuning control. If this control is at or near its mid-position the selected intermediate should be entirely satisfactory. If the fine tuning is near either extreme of adjustment it may be advisable to assume a slightly different intermediate which allows the fine tuning to have plenty of adjustment both ways.

CORRECTING THE RESPONSE. Now we are ready to determine the effect on i-f response of adjusting each transformer or coupler. Connect the sweep and marker generators to the mixer grid, and the oscilloscope to the video detector load or farther along in the video amplifier. Set up a response curve in the usual way. Make a rough pencil sketch of the curve. Use the marker generator to identify the positions of both intermediate frequencies, also the frequencies at peaks, in a valley, and half way down the low-frequency slope for checking band width. Mark these points on your sketch.

For i-f coupling units which are enclosed within shielding cans the only sure way of

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determining the effect of adjustments is to make temporary changes of adjustment. Before altering the adjustment of any unit note the exact position of a slot in its adjusting screw or, in any convenient manner, identify the original position of the adjuster. Watch the response curve while turning the adjustment a half turn clockwise. Then turn back through the original position and go a half turn counterclockwise. Finally return this adjustment to its original position. On your pencil sketch note which portion of the curve is most affected by this adjustment. Make a similar check with each of the other couplers.

From your notes it should be possible now to learn which coupler or couplers will make any desired change in shape of the response curve. While making any adjustments which have principal effect at the high-frequency side of the curve, keep the video i-f marker on the curve. Keep the sound i-f marker on the curve while making adjustments which principally affect the low-frequency side of the response.

Where coupling units are exposed underneath the chassis you can use one or more tuning wands to make the work much easier and faster. These wands were described in lessons on alignment with an r-f signal generator and VTVM. To determine the effect of adjusting each coupling unit it is necessary only to watch the response while inserting first one end and then the other end of a wand in the exposed opening of the winding form.

The easiest way of all is to use several wands at the same time. Three wands are being used in Fig. 14. When either the magnetic or non-magnetic end of a wand causes a desirable change in response shape, leave the wand hanging in the coupler. Then use a second want to test other couplers, and when there is another desirable change in curve shape leave the second wand in position. This may be repeated with any number of wands. Do not fail to use marker frequency pips during the process.

When the response looks fairly good, and frequencies are about where you want them, withdraw one wand. If the magnetic ends was in the coupler, turn the slug of that unit farther into the coil space. If the non-magnetic end of the wand was used, turn the slug farther out. Adjust the slug to restore the curve to the same shape as with the wand in use. Take out one wand at a time, and each time restore the curve shape by adjusting the coupler in which that wand was used. With all wands removed and all couplers adjusted accordingly, you will have a corrected response.

Although it is not a precise method, a quick improvement often may be made by using one or more tuning wands without the generators and oscilloscope - while watching a transmitted picture and listening to the accompanying sound. The wands are used to improve picture reproduction, if possible, while holding the sound. Then coupling units are adjusted accordingly. Technicians use this method for servicing receivers in the homes of owners. Unless you work carefully there is danger of making adjustments that cause regeneration or oscillation, or of getting adjustments so far out of line as to require use of the regular instruments for correction.

How a process of alignment works out in practice may be illustrated by the following example. In a certain four-stage i-f amplifier the five couplers were found to be initially peaked at frequencies shown at A of Fig. 15. The frequency response is shown at B. On the trace are marker positions of intermediate frequencies, of frequencies at peaks and valley, and on the low side of the curve a half-gain frequency for determining band width.

Intermediate frequencies for this job were assumed as 25.75 mc for video and 21.25 mc for sound. The video intermediate is half way up on the high-frequency slope. Band width is 3.25 mc between the half-gain points. Picture reproduction was generally acceptable, although somewhat lacking in fine details and requiring a rather high setting of the contrast control.

It seemed that better results might be attained by keeping the same coupler frequencies, but tuning the first coupler to the approximate middle of the band and the other four alternately to high and low frequencies, as often is done. Accordingly, the tuning was

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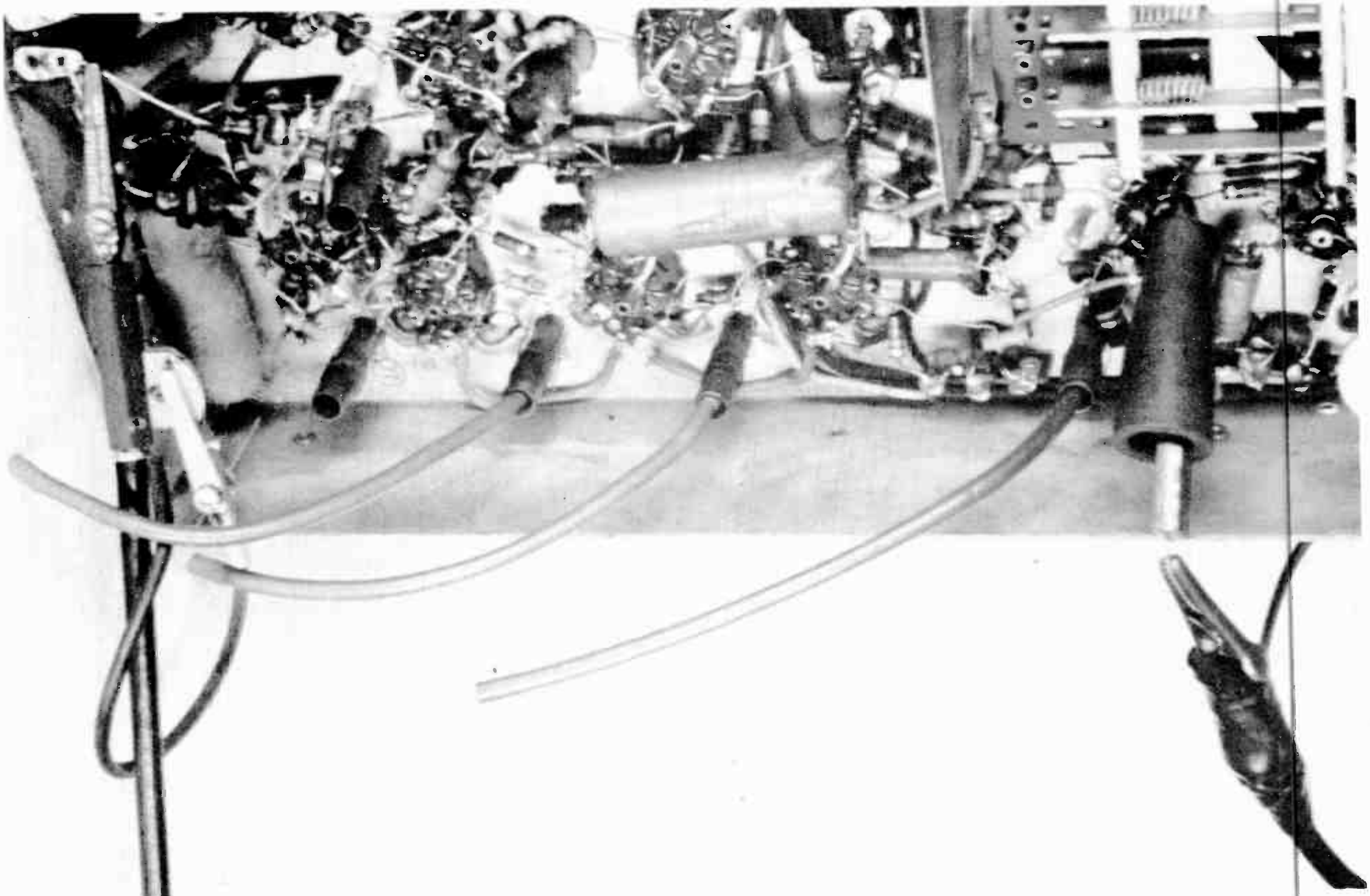

Fig. 14. Several tuning wands may be used at one time for improving a frequency response or for checking the effect of various couplers.

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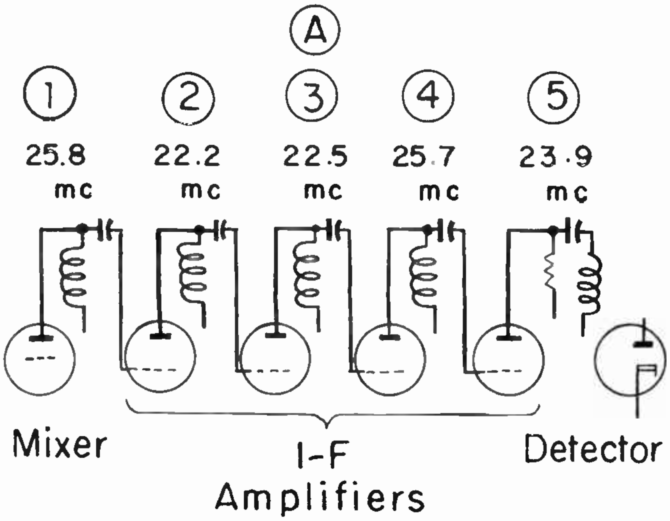
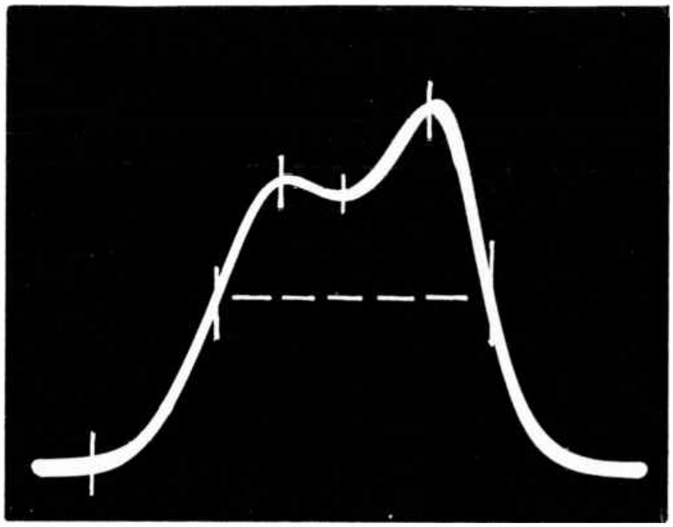


15-A



15-B

Fig. 15. Peak frequencies and resulting response of an i-f amplifier.

changed like this:

Coupler 1,	23.9 mc	Coupler 4,	22.5 mc
Coupler 2,	22.2 mc	Coupler 5,	25.7 mc
Coupler 3,	25.8 mc		

The resulting response is shown at A of Fig. 16. The video intermediate is too far down, causing pictures to lack strong lines. Band width has decreased to 2.4 mc between the half-gain points.

Were gains or amplifications and also the individual frequency responses of all stages to be equal, a given set of peaking frequencies should theoretically give the same overall response no matter in what order arranged. But stage gains hardly ever are equal. Furthermore, some stages tune more broadly than others. As a consequence, the arrangement of peaking frequencies becomes important.

Gain at any particular point along a response curve is affected most strongly by the coupler or couplers tuned at or near the frequency of that point. However, adjustment of any coupler affects all parts of the response in greater or less degree. If you wish to change the response at the high-frequency side of the curve, vary the adjustment of couplers peaked in the high-frequency end of the response band. To alter the low-frequency side of the curve, adjust couplers which are peaked for the lower frequencies. A coupler tuned near the middle of the band will affect both sides of the curve, as well as the middle.

Now to proceed with our alignment. By use of a tuning wand it was determined that improvement could be effected by slight lowering of peaking frequencies for couplers 1 and 4. The resulting response appeared as at B of Fig. 16. The earlier very high peak disappeared and a new peak of less height appeared on the high-frequency side of the response. The video intermediate is too far down. Band width has increased to 3.1 mc.

For the series of responses being examined the output of the sweep generator and vertical gain of the scope were held constant. This allows comparative heights of the traces to indicate changes of amplifier gain. It is evident that we have suffered a reduction of gain at B of Fig. 16 in comparison with earlier responses.

Ordinarily you will vary the output of the sweep generator to keep traces of fairly uniform height as alignment proceeds. Reduce the trace height only by decreasing output from the sweep generator, never by reducing vertical gain of the scope. Remember, we always should use the least possible generator output and thus avoid danger of overloading the i-f amplifiers.

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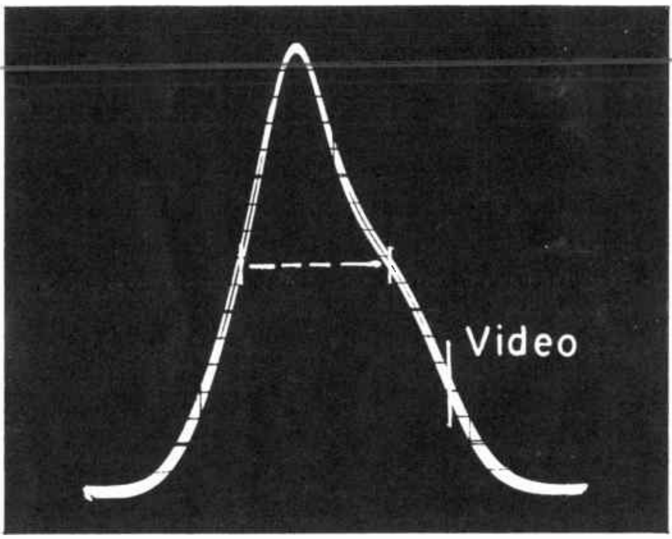
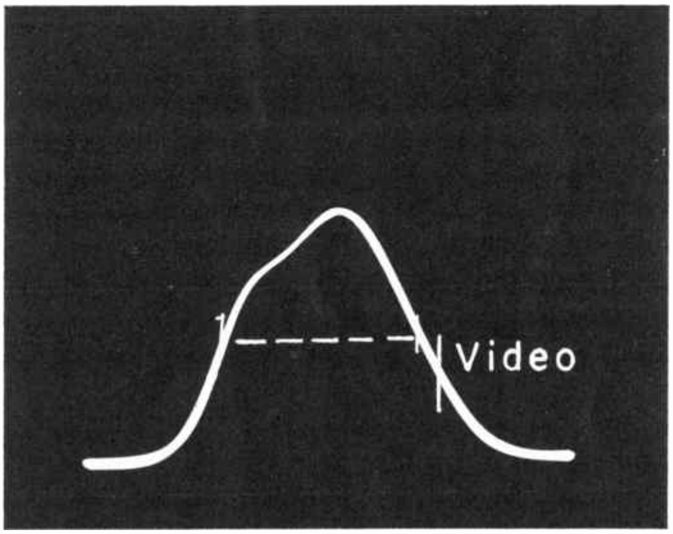
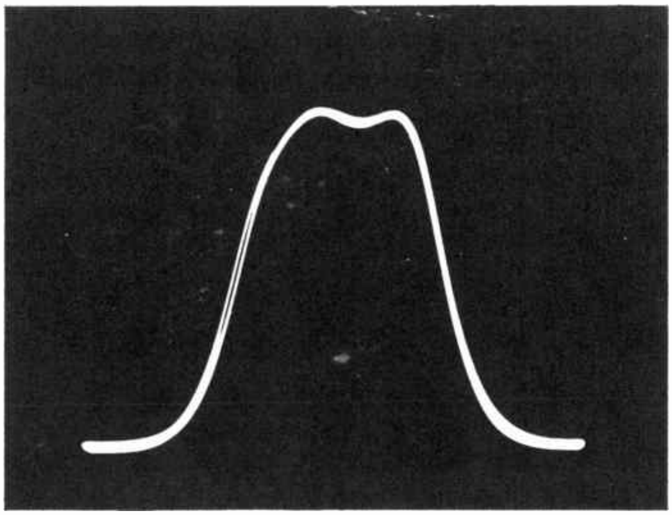


16-A



16-B



16-C

Fig. 16. Responses obtained at successive steps of an experimental alignment.

Further use of tuning wands on other couplers showed a decided improvement when using a much higher frequency for coupler 2, a slightly lower frequency for coupler 3, and a much lower frequency for coupler 5. After making all these changes, the response became as shown at C of Fig. 16. Compared with the initial response of Fig. 14, this final response shows these changes.

	Final	Initial
Band width	3.35 mc	3.25 mc
Curve shape	High and low peaks	Nearly flat top
Width of high-frequency slope	1.3 mc	1.5 mc
Average peak gain		About 25% more

Practice in alignment will bring out this important fact. Adjustment of any one coupling unit may either increase the gain or else may increase band width, but it cannot do both at the same time. Every increase of gain, when caused by a single adjustment, is accompanied by decrease of band width. Every increase of band width is accompanied by a decrease of gain. Two or more adjustments are needed in order to improve both band width and gain.

Note that frequencies at peaks on a response curve seldom if ever coincide with frequencies at which any of the coupling units are peaked. You can see the truth of this by examining frequencies at response peaks in Figs. 15 and 16, and comparing them with frequencies at which the couplers are tuned.

An entire response curve may be shifted to higher or lower frequencies without material change of shape. For a response at higher frequencies turn all slugs a little farther out of their windings, and at lower frequencies turn all slugs a little farther in.

When making i-f alignments on sets having intercarrier sound systems, which means on practically all recent models, be sure to get the sound intermediate well down on the response. The sound intermediate should be so far down that output of the

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marker generator must be advanced to nearly its limit in producing a barely visible pip. Even when the sound i-f pip is moved down the slope to practical invisibility on the flat base of the trace, it is almost certain that there will be plenty of sound volume during normal operation of the receiver.

STAGE-BY-STAGE ALIGNMENT. If one or more i-f coupling units are badly out of adjustment it may be impossible for sweep signal voltage to pass from mixer to video detector, and no useful response trace can be produced on an oscilloscope connected to the detector load. When you encounter a receiver in this condition, sweep signal voltage may be passed through only a single coupler to begin with, and after that unit is adjusted you can bring in the others, one at a time, until the job is finished.

This general method of alignment is illustrated by Fig. 17. The oscilloscope is connected to the detector load and remains there during the entire process. The sweep and marker generators are connected first to the grid of the i-f amplifier immediately preceding the detector. This allows adjusting the coupler numbered 1 in the diagram. Then the generator connection is shifted to the grid of the amplifier second from the detector, and coupler 2 is adjusted. The generator connection is moved successively to amplifier grids farther from the video detector, through all i-f stages, until finally reaching the grid of the mixer tube. One additional coupling unit is adjusted at each step.

What happens during such a process of alignment is illustrated by response traces which follow, assuming that we are working toward a video intermediate of 25.75 mc and a sound intermediate of 21.25 mc.

To begin with, the coupler nearest the video detector may be peaked at or near a frequency midway between the intermediates, which would be 23.5 mc in the case assumed. Depending on the design of the i-f amplifier system and detector circuit you may obtain a rather sharp peak, as at A of Fig. 18, or a very low broad peak as at B. If the peak is so low as to make identification difficult, temporarily shift the scope connection to the plate of a video amplifier and adjust the sweep generator for greater sweep width.

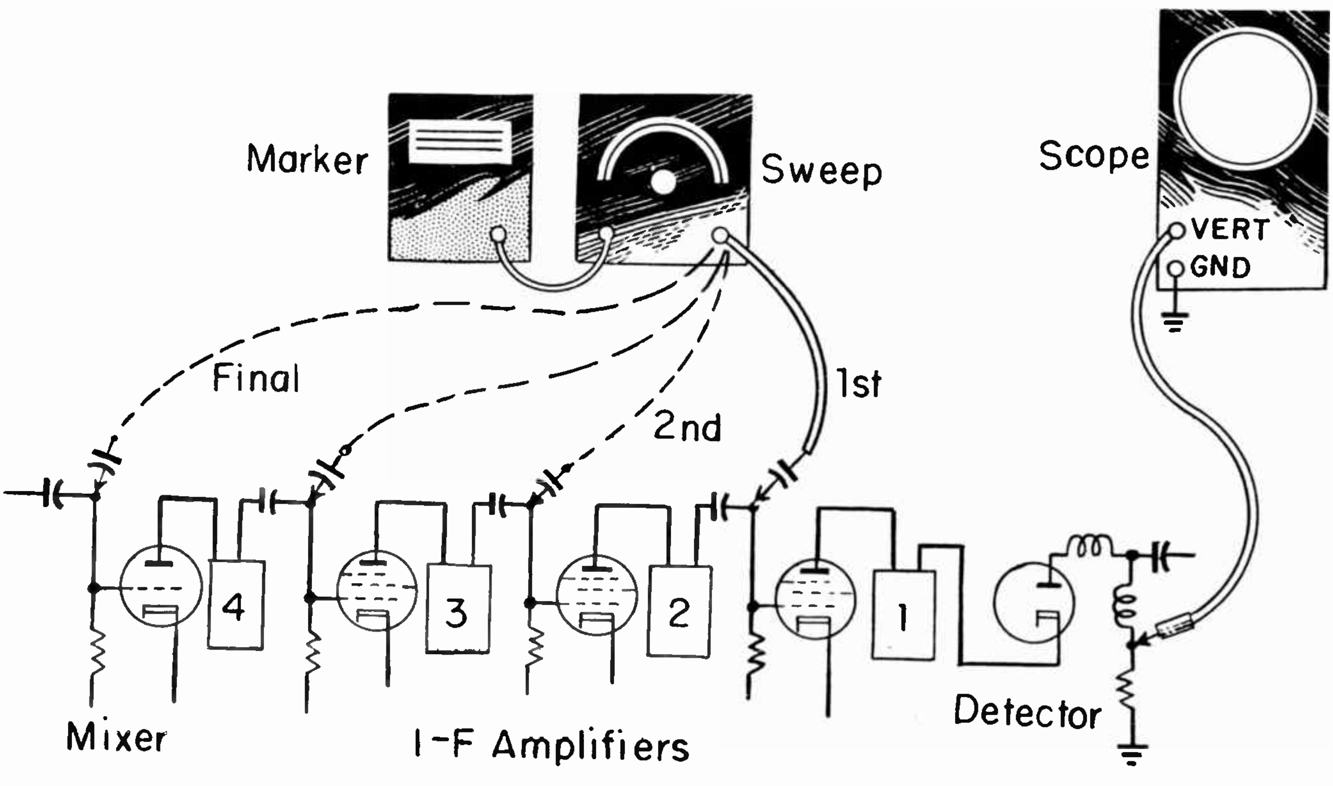

Fig. 17. How generator connections are shifted during stage-by-stage alignment.

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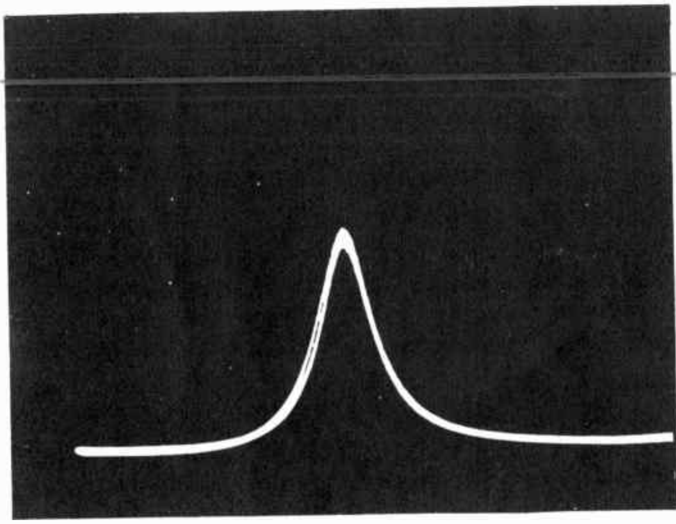
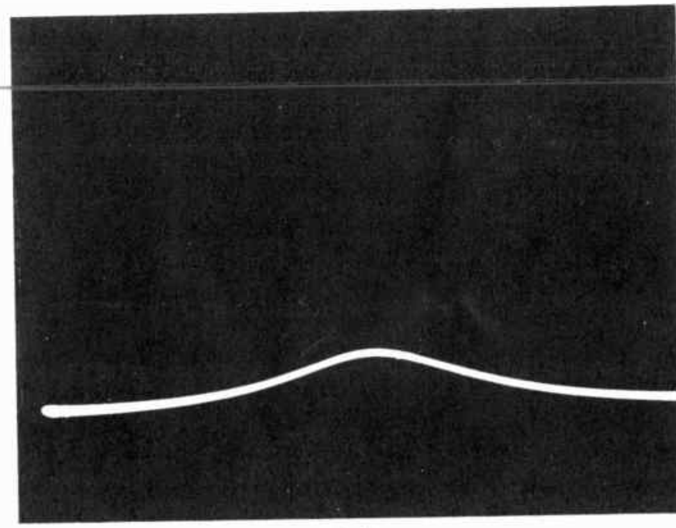


18-A



18-B

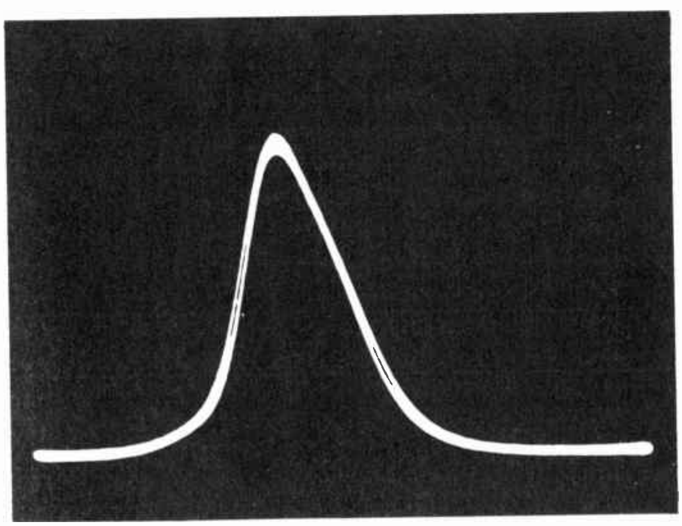
Fig. 18. Response with only one coupler between generators and oscilloscope.

Keep the scope adjusted for strong vertical gain, use a grid connection capacitor no larger than 10 mmf on the generator lead, and keep the sweep generator output as low as possible.

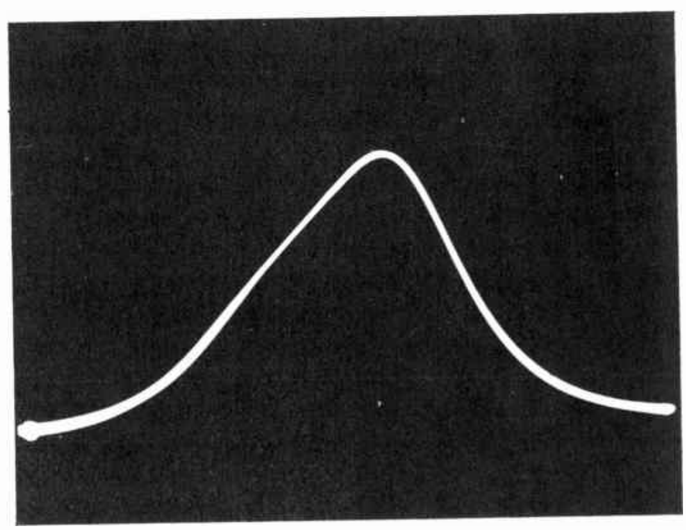
Move the generator connection to the grid of the preceding i-f amplifier and adjust the next coupler for a curve peak somewhat more than one megacycle higher or lower than the peak frequency used in the first step. At A of Fig. 19 is the response obtained by tuning the second coupler to a lower frequency, with a curve peak at about 23.2 mc. The slopes are not alike, because they are affected by two couplers working together.

Trace A of Fig. 19 was obtained with the automatic gain control overridden, with a 3-mmf series capacitor to the amplifier grid, and with only moderately strong sweep voltage. Removing the agc override, using a 50-mmf series capacitor, and maximum sweep signal voltage produced the trace at B. This second trace is so badly distorted as would lead to incorrect alignment.

With the generator connection at the next preceding grid the third coupler is adjusted for a response peak toward the other side of



19-A



19-B

Fig. 19. Response with two couplers in circuit. Trace at B is distorted.

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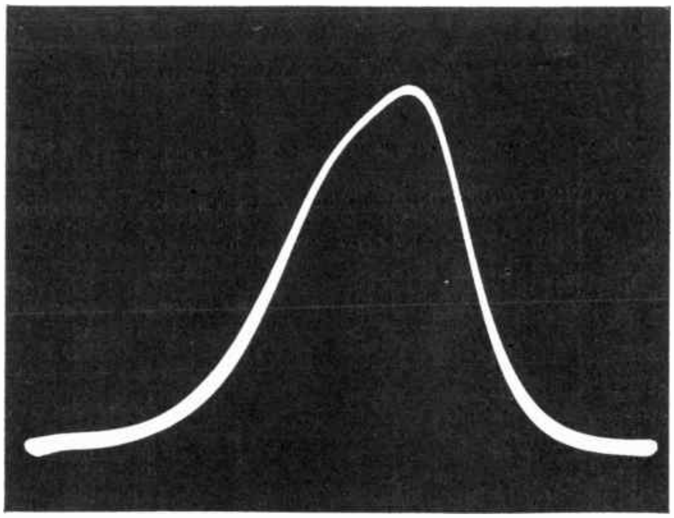
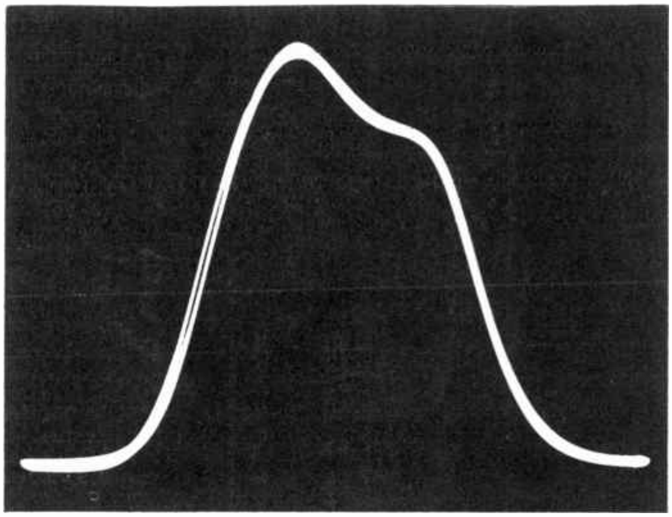


20-A



20-B

Fig. 20. Responses which result from bringing additional couplers into the circuit between generators and oscilloscope.

the curve from the peak first obtained. During the experimental alignment being described the curve was as shown at A of Fig. 20, with the high peak at 25.2 mc. The outward bulge on the lower-frequency side shows the remaining effect of the peaking at A of Fig. 19.

With the generator connection moved to the mixer grid, the final i-f coupling unit is adjusted for best possible positions of the intermediate frequencies and for reasonably good overall shaping of the curve. This result, in our experimental alignment, is shown at B of Fig. 20.

Independent measurements, not part of the alignment process, showed the four coupling units to have been tuned to these peak frequencies.

Coupler 1, for Fig. 18.	23.5 mc
Coupler 2, added in Fig. 19	22.0 mc
Coupler 3, added in Fig. 20-A.	25.5 mc
Coupler 4, added in Fig. 20-B.	21.9 mc

Note how the addition of each coupling unit and amplifier tube alters the positions of the intermediate frequencies on the responses. It is necessary to make continual use of marker pips to avoid getting these frequencies too far out of line. In Fig. 18 the video intermediate is so far out on a nearly flat portion of the response as to have exceedingly small gain, but amplification in other stages brings this frequency up where it belongs. So long as it is possible to produce a visible marker pip on a response, there must be at least some gain at the point where the pip appears.

Alignment in the manner just described may or may not result in a final response considered satisfactory. It will, at least, produce a curve of ample height with generators to the mixer grid and scope to the video detector lead, after which further improvement may be made by readjustments of various coupling units.

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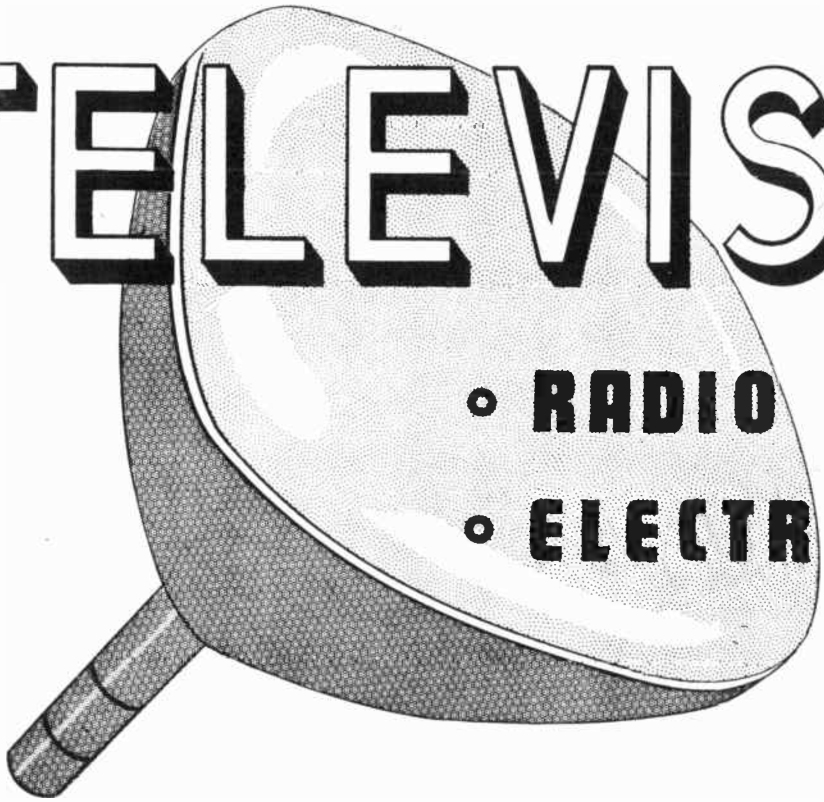

• RADIO
• ELECTRONICS

LESSON 58 — OSCILLOSCOPE ALIGNMENT OF SPECIAL CIRCUITS

Coyne School

practical home training

Chicago, Illinois

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Lesson 58

OSCILLOSCOPE ALIGNMENT OF SPECIAL CIRCUITS

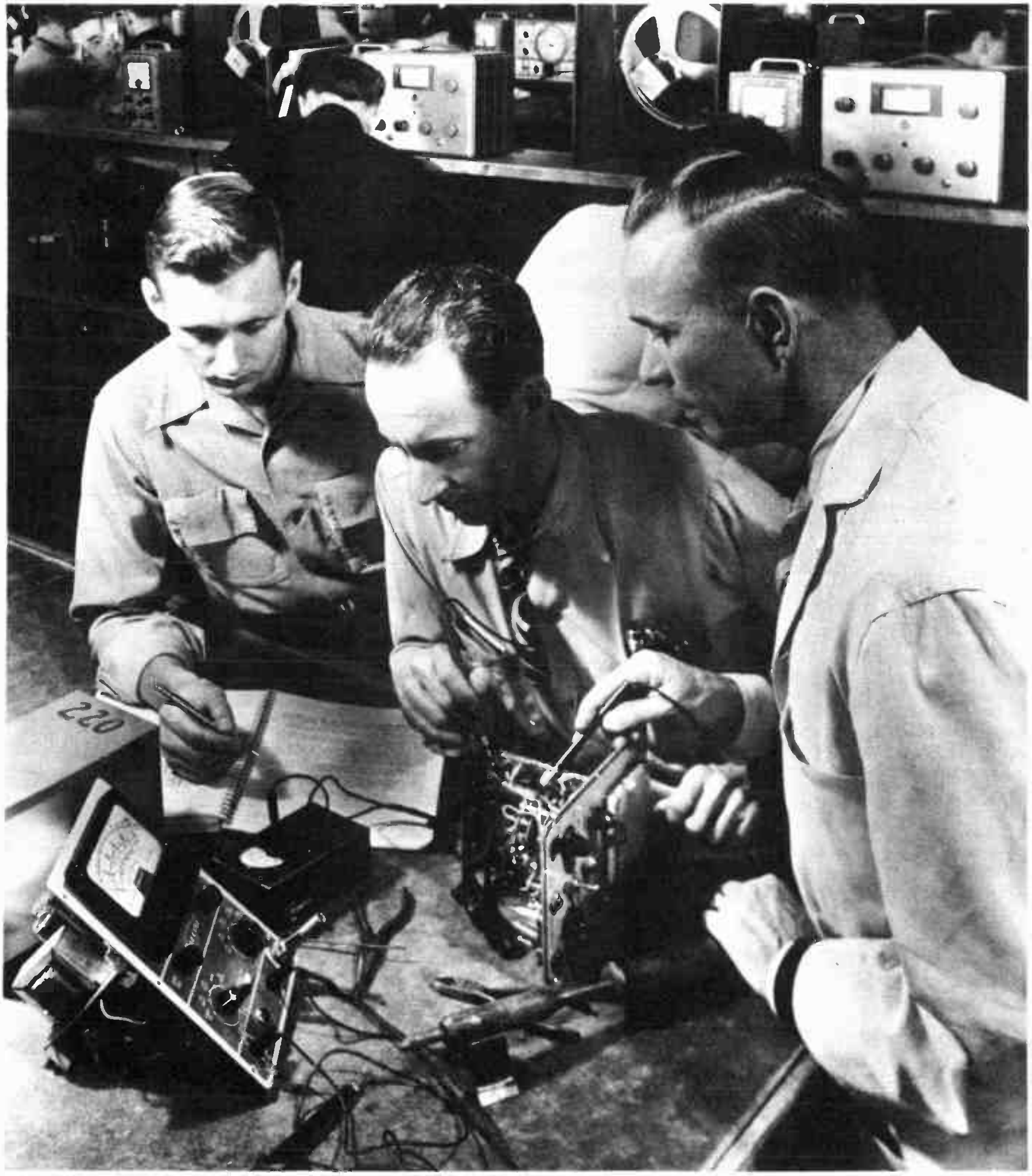

Fig. 1. Servicing may be required on test instruments which fail. These Coyne students are learning how it is done.

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We have been working with i-f amplifier systems in which each coupling unit, taken by itself, will produce a response having a single peak at its resonant frequency. By stagger tuning successive couplings of this kind we secure an overall i-f response of correct shape, with intermediate frequencies at correct points. I-f amplifiers with couplers of this general type are used in the majority of television receivers.

Where the entire i-f amplifier is not of the stagger tuned variety we find one or more i-f transformers capable of producing, by themselves, a response with two peaks separated by a valley. In earlier lessons we learned that a double-peaked response may be produced in either of two ways. First, we may employ an overcoupled transformer, with which separation of the peaks is due to closeness of coupling, both windings being tuned to the same frequency. Second, we may use an undercoupled transformer with its two windings tuned to different frequencies.

On any double-peaked transformer, whether overcoupled or double-tuned, there will be two adjusters, as for two slugs or for two trimmer capacitors. Sometimes there will be more than two adjusters. Some adjusters may be reached from on top of the chassis, and others from underneath. When there are two or more adjusters, the i-f transformer nearly always is one or the other of these three types.

A. Either overcoupled or double-tuned, for producing a response with two peaks.

B. A single-peaked or stagger-tuned transformer with which is combined a trap.

C. In receivers having dual sound systems not intercarrier sound, the first or second i-f transformer contains a sound take-off winding furnishing the sound intermediate frequency to the first amplifier in the sound section. Such a transformer may be identified by the fact that one or more of its terminal connections go to the sound section.

A transformer combined with a trap cannot be positively identified by tracing its external connections, for on many trap windings there are no external connections at all. To identify an i-f transformer combined with a trap, and to identify also the trap adjustment, proceed as follows.

1. Set up an oscilloscope trace from any amplifier circuits which include the transformer in question.

2. Watch the trace while carefully altering each adjuster a little ways in each direction, then return it to the original position.

3. The adjuster for a trap winding will cause a dip to appear on the response, as in Fig. 2. This dip will move on the response as the adjuster is altered. A trap adjustment will affect also the steepness of slope on one side of the response, and, if altered very much, will change the height of one side of the response. Any adjuster which does not cause these things to happen doubtless is for tuning one of the coupling windings.

It would be difficult to identify, by inspection, the differences between double-peaked transformers of the overcoupled and double-tuned varieties. Fortunately, it is not necessary to distinguish between these two types, because alignment of both kinds is carried out in the same general manner.

If you have manufacturer's service instructions for alignment of an i-f amplifier system containing double-peaked transformers, follow those instructions precisely. Methods explained in this lesson apply to cases in which no specific information is available, and include hints which will be useful even when you do have instructions for the particular receiver being worked on.

In nearly every case the alignment of an i-f amplifier containing double-peaked transformers should be made stage-by-stage, as explained in the preceding lesson. That is, the scope is connected to the load of the video

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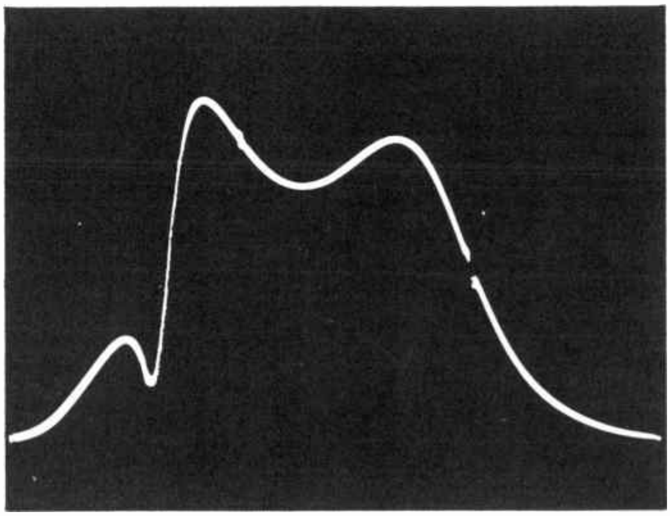

Fig. 2. The dip on the low-frequency side of this response is caused by a trap.

detector, or to a video amplifier plate, and remains there. The sweep and marker generator connections are shifted from grid to grid of the i-f amplifiers, commencing at the amplifier just ahead of the video detector and working toward the mixer. This procedure will take in all couplers which are single-peaked as well as those which are double-peaked.

If all single-peaked stagger-tuned couplers are together, and toward the video detector, they may be peaked, if you so prefer, by using an r-f signal generator and VTVM until arriving at the first or only double-peaked transformer. These two instruments may be used also for preliminary adjustment of some double-peaked transformers, but it is difficult or impossible to make a completely satisfactory adjustment of a double-peaked transformer without using the sweep and marker generators and the oscilloscope.

SINGLE STAGE ALIGNMENT. When you come to a double-peaked transformer it must be isolated from resonant and detuning effects of other couplings which precede and follow it in the amplifier system. These other couplings must be made inactive so far as resonant effects are concerned. The procedure is no different from that of adjusting any single stage in any kind of amplifier system, and for observing the response of any single stage without interference from other stages.

Fig. 3 illustrates a method for adjusting only the final coupler in any i-f amplifier system, or for observing the response of this one coupler. The interstage couplings may be of types shown in our diagrams, or of any other types. Próceed as follows.

1. Connect the scope to the video detector load, as usual.

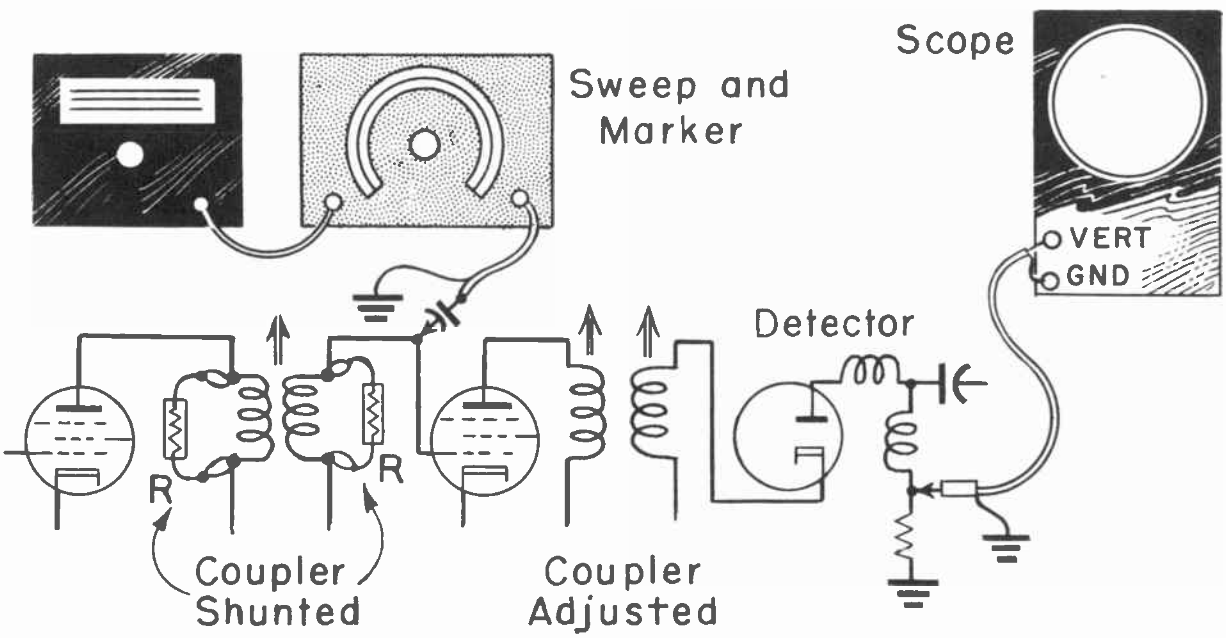

Fig. 3. The setup for test and adjustment of the final coupling unit in an i-f amplifier.

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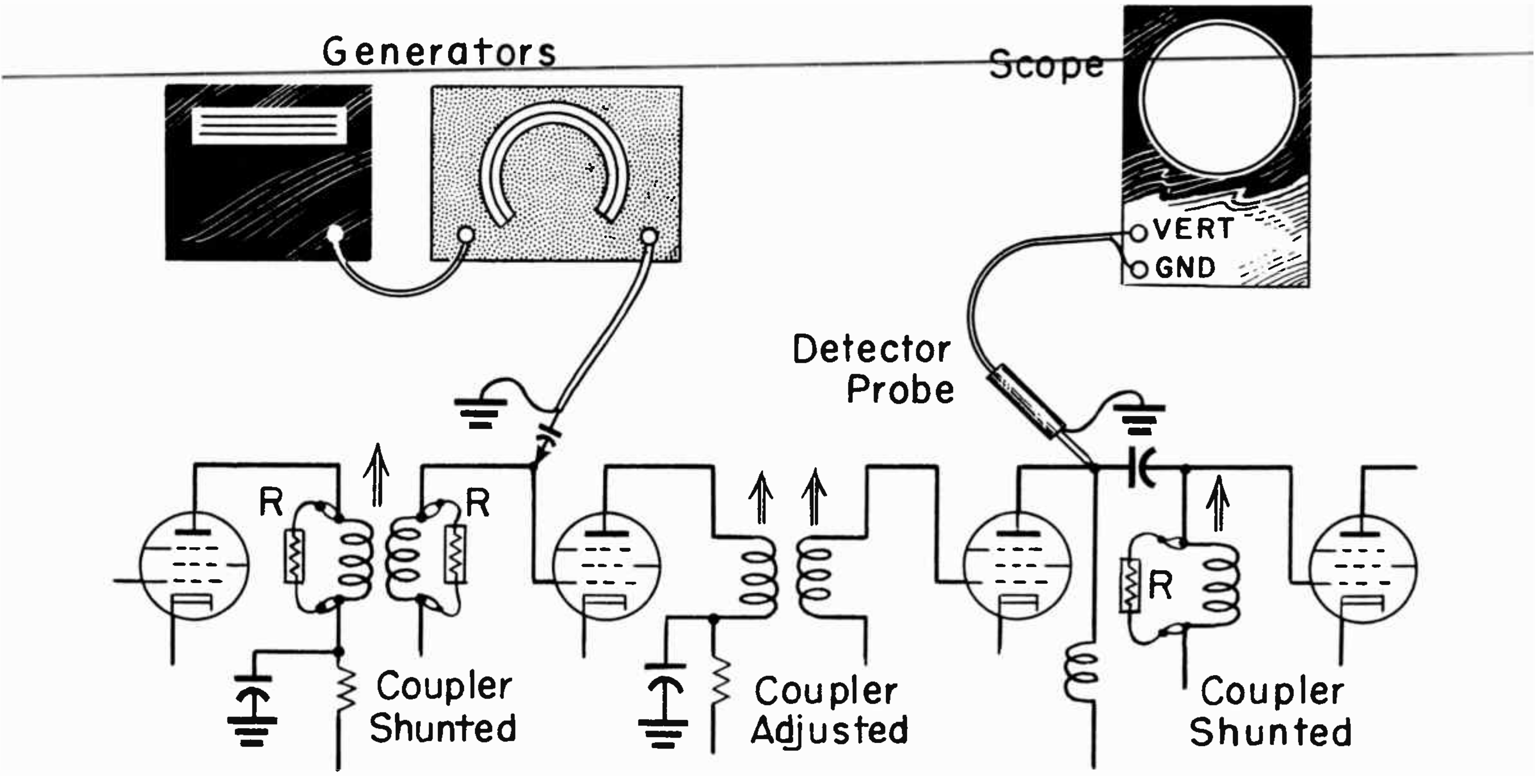

Fig. 4. Setup for test and adjustment of a coupler not followed by the video detector.

2. Shunt the winding or windings of the preceding coupler with resistance, to prevent that coupler from resonating at any intermediate frequency. Shunting resistors should be of about 300 ohms, 1/2-watt rating. The resistors may be connected to transformer terminals or socket lugs by attaching small spring clips to the resistor pigtails. Insulate the clips, or make sure that they will remain clear of all other metal conductors.

3. Connect the sweep and marker generators to the grid of the amplifier tube just ahead of the coupling to be adjusted. Do not connect the generators to the plate circuit in which is the adjusted coupler, for this would add generator and cable capacitance to the adjusted circuit. Do not remove the tube which precedes the adjusted coupler, for then the tube capacitance would be out of the adjusted circuit.

For adjusting or observing the response of any i-f coupling other than the one just ahead of the video detector the setup is shown by Fig. 4. We no longer have the video detector to demodulate i-f signal voltage coming from the sweep generator, therefore must use a detector probe to take the place of the video detector. Such a probe was described in the lesson on "The Vacuum Tube Voltmeter." The same probe, or any generally similar type, is connected to the vertical input of the scope. As mentioned before, interstage couplings may be of types shown or of any other types without affecting the setups for testing and alignment.

1. Connect the sweep and marker generators to the grid of the tube preceding the coupler to be worked on. This preceding tube might be an i-f amplifier or it might be the mixer.

2. Connect the detector probe, leading to the scope, to the high side of the plate circuit of the i-f amplifier which follows the coupler being adjusted. None of the test instruments may be connected to the circuit of the adjusted coupler without a tube intervening between instruments and coupler. Such a connection would completely upset the response, by adding capacitances to the circuit being worked on. Do not remove any of the tubes; this would remove capacitances normally in circuit.

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3. Use resistance shunts across the coupling unit ahead of the one being worked on, also across the coupling unit which follows. Some service instructions recommend the use of capacitor shunts, about 1,000 mmf, for detuning adjacent couplers. When capacitors are specified in service instructions, use capacitors, but resistance shunts have been found entirely satisfactory.

4. Make certain that adjacent couplers really are inactive. If these couplers can be reached with a tuning wand, either end of the wand inserted in a coupler form should make no appreciable change in the response. If a wand cannot be used, touch the grid or plate socket lugs of tubes which are on the far sides of shunted couplers. If these couplers actually are inactive there will be very little effect on the response. Touching a plate lug with one finger won't give a shock provided you keep other fingers and your other hand away from all metal.

A different method of observing the response while making adjustments on any one i-f coupling is illustrated by Fig. 5. The steps are as follows.

1. Connect the sweep and marker generators to the grid of the mixer, and leave them so connected during all remaining steps.

2. Connect the vertical input of the scope to the video detector load. Do not use a detector probe, but make the connection through the usual series resistance and bypassing capacitance. Leave the scope so connected for all remaining steps.

3. Attach resistance shunts across all couplers except the one unit which is first to be tested and adjusted.

4. The curve shown by the scope will be the response of the unshunted coupling unit. Because of the long path followed by sweep signal voltages it will be necessary to use high output from the sweep generator and to set the scope for maximum vertical gain.

5. To test and adjust each other coupler, remove its resistance shunt or shunts, and shunt the coupler on which work has been completed.

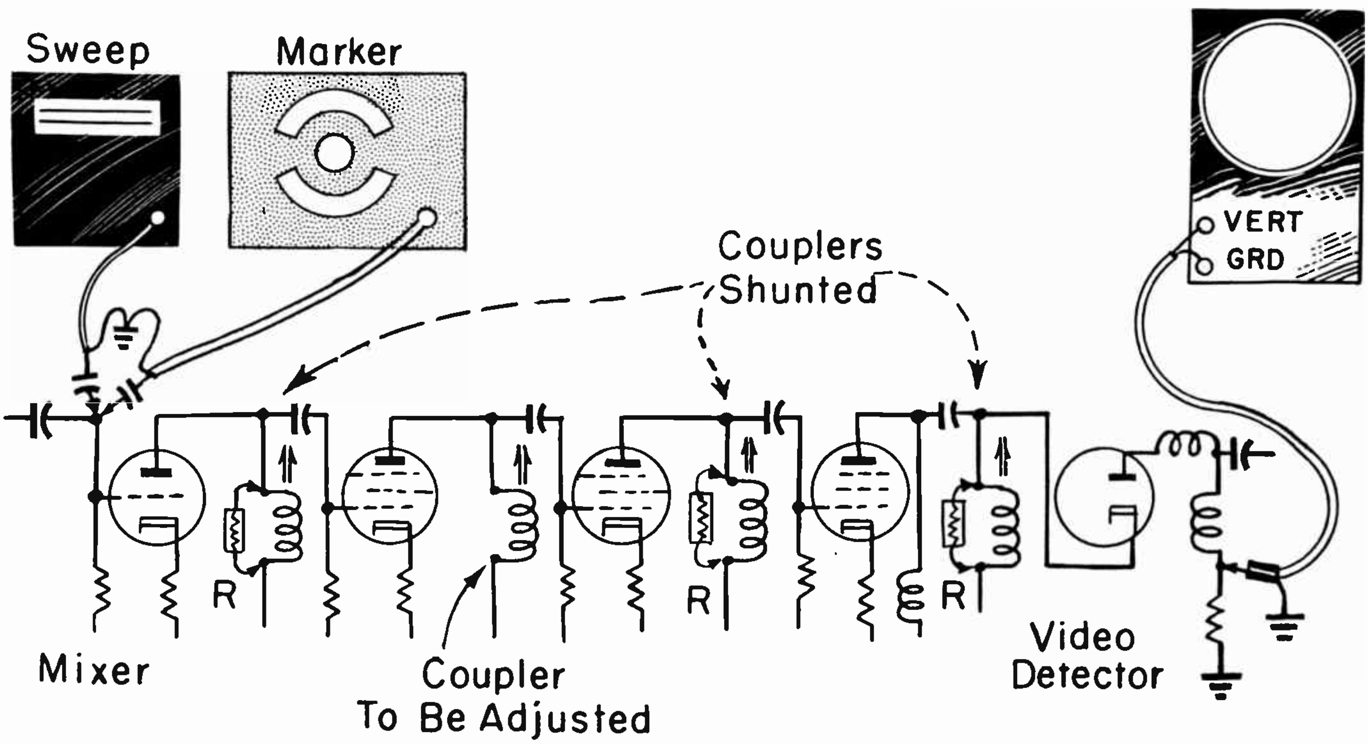

Fig. 5. Adjustment and test of any one coupler with generators connected to the mixer grid.

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IDENTIFYING COUPLER FREQUENCIES. The setups of Figs. 3, 4, or 5 may be used for determination of frequencies at which various i-f couplers are peaked. Procedures are the same as previously explained in connection with each diagram. The center frequency of the sweep generator is adjusted to bring a single-stage response curve onto the scope screen. Then the marker generator is tuned to place pips at the single or twin peaks, reading the marker tuning to identify the peak frequencies.

For checking peak frequencies, the VTVM may be connected in place of the scope, and an r-f signal generator giving a constant tuned frequency may be connected in place of the sweep and marker generators. Shunting of couplers except the one measured is the same as in the diagrams. The detector probe is used as shown in Fig. 4, but not when the VTVM is connected to the video detector in Figs. 3 and 5.

Carefully tune the signal generator for maximum reading on the VTVM. Tune back and forth several times to make certain of a true maximum reading. The generator frequency then is the frequency at which the coupler is peaked. The marker generator, if a separate unit, may be used instead of another r-f signal generator. Any generator is to be used without modulation.

OSCILLOSCOPE AS A VOLTMETER. The vertical height of a trace on the oscilloscope may be used for measurements of voltage, in connection with a voltage calibrator, or may be used without calibration to indicate maximum or minimum voltages during alignment and for identification of peak frequencies. With a scope having, for example, maximum vertical sensitivity of 20 r-m-s millivolts per inch, when a trace from a video detector is about four inches peak-to-peak, a VTVM connected to the same point will read about 3/4 d-c volt. The height of the scope trace is equivalent to having a meter with which a deflection for 3/4 volt covers a scale length of four inches. Few, if

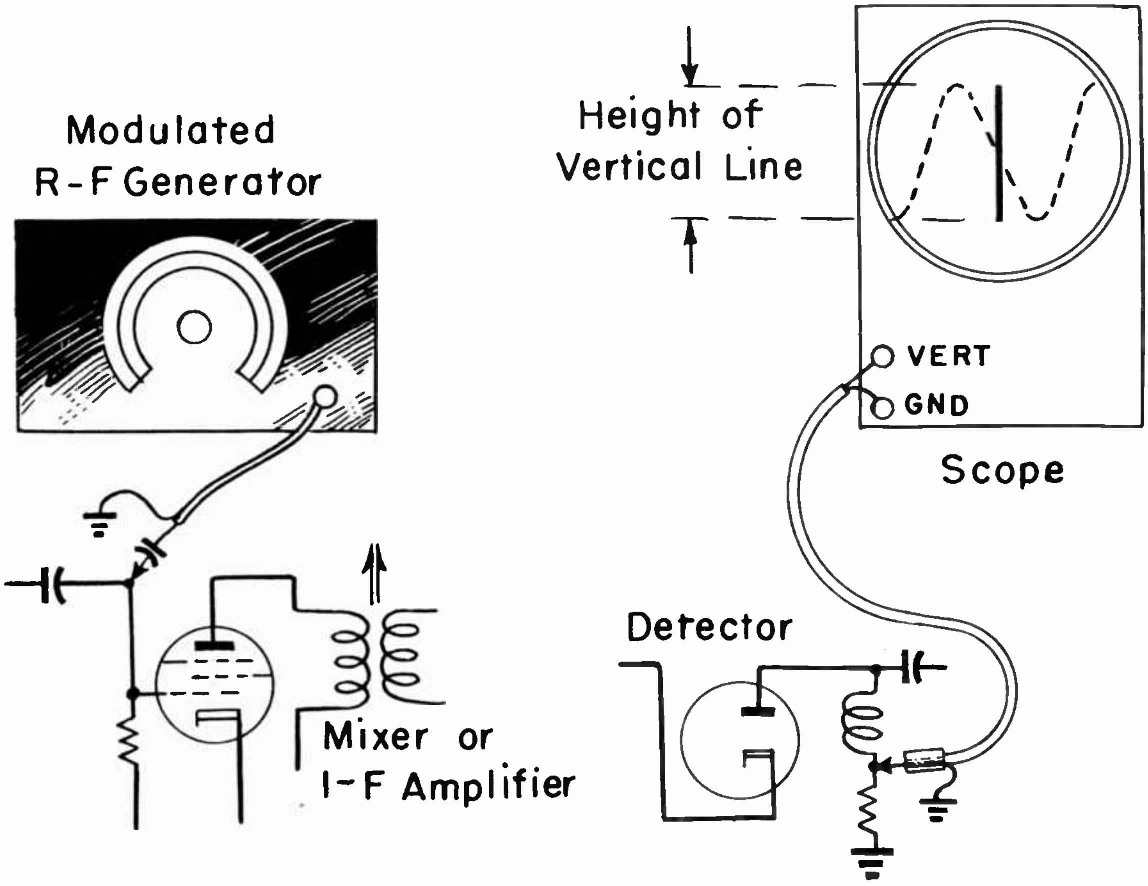

Fig. 6. Using the oscilloscope as a sensitive voltmeter.

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any VTVM's have scales of such proportions. Consequently, the scope can act as a more sensitive voltmeter on which it is easier to read small changes of voltage.

To use the scope as a voltmeter on a video detector load make the setup of Fig. 6, proceeding in this manner.

1. Connect the vertical input of the scope to the detector load with the usual isolating resistance and bypassing capacitance; do not use a detector probe.

2. Connected a modulated r-f signal generator or modulated marker generator to the mixer grid or to the grid of any i-f amplifier, just as the sweep and marker generators are connected in Figs. 3 and 5.

3. Set the scope for internal sweep, adjust the sweep frequency to match the modulation frequency from the signal generator, and bring a trace of the modulation waveform onto the screen of the scope.

4. Vary the r-f output voltage from the generator. If possible, vary also the modulation voltage. Both variations should cause the trace to increase or decrease in height.

5. Retard the intensity control of the scope. Reduce horizontal gain to minimum, or turn off the horizontal amplifier if possible. Advance the intensity only enough to make a vertical line clearly visible on the scope screen, but do not make this line unnecessarily bright.

The overall height of the vertical line is proportional to output voltage from the video detector. This voltage may be measured with a calibrator in the manner explained in another lesson.

To check voltage at the output of any i-f amplifier, not at the video detector, use a detector probe on the scope vertical input as in Fig. 4. Height of the vertical line or trace still will vary proportionately to output voltage.

Observation of the modulation waveform in preceding steps 2 and 3 is only to make certain that the instruments are working correctly and that output voltage varies with both r-f and modulation voltages. So far as tests and measurements are concerned it would not be necessary to synchronize the horizontal sweep of the scope with modulation voltage, nor to keep the sweep synchronized.

The scope as a voltmeter may be used for adjusting signal-peaked couplers to a specified frequency. The modulated r-f generator is tuned to the desired frequency. Then the coupler is adjusted for maximum height of vertical line on the scope. This is a convenient method when both single-peaked and double-peaked couplings are to be adjusted, since it is not necessary to change back and forth between the scope and the VTVM.

The scope as a voltmeter may be used also for determining the frequencies at which individual couplers are peaked. For such work it is necessary only to vary the r-f tuning of the modulated signal generator until locating the frequency at which the vertical line on the scope becomes of maximum height. This will be the frequency at which the coupler is peaked.

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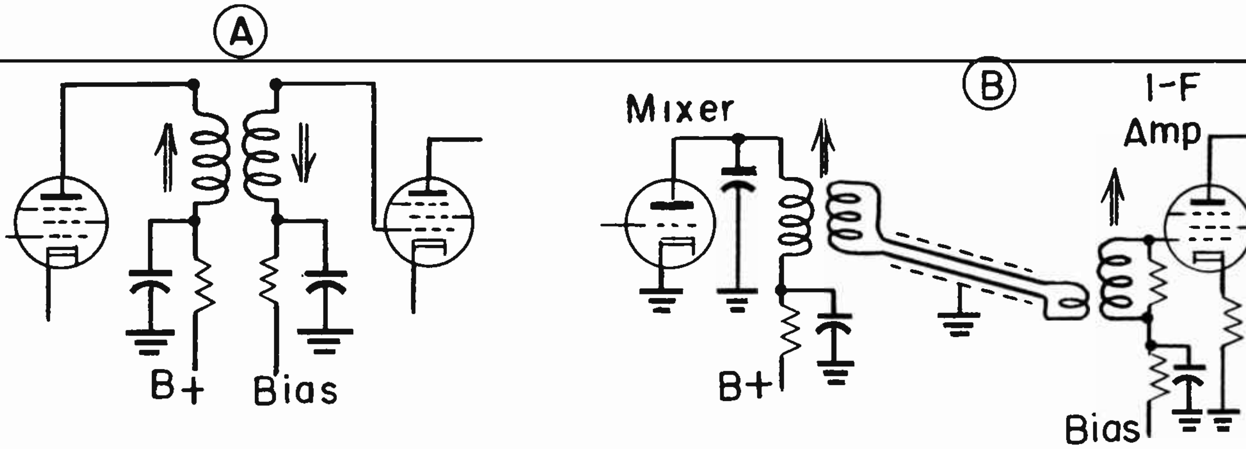

Fig. 7. Double-peaked transformers which are undercoupled.

DOUBLE-PEAKED TRANSFORMERS. The simplest of double-peaked transformers is shown at A of Fig. 7. Primary and secondary are inductively coupled, with separate adjustable cores in each winding. Such a transformer may follow the mixer, or it may precede the video detector, or several may be used anywhere in the i-f system. The two slugs should be adjusted for maximum gain combined with best possible band width, and, when no single-peaked couplers are in the same amplifier system, for correct positioning of the intermediate frequencies on the response curve.

At B of Fig. 7 are two transformers, separately tuned, with a link connection from the secondary of the unit at the mixer to the primary of the unit at the first video amplifier. When making a stage-by-stage alignment, final adjustments will be of these two transformers. They should be aligned for maximum gain combined with correct shaping and correct placing of intermediate frequencies on the overall response.

Fig. 8 shows connections for one style of overcoupled transformer. Between plate winding La and grid winding Lb there is no inductive coupling whatever. In fact, either or both windings may be enclosed with shielding cans. The sole coupling is through adjustable capacitance Ca, with the high-frequency circuit completed through bypass capacitors Cb and Cb. These bypasses are of large capacitance, usually 1000 or more mmf, and of proportionately small reactance at intermediate frequencies. Capacitance at Ca is very small, often less than 1 mmf, and usually is provided by some form of gimmick.

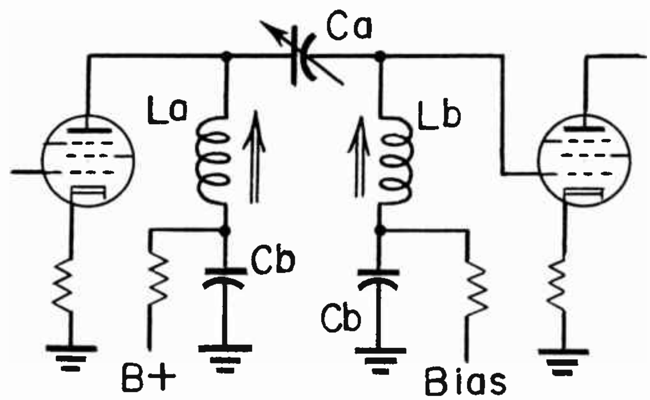

Fig. 8. One type of overcoupled transformer employing top coupling.

When the two windings of Fig. 8 are separately adjusted to the same frequency, and capacitance at Ca is made exceedingly small, to provide a small coupling coefficient the stage response is at A of Fig. 9. A slight increase of capacitance Ca causes two peaks to appear, as at B. Further increase of capacitance Ca causes the peaks to move apart in frequency, leaving a deep valley in between. Frequency separation between the peaks at C is more than five times the width of the flat top at A. Increase of peak separation with closer coupling is characteristic of all overcoupled transformers. The separated peaks remain of about the same height or gain as the single flat-topped peak.

Commencing with two peaks as at B of Fig. 9, raising the tuned frequency of one winding will decrease the height of one peak,

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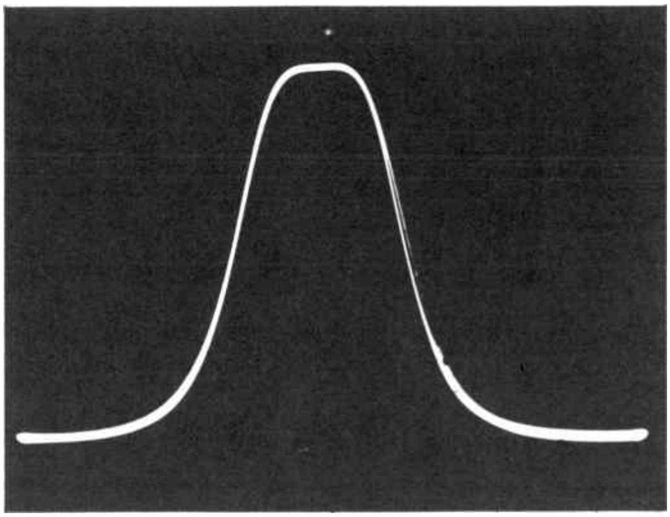

Fig. 9A.

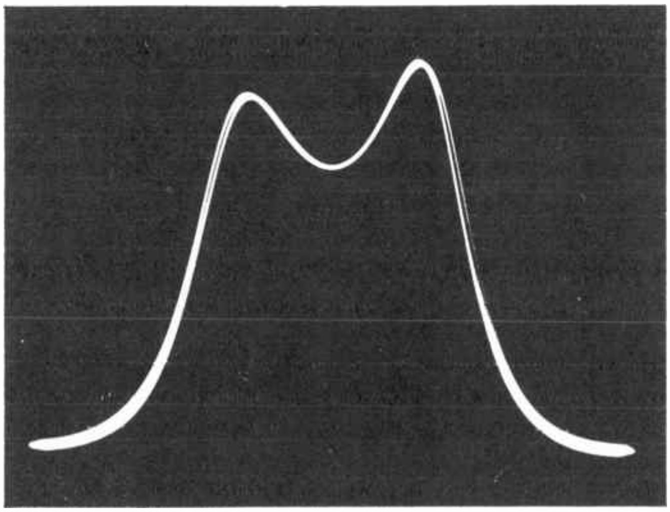

Fig. 9B.

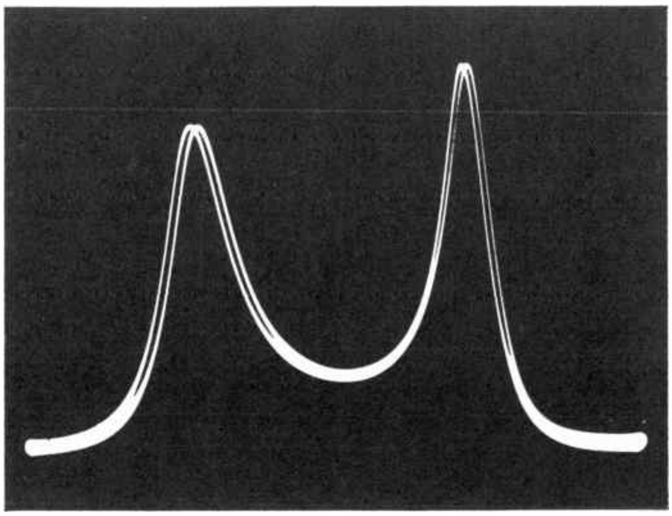

Fig. 9C.

Fig. 9. Peaks are made to appear and their separation is increased by increasing the coupling in an overcoupled transformer.

as at A of Fig. 10, and will move the center of the response to a somewhat higher frequency. Lowering the tuned frequency of that same winding will decrease the height of the other peak, as at B, and will shift the center of the response to a somewhat lower frequency. If the two peaks are only slightly different in height, adjustment of one or the other of the windings will equalize the heights.

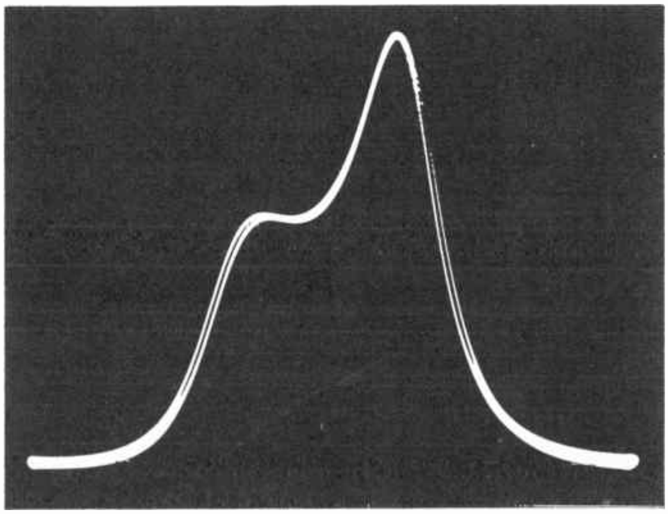

Fig. 10A.

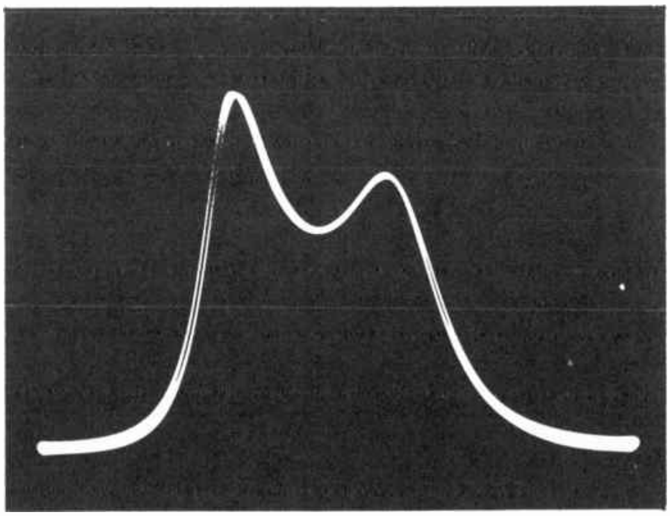

Fig. 10B.

Fig. 10. Effects of changing the tuning of either winding of an overcoupled transformer.

The height of one peak or of one side of the response depends largely on amplification in the tube preceding the transformer, while height of the other peak or other side of the response depends on amplification in the following tube. Changing either or both tubes,

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or changing their plate or screen voltages, will alter the shape of the response to a degree which may call for realignment.

An entire response, such as those of Figs. 9 and 10, may be shifted to a lower or higher band of frequencies without material change of curve shape. For higher frequency both windings are tuned together to higher frequencies, as by turning both slugs farther out of their winding spaces. For a lower band of response frequencies both slugs would be moved farther in.

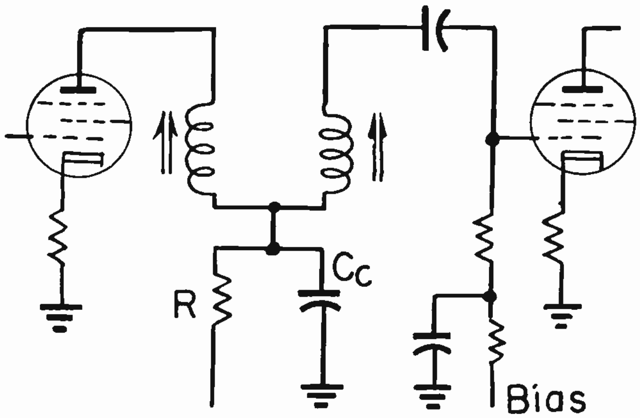

Fig. 11. A transformer in which bottom coupling may cause the unit to be either over- or undercoupled.

Fig. 11 shows an i-f transformer which may be made to act either overcoupled or undercoupled and double-tuned. The plate and grid windings ordinarily have little or no inductive coupling, although when both are on the same form there may be some inductive coupling. Performance, in general characteristics, is not altered when the two windings are completely separated, even when one or both are in shield cans.

Coupling is through the impedance of voltage dropping resistor R and capacitor Cc, but is affected chiefly by capacitive reactance at Cc. So far as intermediate frequencies are concerned, this reactance is in the plate circuit of the first tube and in the grid circuit of the second tube. This method often is called bottom coupling, because the coupling element is at the low sides of the windings. The method of Fig. 8 may be called top coupling, because the coupling element is between the high sides of the windings.

If capacitance at Cc of Fig. 11 is more than about 500 mmf, and of values up to 10,000 mmf, the transformer is not overcoupled but is merely double-tuned. Then each winding produces one peak on the response. Tuning of that winding shifts its peak, with reference to frequency, and has almost no effect on frequency of the other peak. Consequently, adjustment of either winding will alter the band width and the separation between peaks. Adjustment of both windings together will shift the entire response to lower or higher frequencies. Average height of the response curve, and average gain, increase as the peaks are tuned closer together.

With the transformer double-tuned, not overcoupled, and having large capacitance at Cc, this capacitance acts principally as a bypass for resistance at D. Changes of capacitance at Cc between any values in the approximate range of 500 to 20,000 or more mmf will not appreciably alter peak frequencies, peak separation, nor shape of the response. Increases of capacitance allow some increase of stage gain, because of better bypassing effect for the intermediate frequencies around resistance at R. When capacitor Cc acts principally as a bypass, it is not adjustable.

Fig. 12 shows successive responses obtained during stage-by-stage alignment of an i-f amplifier containing undercoupled double-tuned transformers of the type shown in Fig. 11. At A is the response with sweep and marker generators to the grid of the last i-f amplifier. The scope is on the video detector load, and remains there for all following steps. Separation between peaks is 4.7 mc. The photograph shows a marker on one peak.

At B is the response with the generator connection moved to the grid of the preceding i-f amplifier. The irregular dips on the low-frequency side of the curve are due to a trap adjusted for the sound intermediate. At C is the response with the generators moved back one more stage. The sides of the curve have drawn in far enough that the trap effect no longer is clearly visible. At D is the final response or overall response for the entire i-f amplifier, with the generators at the grid of the mixer.

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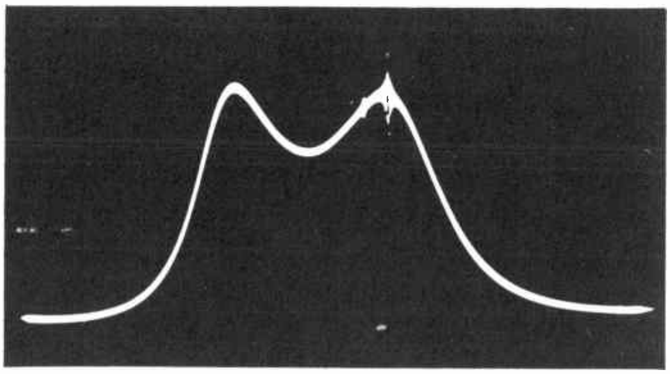

Fig. 12A.

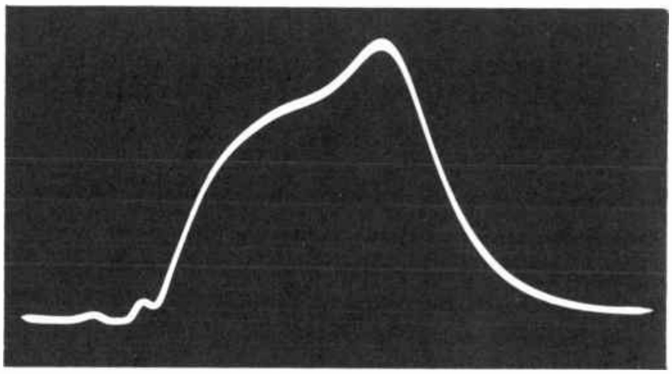

Fig. 12B.

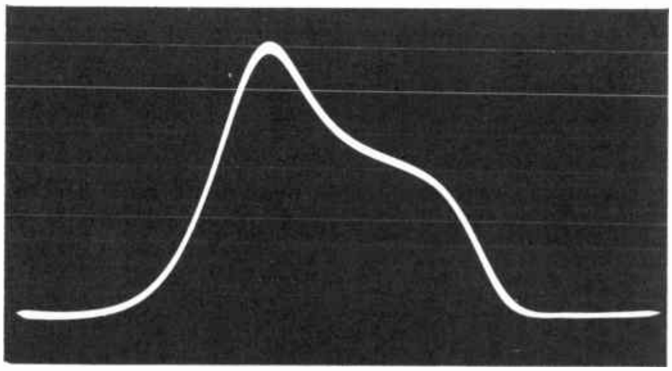

Fig. 12C.

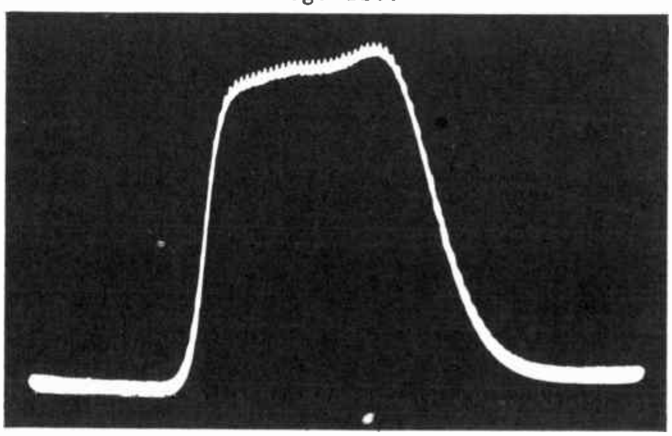

Fig. 12D.

Fig. 12. Responses obtained as more and more double-peaked transformers are brought into circuit between generators and scope.

If capacitance at Cc of Fig. 11 is on the order of 100 mmf or less, or if it is adjustable, this type of transformer acts overcoupled. The degree of coupling depends on capacitive reactance at Cc. Coupling is increased by using less capacitance, which means greater reactance. Adjustment for less capacitance, greater reactance, moves the peaks farther apart in frequency, but causes little change in maximum gain. More capacitance, less reactance, brings the peaks closer together until they merge into a single flat top curve and eventually into a single peak.

When double-peaked and single-peaked coupling units are in the same amplifier system, the double-peaked transformers most often are used for obtaining a desired band width, for flat-topping the response, and for making the curve of generally satisfactory shape. Single-peaked couplers most often are used to bring certain frequencies to desired positions on the response and for correction of peaks which are excessively high. With a double-peaked transformer that is not overcoupled, one of the adjusters usually may be used to shape and move one side of the response, while the other adjuster is used to shape and move the other side of the response.

If a double-peaked transformer is completely out of alignment to begin with, turn one slug all the way out and adjust the other to obtain the highest possible peak, showing that you have this second slug in a position where it does effective tuning. Next, count the number of turns of the adjuster in bringing the second slug all the way out, so that it may be returned to the effective position. Then turn the first slug to a position where it gives maximum gain. Finally, bring the second slug back to its effective position as first determined. Thereafter it should be possible to make careful adjustments of both slugs in securing a correct response.

If the foregoing method gives difficulty, try shunting first one winding and then the other with about 1000 ohms or less, and while each is shunted adjust the other for a peak at a frequency near the center of the i-f pass band. This probably will require maximum or nearly maximum output from the sweep

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generator, and maximum vertical gain of the scope.

When there is an adjustable top or bottom coupling for an overcoupled transformer the windings may be brought into approximate alignment by first making the coupling as loose as possible. This means minimum capacitance for a top coupling, maximum capacitance for a bottom coupling. This should make the response almost single-peaked. When the two windings are adjusted for maximum height of a single peak, they are tuned to approximately the same frequency. This setting serves as a starting point. Then the adjusters may be used to obtain desired peak separation, band width, and curve shape.

It is not necessary that the two peaks of a response be of exactly the same height, a difference of as much as 20 per cent seldom causes performance difficulties. It is, however, essential that the valley between peaks be as shallow as possible. The bottom of the valley should be at least 70 per cent as high as the higher peak.

In most double-winding transformers there are two slugs which enter the form from opposite ends, one accessible from above the chassis and the other from underneath. It may be, and usually is, possible to turn either slug to the center of its winding and then still farther into the form. It will be possible to obtain the same peak frequency with the slug at two different positions, one where the slug is turned out beyond the center of the winding, the other where the slug is turned an equal distance in beyond the winding center. Always use the settings which bring the slugs toward the outer ends of the winding form, and which keep the two slugs as far apart as possible. The other settings, where the slugs are closer together, may alter the degree of coupling and make alignmen difficult or impossible.

ALIGNMENT OF TRAPS. The subject of traps in general, and how they are used, was discussed in the lesson on "I-f Traps and Video Detectors." Later we learned how to adjust traps by using an r-f signal generator and the VTVM, adjusting the trap for minimum voltage with the generator tuned to the frequency to be trapped.

When i-f alignment is being carried out with sweep and marker generators and the oscilloscope, trap adjustment becomes a simple process because we see the dips which are due to traps and may bring these dips to desired frequencies by checking with the marker generator.

It is possible to align traps and coupling units in various orders or sequences. A method which usually gives good results when sweep and marker generators are at the mixer grid is to first make a preliminary adjustment of all traps. Then, as each coupling unit is aligned, any trap associated with or acting on that coupling unit is readjusted as may be found necessary.

The instrument setups for trap adjustment are the same as for alignment of i-f coupling units. If sweep and marker generators are connected to the mixer grid for all steps of coupling alignment, traps may be adjusted at the same time or, at least, without altering the setup. When making a stage-by-stage alignment, by moving the generator connection from grid to grid, coupling units and traps in each stage will be adjusted at each connection of the generators. The oscilloscope will remain at the video detector load for all steps with either method of alignment.

A trap absorbs energy at and near the frequency to which the trap is tuned, and thus reduces gain at and near this frequency. The result, as we saw in Fig. 2, is a dip in the response curve where gain is decreased at the trap frequency.

When, as is usually the case, a trap is tuned to a frequency near the lowest part of either slope on a response, where gain always is very small, it may become difficult to see a dip which is due to trap action. This difficulty may be overcome to a great extent by using maximum vertical gain in the scope, by using a rather high output from the sweep generator, and by using only 1-1/2 volts (a single dry cell) for agc override instead of the usual three or more volts.

Upon commencing to adjust a trap we

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often wish to first identify the frequency at which the trap already is tuned. This is done by bringing a marker pip to the bottom of the dip caused by the trap, and reading the trap frequency from the tuning dial of the marker generator.

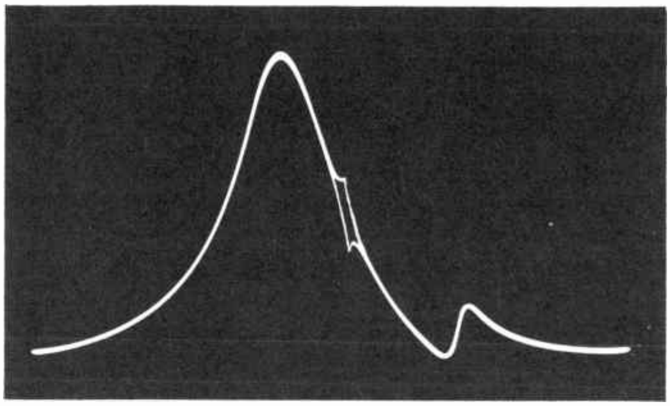

Fig. 13A.

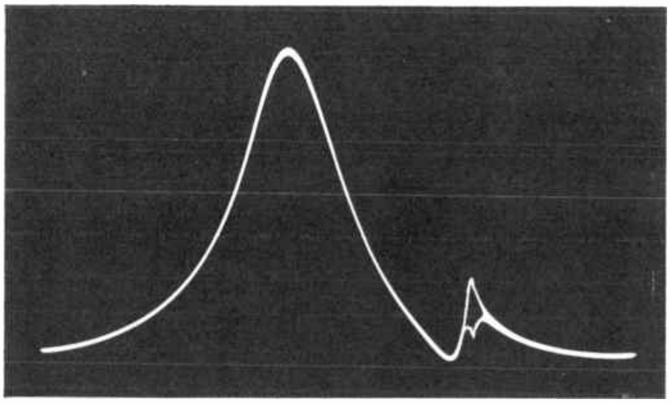

Fig. 13B.

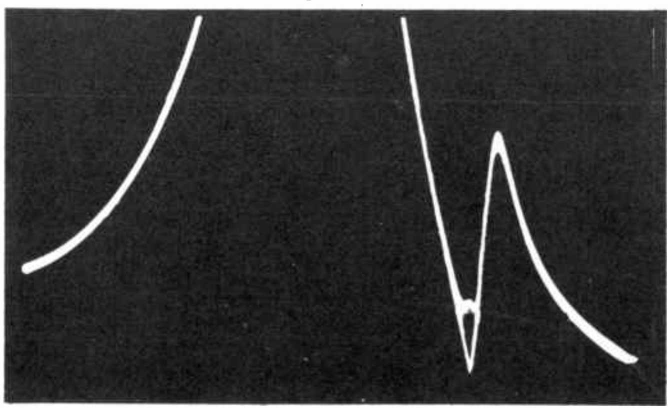

Fig. 13C.

Fig. 13. A marker pip is clearly visible on both sides of a trap dip, but may be difficult to see at the bottom of the dip.

As the tuning of the marker generator is varied to move the pip down one slope of the response toward the trap dip, as at A of Fig. 13, the pip will be clearly visible. But at and near the deepest part of the trap dip the marker pip becomes almost invisible, and trap frequency is difficult to determine. If the marker generator tuning is changed still farther in the same direction, the pip will reappear on the rise of the response which is beyond the trap dip, as at B.

A marker pip may be made more visible when at the bottom of a trap dip by increasing the vertical gain of the scope, or by increasing the output from the sweep generator, or by doing both. The result will be a trace such as at C of Fig. 13. Here the response curve has been made so high that its peak portions are cut off by the top of the CRT screen. The marker pip is quite distinct at the lowest point of the trap dip, and trap frequency may be determined accurately from frequency setting of the marker generator.

A trap is aligned or adjusted to a certain frequency in this manner.

1. Tune the marker generator to the desired trap frequency.

2. Adjust outputs of marker and sweep generators for the combination of outputs making the marker pip most clearly visible on the response curve. The best combination usually is that of high output from the marker and low output from the sweep. It may be desirable, as explained in connection with trace C of Fig. 13, to make the response trace so high as to throw part of it off the CRT screen in order to see the marker pip.

3. Adjust the trap until the deepest point of its dip is at the marker frequency identified by the pip on the response curve.

The effect of a trap having a wide range of adjustment may be made to appear almost anywhere on a response curve. At A of Fig. 14 a trap has been tuned to a frequency about half way up on the slope of a response, and at B has been tuned to a frequency at the top of the response. The effect of a trap becomes more pronounced, in appearance, as trap frequency is changed to points of greater and greater gain on the response. Deep dips and high, sharp peaks caused by badly misadjusted traps may be highly confusing during

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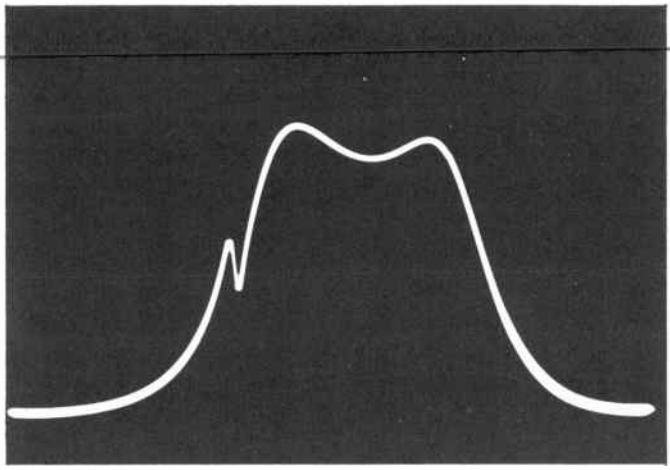

Fig. 14A.

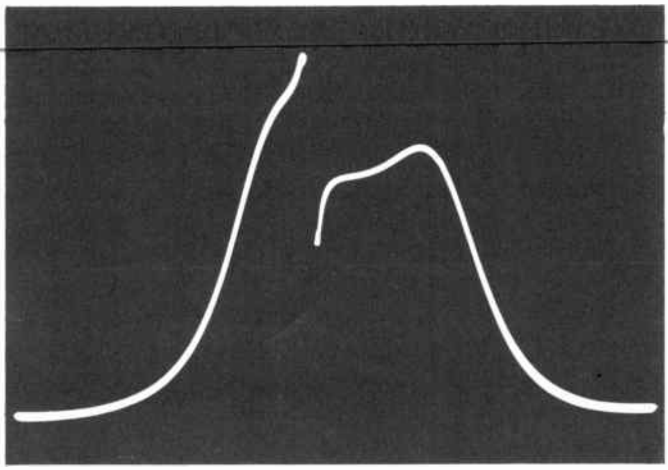

Fig. 14B.

Fig. 14. Tuning of a trap may move its effect to almost any point on the response.

alignment of coupling units. If both terminals of a trap windings are accessible, the trap may be made temporarily inactive by shorting its terminals together with a piece of wire.

When making a stage-by-stage alignment the dips due to various traps will show one after another on successive responses when the traps are in different stages of the i-f amplifier system. This is illustrated by Fig. 15. It is assumed, merely for illustration, that a trap for adjacent sound is between mixer and first i-f amplifier, that another

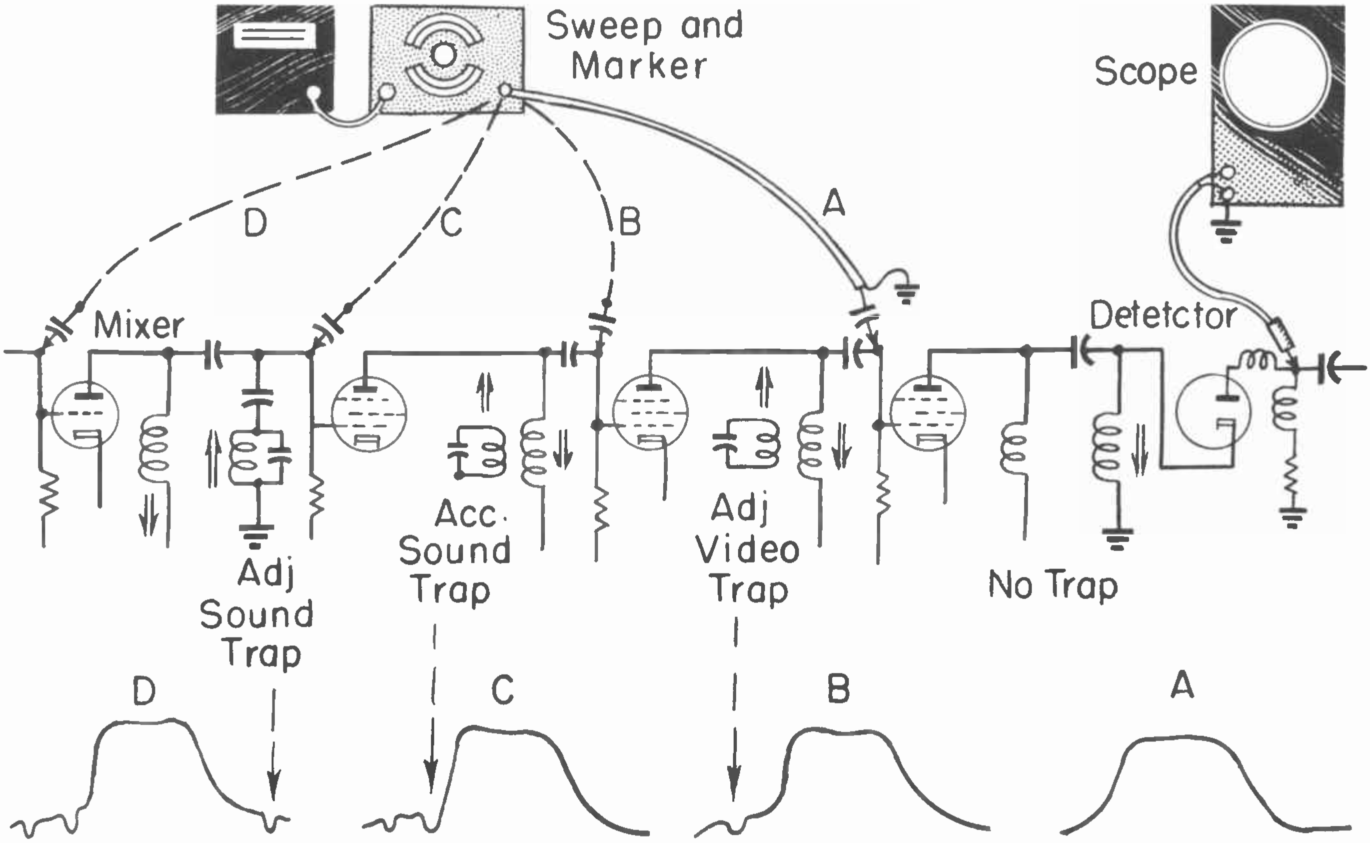

Fig. 15. Responses show effects of traps only when the traps are between the generator and oscilloscope connections.

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trap for accompanying sound is between first and second i-f amplifiers, and a third trap for adjacent video is between second and third i-f amplifiers. No trap is here used between the final i-f amplifier and the video detector.

With the generators connected to the grid of the final i-f amplifier, at A, the sweep signal passes through no trapped circuit and the response will show no dips due to trap effects. With the generator connection moved to the preceding grid, at B, the response will be affected by the trap for adjacent video frequency, and a dip should appear at this frequency on the response.

With the next generator connection, at C, the response still will show the dip due to the adjacent video trap and there will be an additional dip due to the accompanying sound trap, since both traps now are between the generator connection and the scope connection. With the generators at the mixer grid, D in the diagram, the response shows dips due all three traps, because all three are now between the sweep signal input and the scope.

Were the sweep and marker generators connected to the mixer grid, with the scope at the detector load, for all steps of alignment, the dips due to all traps would show or should show throughout the alignment process.

<u>VIDEO AMPLIFIER FREQUENCY RESPONSE.</u> Pictures which appear slightly blurred and lacking in fine details, even when focusing is correct, may result from poor frequency response in the video amplifier. This frequency response, from video detector to picture tube input, may be observed by using sweep and marker generators and an oscilloscope in much the same way as for observing the response of an i-f amplifier system, from mixer to video detector.

The method to be described requires a sweep generator capable of tuning to a center frequency of two to three megacycles, with sweep width of five to eight megacycles. The sweep output must be practically flat or uniform within the band of swept frequencies and should contain no harmonics of measurable strength. Sweep output voltage high enough for i-f alignment is ample for video amplifier tests. Sweep generators designed for alignment of f-m sound receivers seldom provide a great enough width of sweep for television video amplfier testing. The mark-

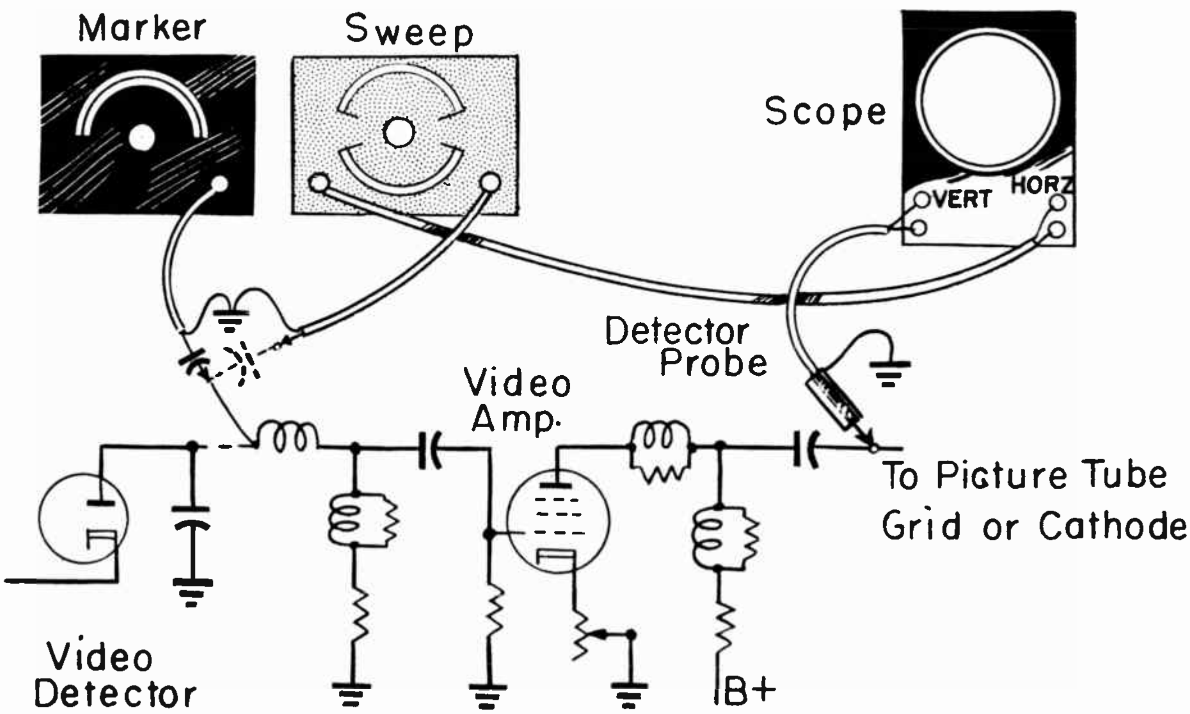

Fig. 16. The setup for observing frequency response of a video amplifier system.

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er generator may be any r-f signal generator of fair accuracy.

The instrument setup is illustrated by Fig. 16. Procedure for observing frequency response is as follows.

1. Sweep generator connection.

A. If the video detector is a tube type, remove this tube from its socket and connect the generator to the socket lug which is the detector output; it may be the lug for either a cathode or plate, depending on design.

B. If the video detector is a crystal type, not readily demountable, temporarily disconnect the lead indicated in the diagram and connect the generator to the free end of this lead.

C. When no bias voltage for the video amplifier tube is on the detector output, the high-side lead from the sweep generator may be connected directly to the socket lug or disconnected lead. If there is amplifier bias voltage on the detector, make this connection through a capacitor of about 0.01 mf.

D. The generator must be connected ahead of any peaker which is between the detector output and the video amplifier grid, and to the high side of any peaker in the line with the detector load resistor.

2. Marker generator connection. Connect the marker generator through a capacitor of 10 to 20 or more mmf to the same point as the sweep generator. Use no more capacitance than later found necessary for clearly visible marker pips.

3. Oscilloscope connections.

A. If possible, use synchronized sweep voltage at the horizontal input of the scope.

B. Connect the vertical input of the scope through a detector probe to the lead for picture tube grid or cathode, whichever of these elements is used for video signal input to the picture tube.

Note: The detector probe may be a germanium diode type as shown by Fig. 17. The diagram shows suitable values for probe capacitors and resistors. This probe need not be enclosed within a grounded shield, but its high side parts must be kept isolated by high-quality insulation from all metals and poor conductors, such as bench tops. The probe may be connected to the scope through a plain shielded cable containing no additional capacitors or resistors.

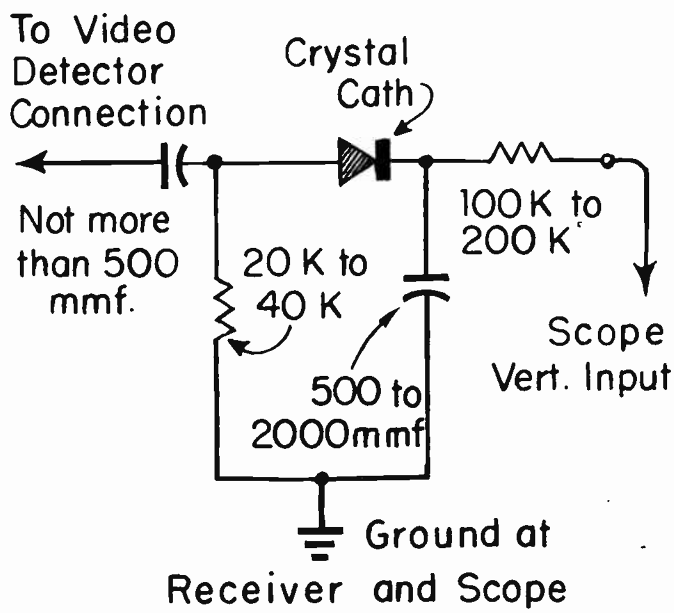

Fig. 17. Circuit of detector probe for checking video amplifier response.

4. Make the horizontal sweep system inactive to prevent a fuzzy response trace due to pickup of 15,750-cycle sweep voltage. This may be done by removing the horizontal oscillator tube from its socket.

5. Disable the vertical sweep system to prevent 60-cycle sweep voltage from causing the response trace to weave up and down, and from side to side. Removal of the vertical sweep oscillator from its socket is a satisfactory method.

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6. Set the receiver channel selector at a channel not in use locally. Adjust the contrast control as for normal picture reception. Adjust brightness for minimum.

7. Preliminary steps.

A. Adjust the sweep generator for a center frequency of 2 to 3 mc and for sweep width of about 5 mc. Place the output attenuator at half or more of maximum.

B. Tune the marker generator between 2 and 3 mc.

C. Adjust the scope for external horizontal input if synchronized sweep is used, or for 60-cycle internal sweep.

8. Turn on instruments and receiver, and let them warm up. A response trace somewhat similar to those of Fig. 18 should appear on the scope. Adjust sweep width and center frequency to bring onto the screen both ends of the response, where it comes down to zero gain, and to center the trace on the screen. Keep vertical gain of the scope at maximum and use the attenuator of the sweep generator to make the trace of height suitable for observation.

Varying the receiver contrast control will change the height and also the shape of the response curve when this control acts anywhere in the video amplifier system. With contrast set too low there will be no response curve. The trace at A of Fig. 18 was taken with the contrast control at a low setting, the one at B with contrast as for normal picture reception, and at C with a setting near maximum.

The short, flat base line at the low-frequency side of the response represents zero frequency. As frequency increases, the curve rises rapidly, and when there is correct peaker action, continues high through frequencies to three or more megacycles. At still higher frequencies the gain should drop and reach a low level not much beyond four megacycles.

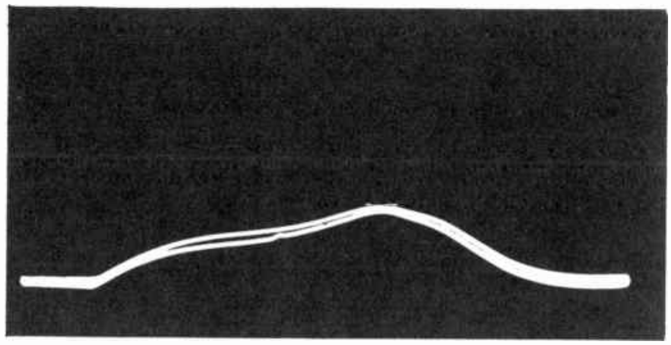

Fig. 18A.

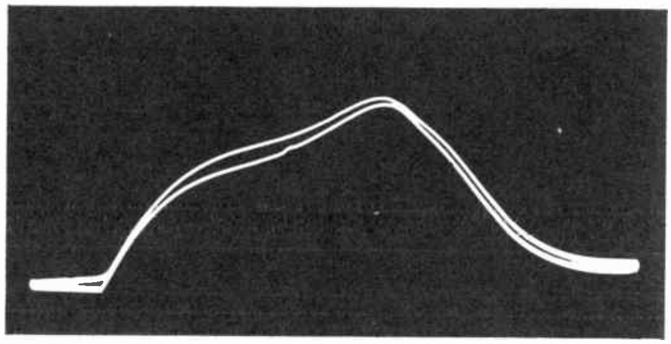

Fig. 18B.

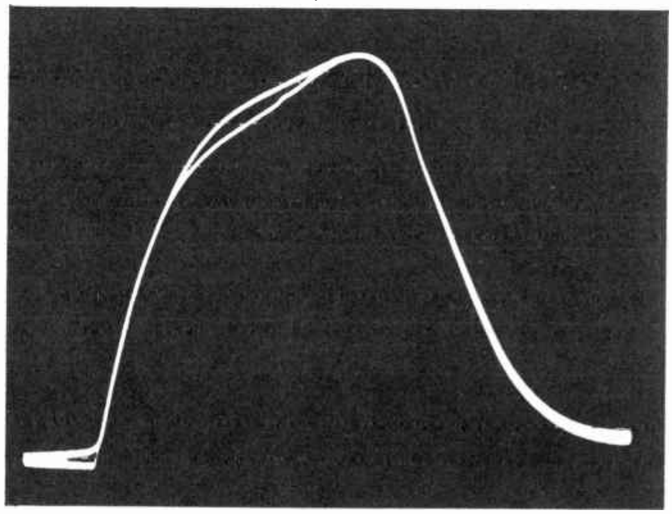

Fig. 18C.

Fig. 18. Video amplifier responses as affected by adjustment of contrast control.

Frequencies at various points on the response may be identified by marker pips and marker generator tuning, in the usual way. If the marker generator produces strong harmonics it may be set for something like one megacycle, whereupon pips will appear at intervals of one megacycle across the response trace.

Frequency distribution is fairly uniform all across the response, with each megacycle of frequency change covering about the same

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distance as every other megacycle. Since the total width of the curve takes in four to five million cycles it is impossible to note with any accuracy frequency differences, such as 50, 100, or 500 cycles. Consequently, this method of checking the video amplifier gives no useful information about its performance at very low frequencies, but does allow observing the effects of peakers, and the manner in which gain drops at three to five megacycles.

The functions of various peakers in the video amplifier system were explained in the lesson on "The Video Amplifier". That the peakers actually do perform according to theory is easily demonstrated while observing a frequency response. For example, a peaker in series with a plate load resistor or with a detector load resistor is supposed to maintain load impedance and amplification as frequencies increase. If we commence with a response as at A of Fig. 18, and short circuit a peaker coil which is in series with a load resistor, the change is shown at A of Fig. 19. High-frequency gain has all but disappeared.

You will recall that the purpose of a peaker between the output of one tube and the input of a following tube is to minimize the effects of tube and stray capacitances, and thereby to improve the gain. Shorting one of these peaking coils changes the response as at B of Fig. 19. Gain is down at all frequencies above the lowest, with greatest loss in the region of three to five megacycles.

In video amplifier systems there may be peakers of adjustable inductance at one or more positions. Increasing the inductance from about 200 to 320 microhenrys in a peaker which is in series with a load resistor caused the effect at C of Fig. 19. Inductive reactance and load impedance increase so greatly that a very high peak appears at a frequency a little lower than four megacycles. Of course, results would be the same when changing the values of fixed-inductance peakers.

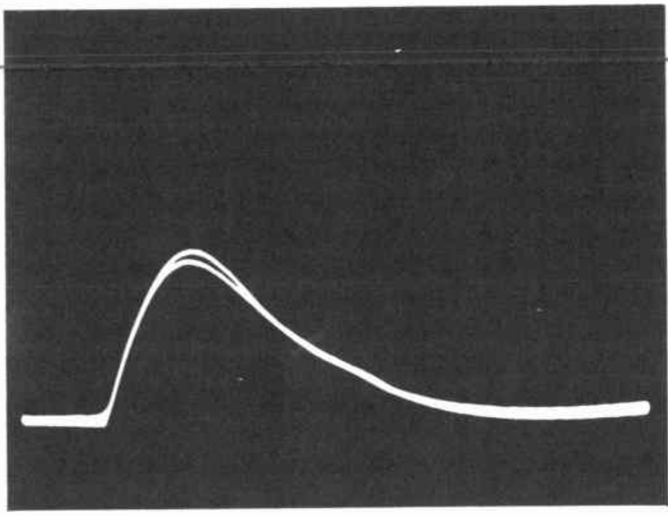

Fig. 19A.

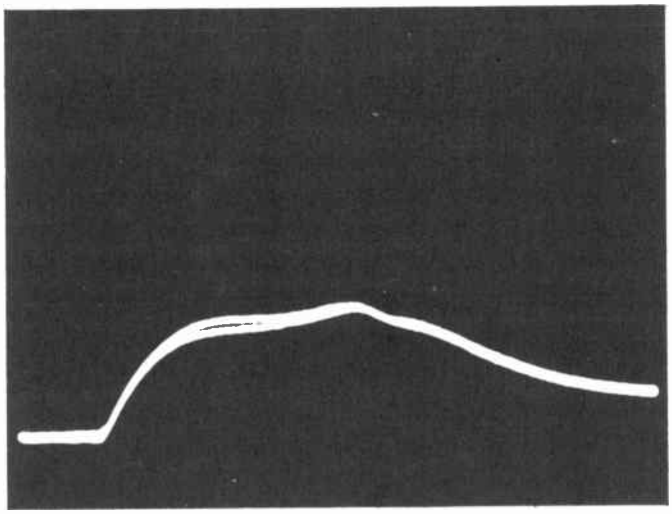

Fig. 19B.

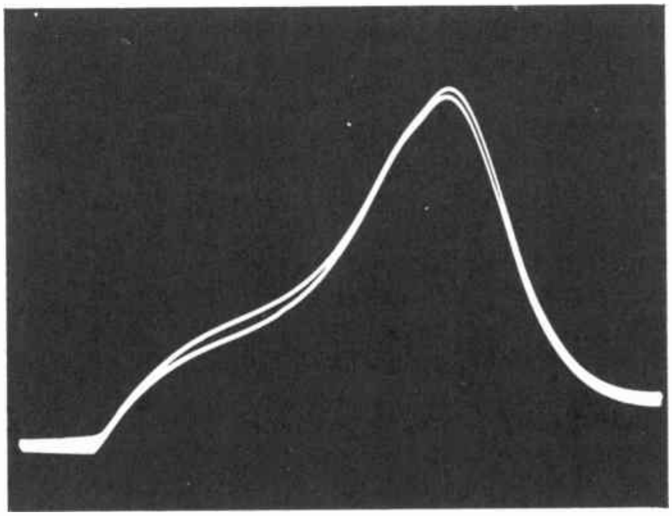

Fig. 19C.

Fig. 19. Effects of short circuiting peaker inductors in a video amplifier.

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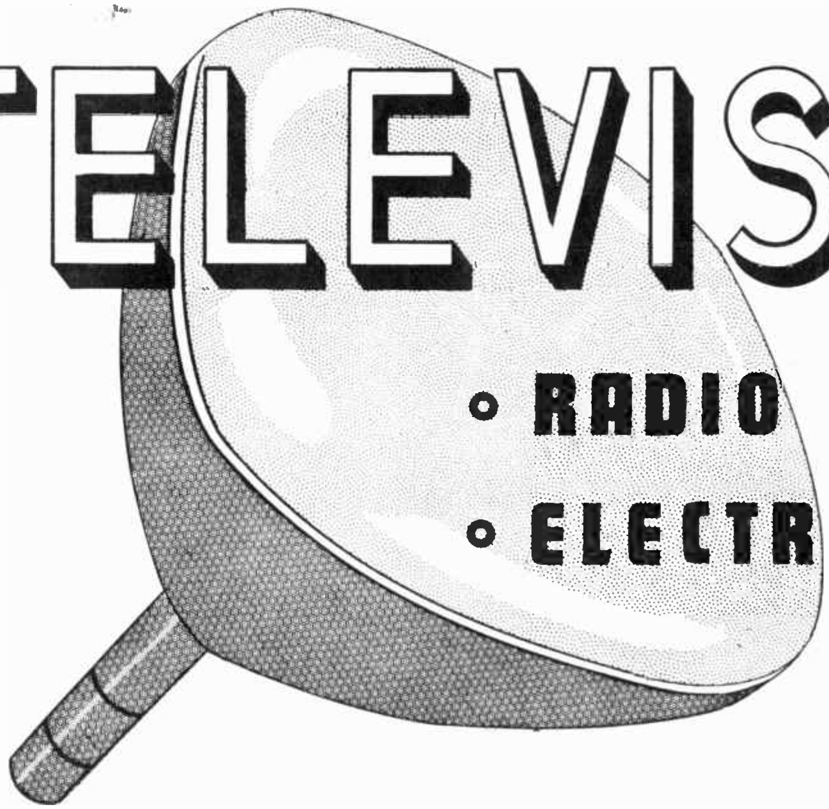
TELEVISION



• RADIO
• ELECTRONICS

LESSON 59 — FREQUENCY MODULATION

Coyne School

practical home training

Chicago, Illinois

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Lesson 59

FREQUENCY MODULATION

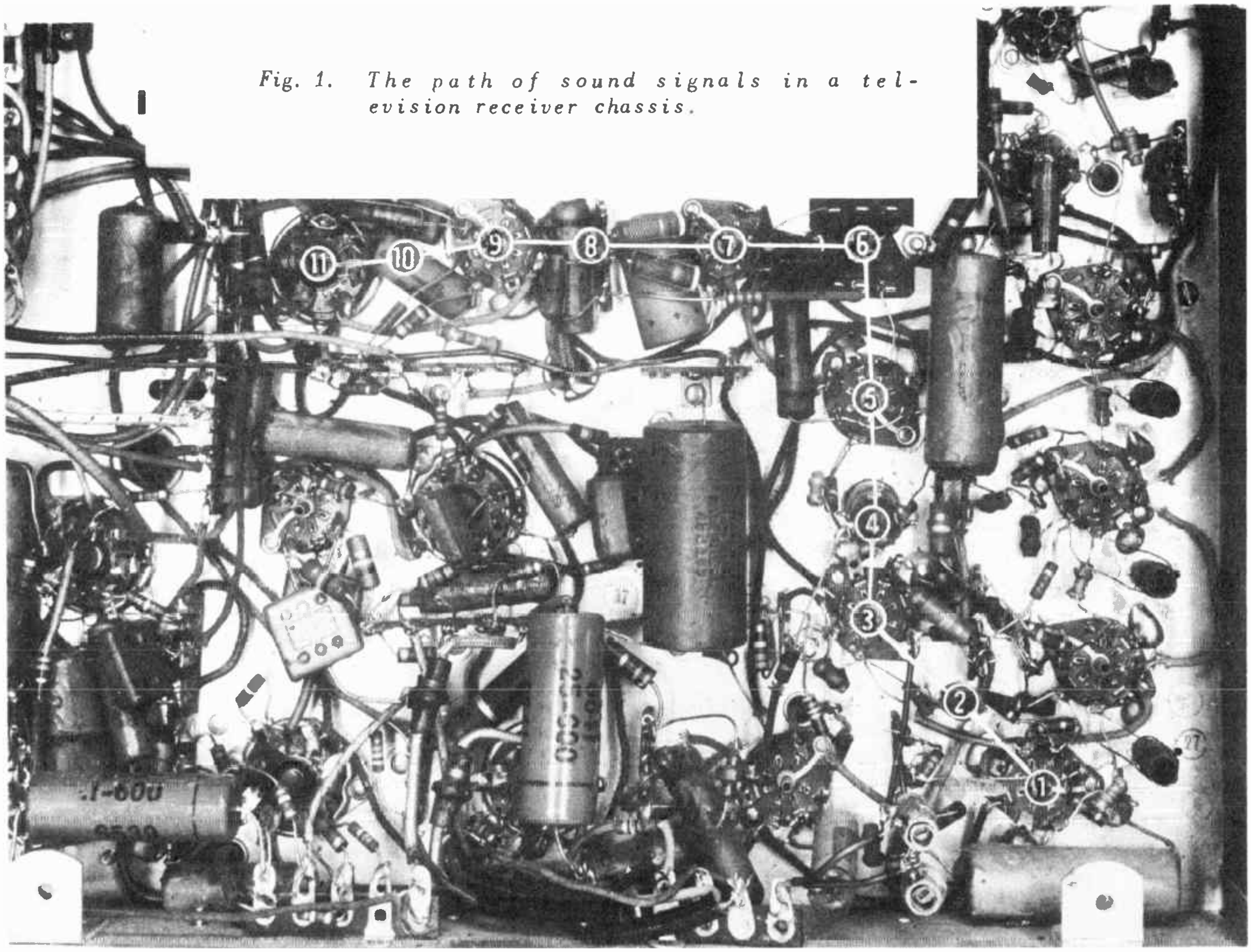

Fig. 1. The path of sound signals in a television receiver chassis.

Looking back at the earliest lessons you will see photographs and diagrams on which are traced the paths of video and sound signals. There are differences in layouts of parts, but in receivers of recent design the two signals always travel together at least as far as the video detector. At or beyond this detector, the video signal takes one path to the picture tube while the sound signal takes another path leading eventually to the speaker.

On Fig. 1, which is a view underneath a television receiver chassis, white lines trace the signal paths. Fig. 2 shows relative locations of parts which are along the white lines on the chassis photograph. Video and sound pass together through the i-f amplifier and to the video detector (1). A sound takeoff (2), similar to a transformer or coupler, removes sound signals from the detector output and passes them to the grid of the first sound amplifier (3). This tube is sometimes called a sound i-f amplifier.

From the plate of the first sound amplifier, signals go to and through a coupling transformer (4) to the sound limiter tube (5). The purpose of the limiter is to prevent strong pulses of noise voltage from going further through the sound section. Sound signals from the limiter go to the demodulator transformer (6), thence to the f-m demodulator or detector (7).

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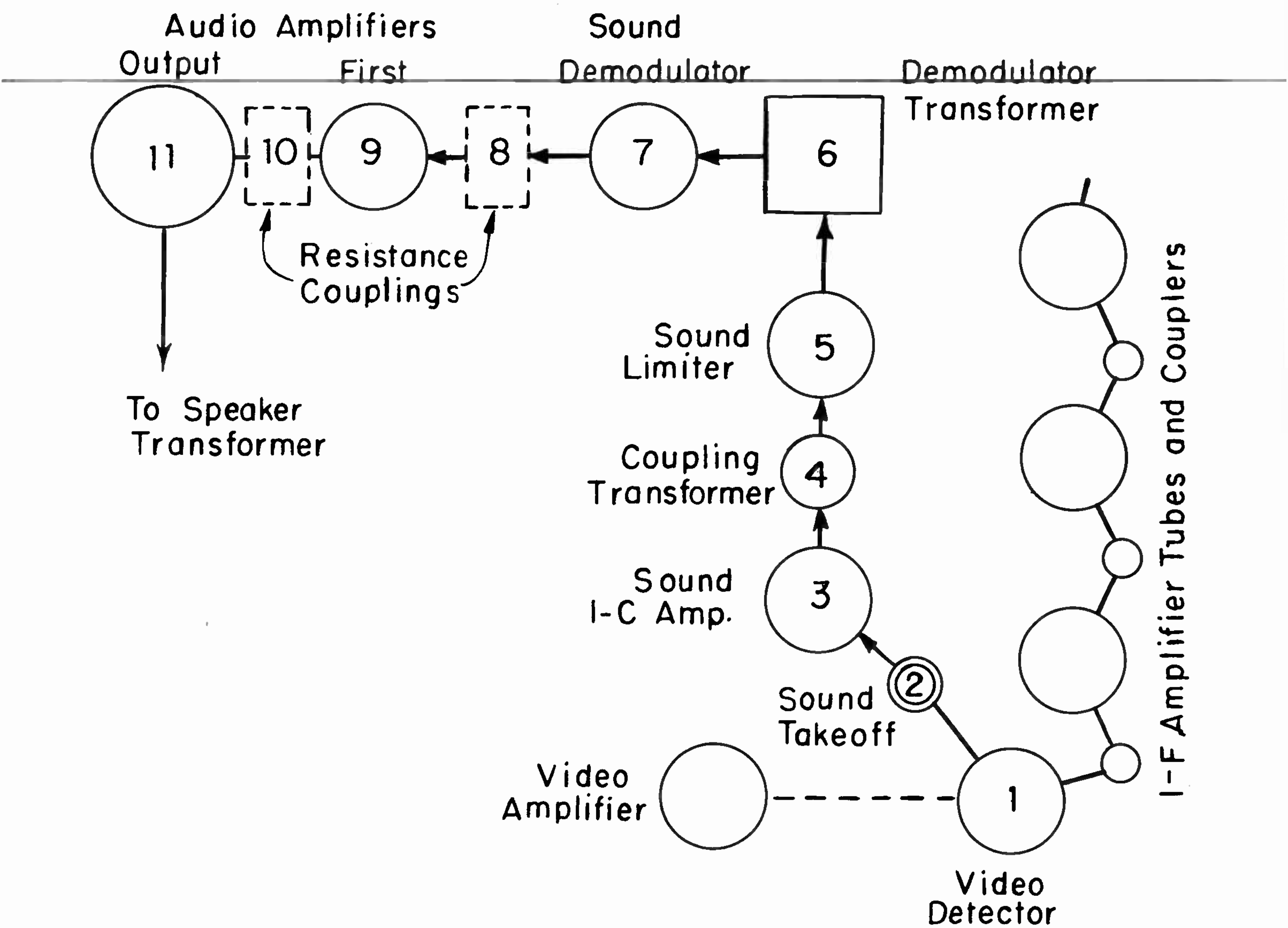

Fig. 2. These are the parts through which pass sound signals between video detector and speaker connection.

The f-m demodulator is entirely different in principle and performance from the simple diode detector for amplitude-modulated sound signals, with which we already are familiar. The television sound demodulator must be of different type because television sound is transmitted by frequency modulation (f-m), not by amplitude modulation (a-m). We shall learn about frequency modulation in this lesson.

At the output of the f-m sound demodulator is an audio signal voltage exactly like the audio signal from an a-m sound detector. This audio signal goes through a resistance coupling (8) to the grid of the first audio amplifier (9) and from the plate of this amplifier through another resistance coupling (10) to the grid of the audio output amplifier or power amplifier (11). The plate of the output amplifier is transformer coupled to the speaker.

INTERCARRIER BEATS AND FREQUENCY MODULATION. When sound signals travel from a transmitter to a receiver these signals ride a carrier wave. Although the carrier is an electromagnetic wave while in space, in the circuits of the transmitter and again in circuits of the receiver the carrier is merely an alternating voltage.

Any alternating voltage may be varied in two ways, in frequency and in amplitude. When transmission is by amplitude modulation, a process with which we are familiar,

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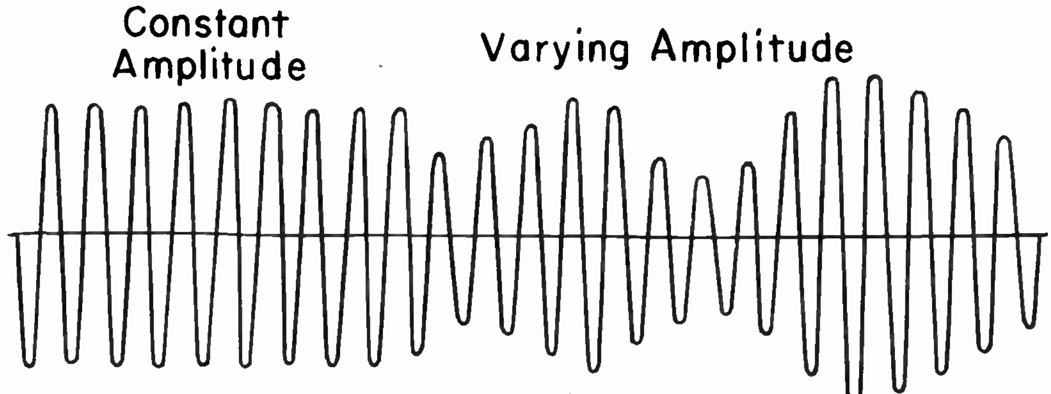

Fig. 3-A.

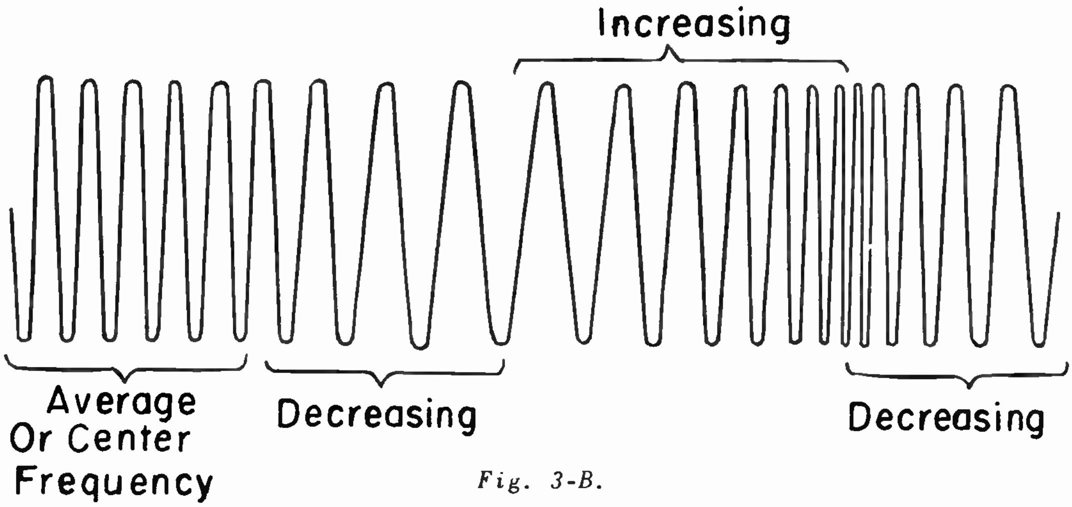

Fig. 3-B.

Fig. 3. Amplitude modulation of a constant-frequency signal, and frequency modulation of a constant-amplitude signal.

the carrier frequency remains constant at a value assigned for use by a certain transmitter or station. Earlier we learned how sound signals ride this constant-frequency carrier in the form of variations of carrier amplitude. Television video signals, for pictures and sync pulses, also are transmitted by amplitude modulation.

Amplitude modulation may be represented as at A of Fig. 3. Frequency modulation as used for television sound signals, may be represented as at B. With frequency modulation, carrier amplitude remains constant and is proportional only to carrier signal power. Television sound signals ride this constant-amplitude carrier in the form of frequency variations. Each station or transmitter sends sound signals on a center frequency or average frequency exactly 4.5 mc higher than the video carrier frequency of the same channel. Sound signals vary the sound carrier frequency above and below its average or center value.

So far as tuning and signal selection are concerned, any type of circuit which may be tuned to an amplitude-modulated carrier of certain frequency will tune to a frequency-modulated carrier. Any kind of amplifier which amplifies an amplitude-modulated carrier will amplify a frequency-modulated carrier equally well. What has been said about tuning and amplification of carrier applies also after the signals have been changed to intermediate frequencies.

The tuner of your television receiver selects, amplifies, and mixes f-m sound signals just as it handles a-m video signals. The two kinds of signals pass together through the entire tuner and out from the mixer. The signals remain independent of each other because they are at different frequencies, as becomes plain when we consider any television channel, number 5 for example.

In channel 5 the a-m video signals extend from 76.50 mc to not more than 81.25 mc.

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F-m sound signals for this channel are confined between 81.5 and 82.0 mc. The two kinds of signals remain separated in frequency as they become video intermediates and sound intermediates, and pass through the i-f amplifier to the video detector.

The video detector not only extracts picture and sync signals from the video intermediate. At the same time the video detector acts on video and sound intermediate frequencies just as the mixer in the tuner acts on r-f oscillator and carrier frequencies.

The video detector can act as a mixer because it is a rectifier which passes currents of one polarity more readily than in the other polarity, this being the feature which allows any mixer to produce beat frequencies.

In the case of the mixer which is part of the tuner, output video intermediate frequencies are differences between r-f oscillator frequency and video carrier frequencies. Because video carrier frequencies are amplitude modulated, the video intermediate has the same amplitude modulation. The sound intermediate from the mixer is the difference between r-f oscillator frequency and sound carrier frequency. Because the sound carrier is frequency modulated, the sound intermediate has the same frequency modulation.

The video intermediate entering the video detector is amplitude modulated, but is not varying in frequency. This video intermediate at the detector is of constant frequency, just as is the r-f oscillator frequency back at the mixer. The sound intermediate entering the video detector is frequency modulated, therefore the beat frequency from the detector is frequency modulated with sound signals. This beat frequency, modulated with sound, may be called the intercarrier frequency or the intercarrier beat.

In every transmitted television signal the center frequency of the f-m sound carrier is exactly 4.5 mc higher than the video carrier frequency. This separation of 4.5 mc exists also between video and sound intermediates. Then the intercarrier beat from the video detector, equal to the difference between video and sound intermediates, always must have a center frequency of precisely 4.5 mc.

No matter what channel is being received, and no matter what may be the particular intermediate frequencies used in the receiver, separation between video and sound never can be other than 4.5 mc, and the f-m intercarrier beat from the video detector always must have a center frequency of 4.5 mc. This f-m intercarrier sound signal is in addition to the demodulated video signal from the video detector. Video signals for the picture tube and sync section are the result of demodulation or detection in the video detector. The intercarrier beat for the sound section is the simultaneous result of beating or mixing action in the video detector.

FREQUENCY MODULATION AND AMPLITUDE MODULATION. Audio signals consist of alternating voltages and of currents caused by these voltages. As stated a few paragraphs back, any alternating voltage may be varied in two ways, in frequency and in amplitude. Audio signals are of various frequencies and various amplitudes.

To avoid possible confusion in using the words frequency and amplitude to describe three kinds of signals, carrier, i-f, and audio, we shall speak of audio signal frequency as pitch. Pitch, with reference to sound, means frequency. High pitch or a shrill sound results from high audio frequency. Low pitch, as in the voice of a bass singer, results from low audio frequency. Audio signal amplitude will be referred to as volume. Strong audio voltage, of high amplitude, causes loud volume. Low amplitude produces weak volume.

When a carrier frequency or intermediate frequency is amplitude modulated, loud volume for audio signals results from large variations of carrier or intermediate amplitude. To transmit high-pitched sounds the amplitude of an amplitude-modulated signal must vary at a rapid rate, at hundreds or thousands of times per second. For low-pitched sounds the amplitude need vary at only a relatively slow rate. This, of course, is only a review of what we learned in earlier lessons.

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LESSON 59 – FREQUENCY MODULATION

With frequency modulation there is constant amplitude of carrier and intermediate signal voltages; variations are only of frequency. For high-pitched sounds the frequency must vary rapidly above and below the center frequency, at a rate of hundreds or thousands of times per second. For low-pitched sounds the frequency need vary only slowly. The rate of frequency variation, in number of times per second, is called the modulation frequency of an f-m signal.

Sound volume in a frequency-modulated signal depends on how great is the change of frequency with reference to the center frequency. If frequency varies 20 kilocycles above and below the center frequency, sound volume will be twice as strong as with variation of only 10 kilocycles above and below the center frequency.

Variation of frequency in one direction from the center frequency is called deviation in an f-m signal. If frequency varies 15 kc above and 15 kc below the center frequency, deviation is 15 kc. It is deviation of an f-m signal that causes sound volume. When there is to be no sound, or zero volume, there is no deviation and the f-m signal remains at its center frequency.

Maximum deviation in television sound signals is 25 kc. That is, for loudest sounds or maximum volume the f-m signal deviates to only 25 kc, to 25 kc above and 25 kc below the center frequency. This is a total variation, between highest and lowest signal frequencies, of 50 kc or 0.05 mc.

In an -fm sound signal there may be any combinations of deviation and of modulation frequency. This is the same as saying that there may be any combinations of sound volume and pitch in the modulation of f-m carrier and i-f signals.

In our work of servicing, the most important difference between amplitude modulation and frequency modulation is in the detector or demodulator which separates the

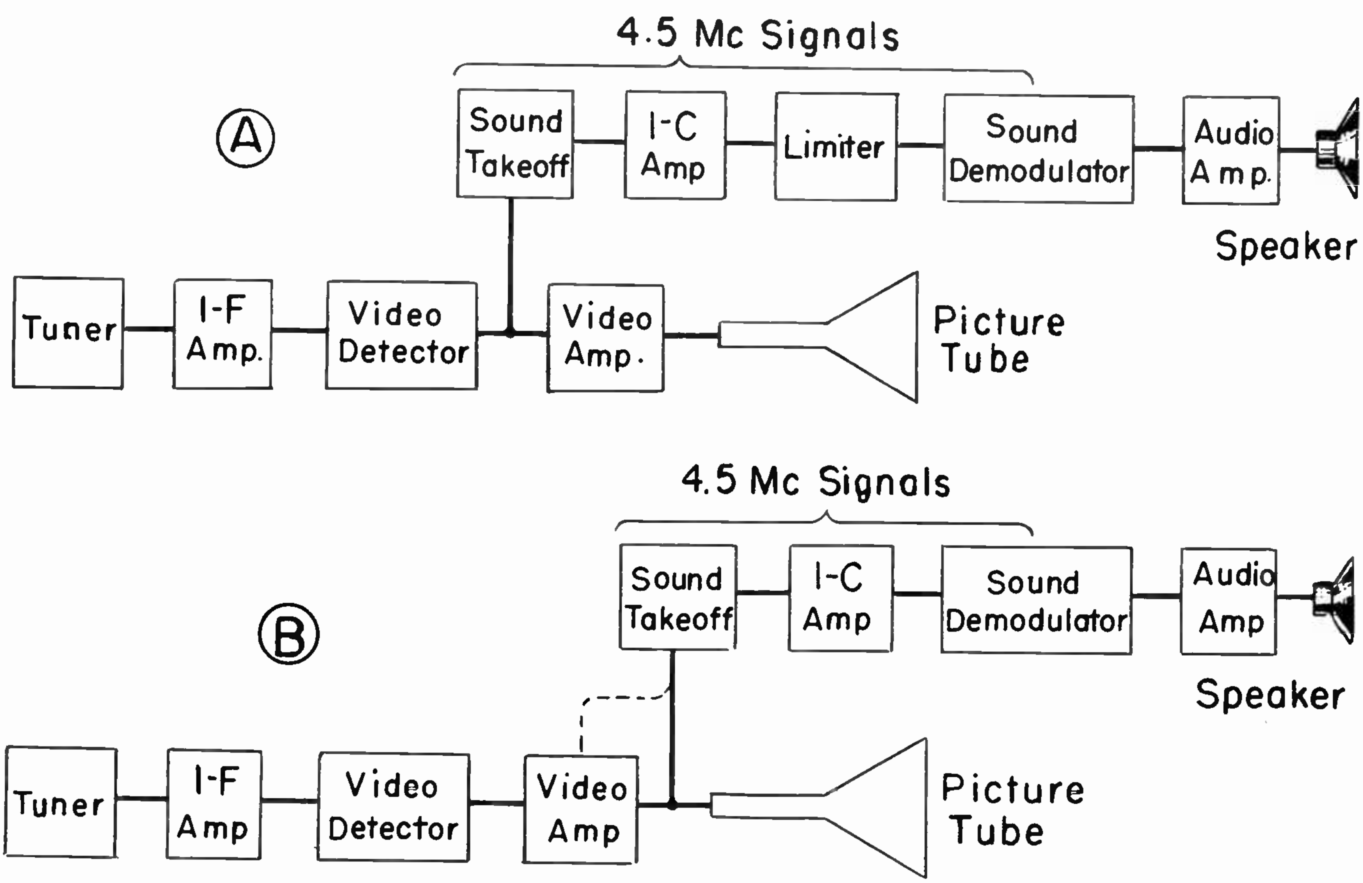

Fig. 4. An intercarrier sound system with takeoff from the video detector, and another with takeoff from a video amplifier.

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audio signals from the modulated intercarrier voltages. For f-m signals we must have a type of detector which changes variations of frequency into corresponding sound signal voltages. Such an f-m demodulator is quite different in principle and action from a detector for amplitude modulation, which changes variations of i-f amplitude to corresponding audio voltages in standard broadcast sets and to video and sync signals in television sets.

TELEVISION SOUND SYSTEMS. F-m demodulators and other elements of television sound systems are found in various arrangements. The sound system illustrated by Figs. 1 and 2 is shown by a block diagram at A of Fig. 4. The 4.5-mc intercarrier sound signal is taken from the output of the video detector. There is a limiter just ahead of the sound demodulator.

Earlier intercarrier sound systems, as well as many in current receivers, have the elements arranged as at B. The 4.5-mc sound signal is not taken from the output of the video detector, but from some point following a video amplifier. With only one video amplifier tube this sound takeoff is connected between the amplifier output and the input to the picture tube. Where there are two video amplifier tubes, sound may be taken from the output of either one. Note also that no limiter tube precedes the sound demodulator.

The first television receivers for home use, many which appeared before 1953, did not employ intercarrier sound. Instead, they used the dual or split sound system of Fig. 5. Sound takeoff is at the mixer output, or sometimes from the output of a first or even a second i-f amplifier. Because sound signals are taken from ahead of the video detector they are at the sound intermediate frequency, they have not been changed to the intercarrier frequency. Sound amplification all the way to the sound demodulator is at the sound intermediate frequency used in the receiver. A limiter precedes the sound demodulator.

TAKEOFFS AND SOUND TRAPS. Before examining the several types of limiters and f-m demodulators in general use we shall look at a few representative sound takeoff circuits. There are connections between the video detector or a video amplifier and the first tube in the sound section.

In Fig. 6 the sound takeoff is through a two-winding transformer tuned to 4.5 mc by a single slug. The transformer primary is in series on the line from video detector output to the grid of the video amplifier. The secondary is in the grid-cathode circuit of the intercarrier sound amplifier. Following this amplifier is a limiter tube operated, as mentioned before, to reduce the effects of strong noise pulse voltages and keep them from the f-m demodulator.

Coupling between intercarrier amplifier and limiter tubes is a transformer with separately tuned primary and secondary. The limiter grid is negatively biased by the grid-leak method, utilizing resistor Rg and

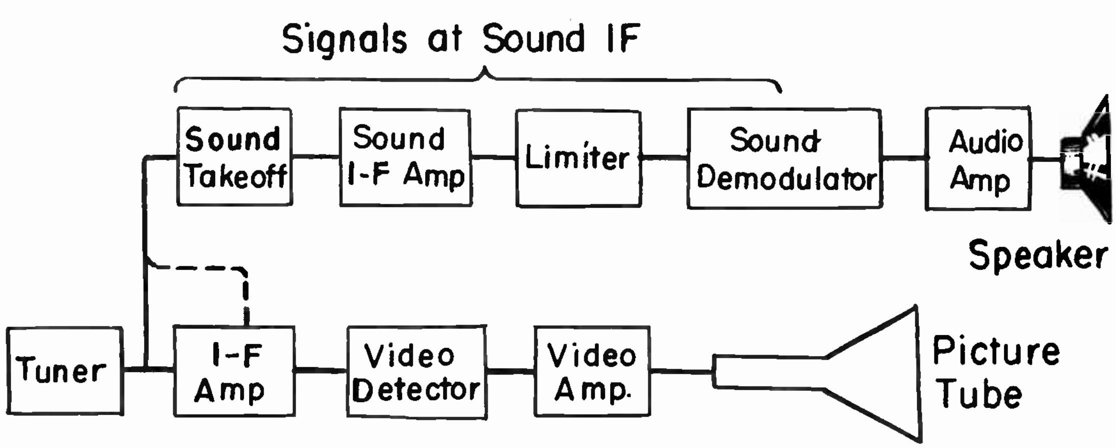

Fig. 5. For a dual sound system the takeoff is from the output of the mixer.

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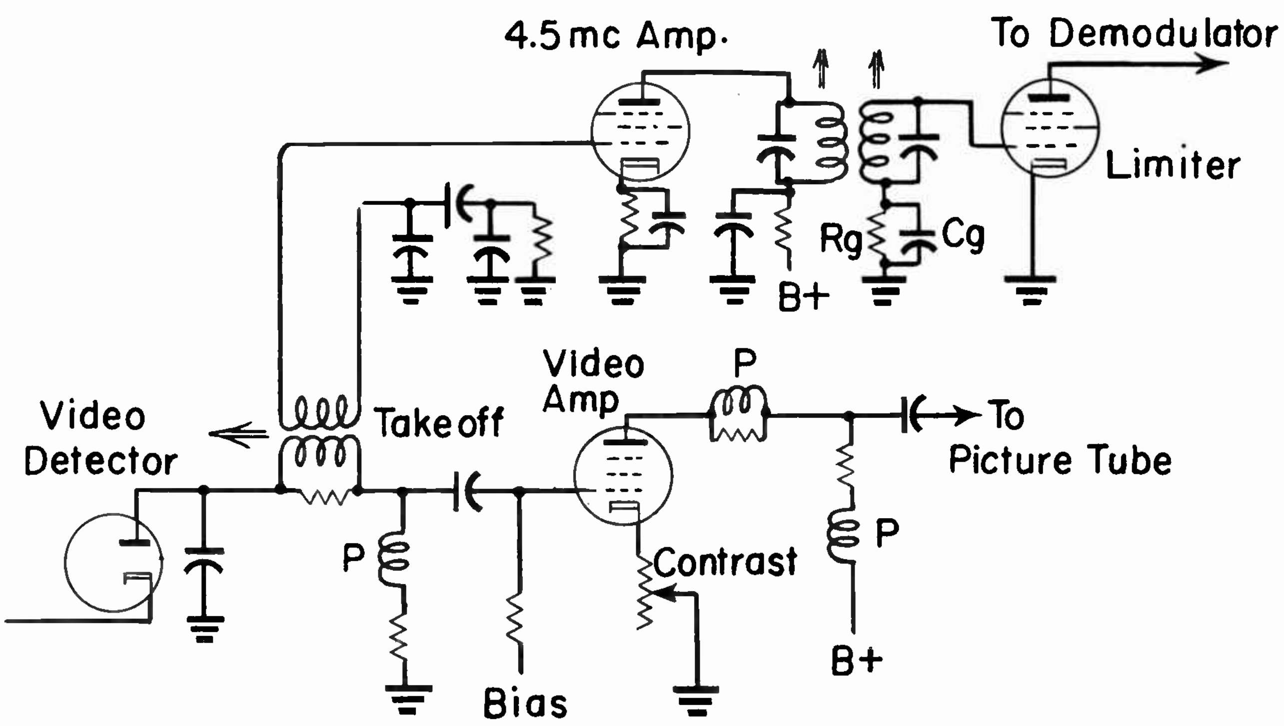

Fig. 6. A tuned sound takeoff coupling in the video detector output.

capacitor Cg connected from the bottom of the transformer secondary to ground and thence to the cathode of the tube. The 4.5-mc intercarrier sound amplifier is cathode biased.

The tuned takeoff transformer removes most of the 4.5-mc sound signal voltage from the input of the video amplifier, so that this signal does not get into pictures too strongly. Peakers which help to shape video amplifier

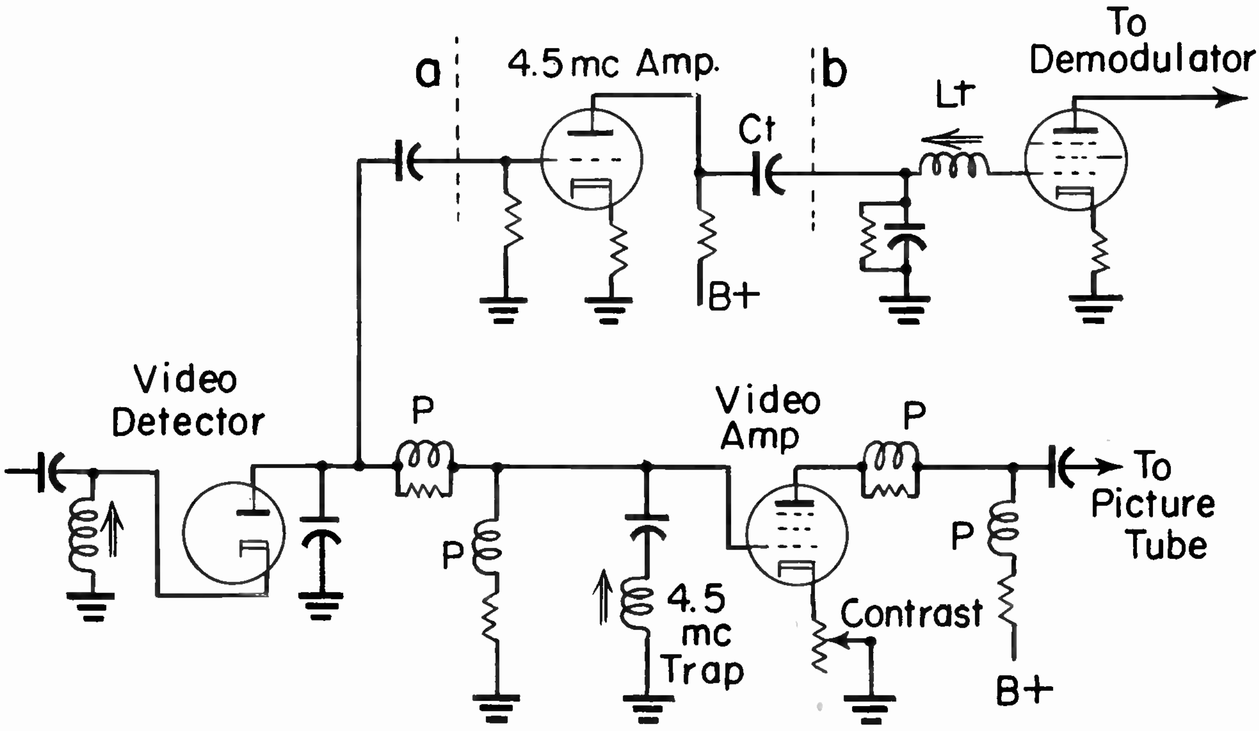

Fig. 7. An untuned sound takeoff connection from a video detector output.

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response are marked P. The sound takeoff precedes the contrast control. As a result, varying the contrast affects pictures but does not affect strength of the sound signal going from video detector to the sound section.

In Fig. 7 the sound takeoff again is from the output of the video detector, but now is through an untuned connection to the grid of the first 4.5-mc intercarrier amplifier. The only tuning in the portion of the sound section shown here is at Lt. This adjustable inductor, with capacitor Ct, forms a series resonant circuit between the plate of the first 4.5-mc amplifier and the grid of the second amplifier.

The second sound amplifier in Fig. 7 is not operated as a limiter. The difference between an amplifier and a limiter is not in the kind of tube used, but in the combination of plate, screen, and grid bias voltages applied to the tube. We shall learn more about limiters very shortly. One of the 4.5-mc amplifier stages might be omitted, by taking out everything between broken lines a and b.

The usual peakers, marked P, are in the output circuits of video detector and video amplifier. Note that the sound takeoff again is ahead of the contrast control, which is on the cathode of the video amplifier. Of special interest in this circuit is the 4.5-mc trap connected between the video amplifier grid and ground, but separated from the sound takeoff by one of the peakers. This trap is a series resonant. The 4.5-mc voltages, which might pass into and be amplified by the video amplifier, are shorted to ground through the trap, thus avoiding an annoying "crosshatch" effect in pictures. We shall have more to say about intercarrier sound traps a little later in this lesson.

In Fig. 8 is another untuned sound takeoff from video detector output to grid of the first 4.5-mc amplifier. The video detector is shown here as a crystal diode type. Whether the video detector is a tube or a crystal diode has no particular bearing on circuits following this element.

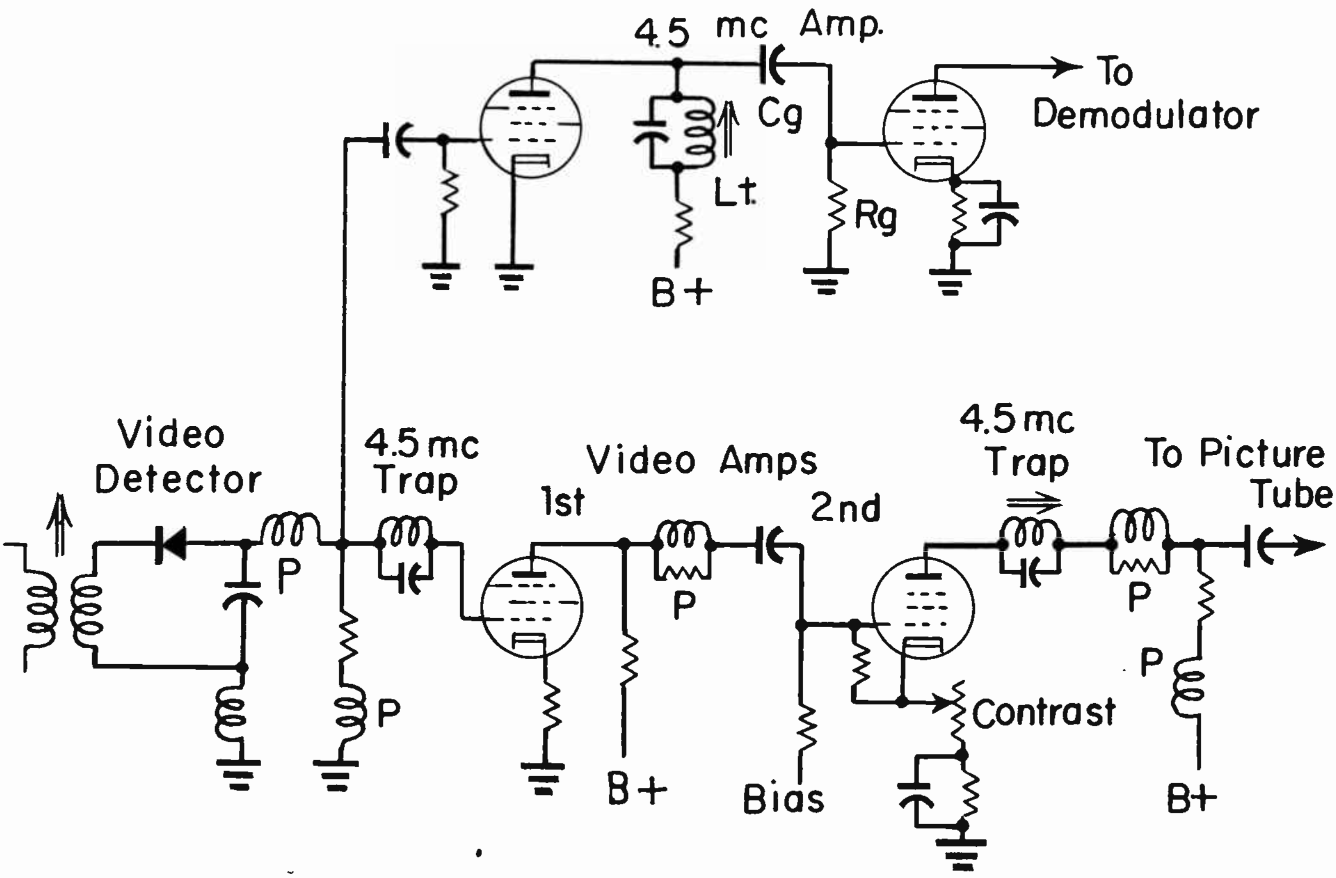

Fig. 8. In this circuit is an untuned 4.5-mc trap and another one adjustably tuned.

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The tuned coupling Lt between the two sound amplifiers is a single-winding type which acts much like single-winding couplers in i-f amplifier stages. Part of the grid bias for the second sound amplifier is secured from a grid-leak arrangement, utilizing resistor Rg and capacitor Cg. This bias, which varies with signal amplitude, provides a certain amount of limiting ahead of the demodulator.

There are two video amplifier stages, in which are peakers marked P. There are two 4.5-mc traps, one at the grid connection of the first video amplifier and another at the output of the second video amplifier, in the lead to the picture tube. Both traps are of the parallel resonant type which, connected in series with any circuit, offers maximum impedance to voltages and currents at the frequency for which the trap is resonant. Inductance and capacitance in the first trap are inherently resonant at 4.5 mc. There is no tuning adjustment. The second trap has an adjustable slug for precise tuning to the intercarrier frequency.

In Fig. 9 only one 4.5-mc sound amplifier is ahead of the demodulator. A single amplifier often is called a driver. Sound takeoff is not from the video detector, but from the output of the first video amplifier. Thus the gain of this amplifier acts on sound signals before they go to the driver. The sound takeoff is adjustably tuned at Lt by a single-winding coupler constructed much like similar couplers in i-f amplifiers. The small capacitor connected across the coupler winding allows resonance at 4.5 mc without many more coil turns than in couplers used at higher frequencies without a capacitor.

All of the usual series and shunt peakers, marked P, are in the output circuits of the video detector and the two video amplifiers. In the output of the second video amplifier, on the line to the picture tube, is a parallel resonant trap tuned by an adjustable slug to the 4.5-mc intercarrier frequency.

Circuits of Fig. 10 are quite similar to those of Fig. 9 except for having only a single video amplifier tube. Since there is also only a single driver ahead of the demodulator, the sound takeoff is from the video amplifier output rather than from the video detector. The takeoff is tuned at Lt by a single-winding coupler with enough turns and distributed capacitance for resonance at 4.5 mc.

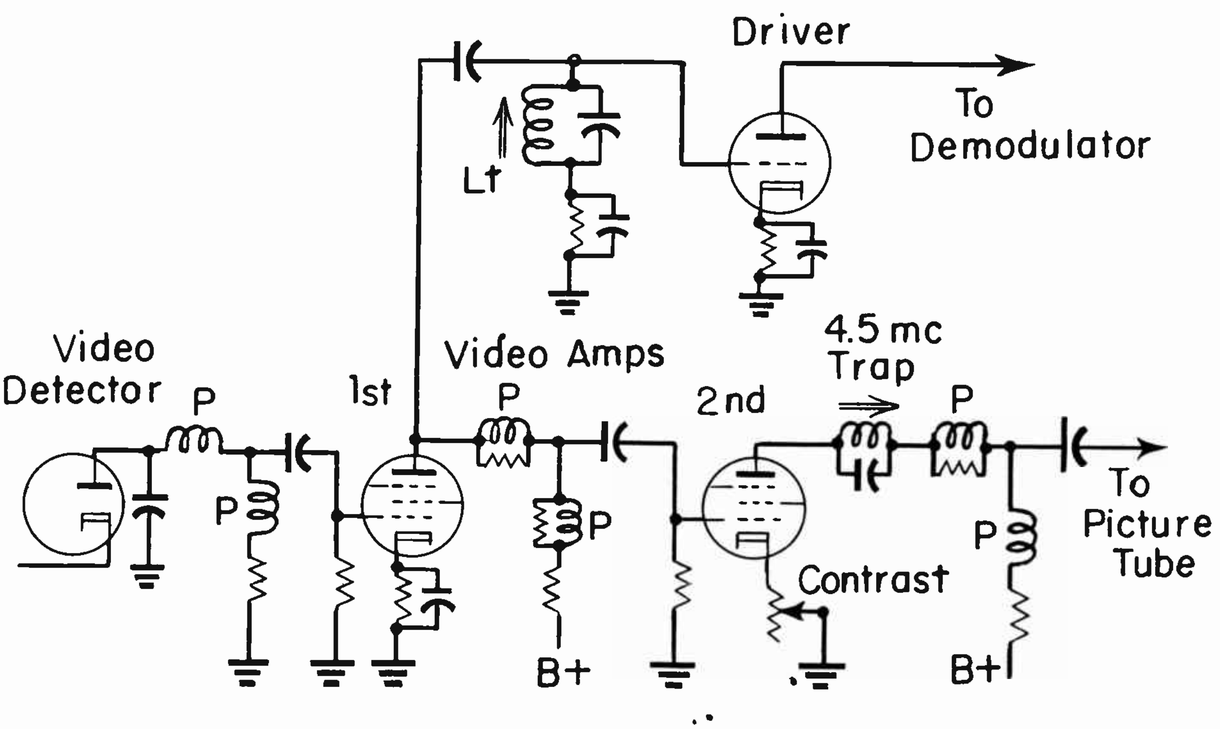

Fig. 9. A single sound amplifier or driver is between takeoff and demodulator.

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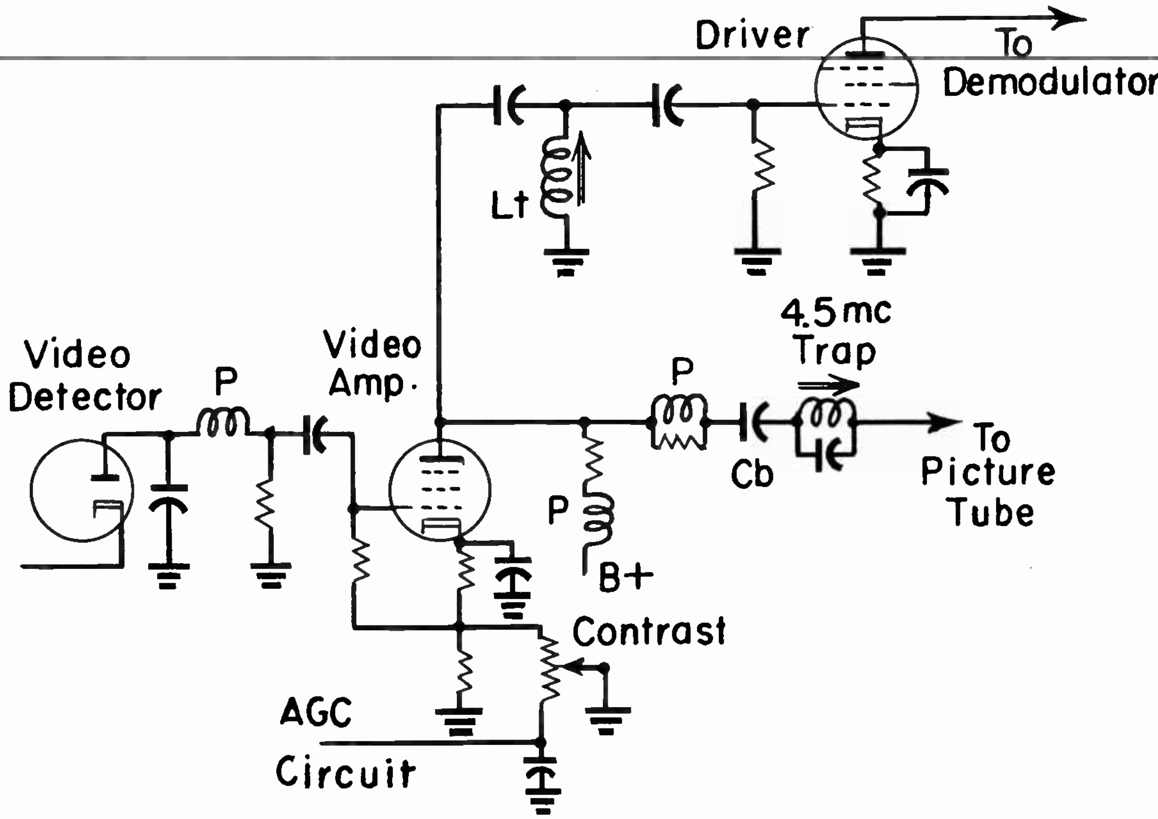

Fig. 10. The 4.5-mc trap must be between the sound takeoff and picture tube.

In the line to the picture tube grid-cathode circuit is a 4.5-mc trap. This trap is beyond the peaker and also beyond blocking capacitor Cb. Note, in Figs. 9 and 10, that sound takeoffs are ahead of contrast controls. This is common practice, since f-m signals to the sound section thus are unaffected in strength by settings of the contrast control for picture quality. Note also that sound takeoffs always are ahead of any and all 4.5-mc traps, for beyond these traps there should be little or no f-m sound signal voltage.

NEED FOR 4.5 MC TRAPS. When a 4.5-mc voltage reaches the grid-cathode circuit of the picture tube it varies the voltage on the picture tube grid just as would a picture signal of this frequency, were picture signals to go so high in frequency. As a result, every horizontal trace in pictures is varied in intensity and becomes alternately light and dark independently of picture variations. With 4,500,000 variations (4.5 mc) per second, and horizontal traces at the rate of 15,750 per second, there will be about 285 light-to-dark variations along each horizontal trace.

If 4.5-mc variations happen to be at the same points along all horizontal traces, the overall effect is a great number of narrow vertical lines on the screen of the picture tube. Slight changes of horizontal sync and beat frequencies cause these lines to tilt one way or the other, and to weave back and forth.

On receivers employing intercarrier sound, and having no 4.5-mc trap, the beat effect is likely to show unless the sound takeoff is through a two-winding transformer (Fig. 7) of fairly high-Q design. Such transformers may act as effective 4.5-mc traps as well as takeoffs. The beat effect will appear also on receivers using dual sound when traps for accompanying sound, in the i-f amplifier system, are not correctly aligned.

The 4.5-mc beat effect in pictures is not due to audio signal voltages reaching the picture tube, for such voltages cause horizontal bars which are alternately light and dark. The 4.5-mc beat effect is due solely to the intercarrier frequency reaching the pic-

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ture tube, and appears whether or not a 4.5-mc beat voltage is modulated. The 4.5-mc trap cannot prevent sound bars due to audio voltages, but it can prevent the narrow vertical lines and the pepper-and-salt effect in pictures.

LIMITERS. The purpose of a limiter is to prevent sound signal voltages in excess of some certain amplitude from reaching the f-m demodulator, while passing without change the variations of frequency which represent audio signals in f-m circuits. The 4.5-mc sound signal, which should be of varying frequency but constant amplitude, may pick up variations of amplitude from noise voltages, various kinds of interference, hum voltage in B-supplies, sync pulses of the video signal, and other causes. A limiter removes these amplitude variations or reduces them to relatively low value.

Tubes operated as limiters are used not only in sound systems of television receivers, but also in f-m broadcast receivers. The principle of amplitude limiting is employed also in the sync sections of television receivers, for noise reduction in various amplifier circuits, and for other purposes. It is a highly important principle. You should give close attention to following explanations.

An f-m signal voltage which has been amplitude modulated may be thought of as at the left in Fig. 11. A perfect limiter would cut off all amplitude modulation and pass all frequency modulation, as at the right. Some types of f-m demodulators are only slightly responsive to amplitude modulation. They may be preceded by partial limiting or by no limiting at all. Other f-m demodulators are almost as responsive to amplitude modulation as to frequency modulation. They must be preceded by one or more limiters.

There are numerous ways of causing limiting action in a tube. The action called plate current saturation results from applying very low plate voltage to a triode or very low screen voltage to a pentode. These are the voltages which determine the rate of electron emission in a tube.

The result of plate current saturation is illustrated by Fig. 12. These traces show plate current in the plate load resistor of a pentode. Plate voltage is 100. Plate voltage in a pentode has little effect on electron emission. Screen voltage is only 6. Grid bias is zero. With about 0.1 r-m-s volt of sine-wave form on the grid the output is a sine wave, as at A. There is no limiting as yet.

Increasing the grid input to 1 r-m-s volt causes plate current to change as at B. Negative alternations of input voltage make the grid so negative, with reference to the cathode, as to cut off the plate current. This is evidenced by flattening at the bottoms of plate current alternations. Positive swings of grid voltage are amplified.

With grid input increased to 2 volts r-m-s, plate current becomes as at C. We still have the negative cutoffs, but now the

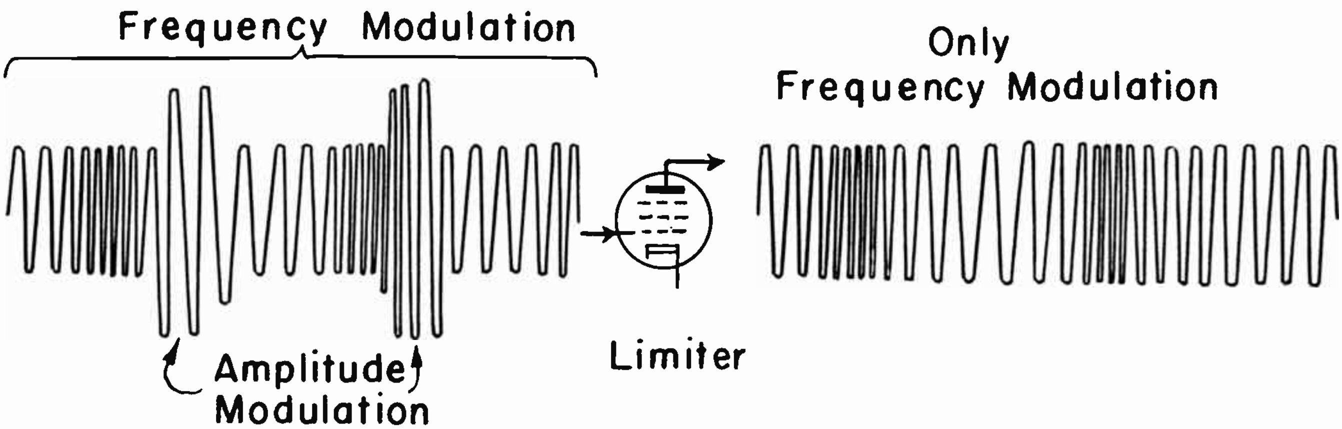

Fig. 11. A limiter removes pulses of amplitude modulation from a frequency-modulated signal without affecting variations of frequency.

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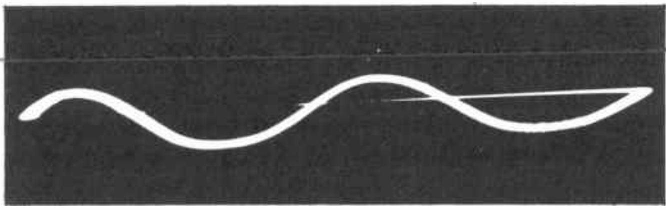

Fig. 12-A.

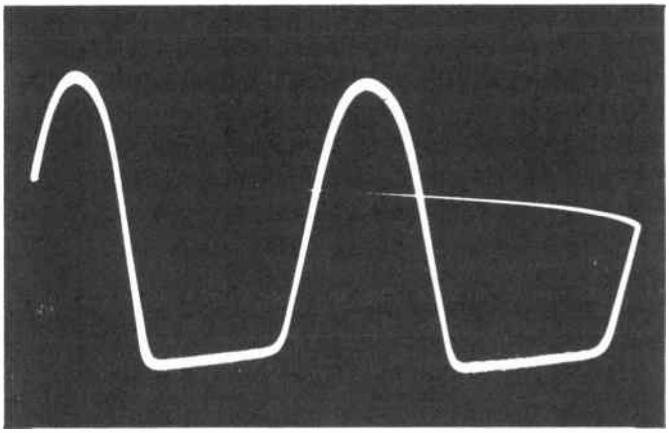

Fig. 12-B.

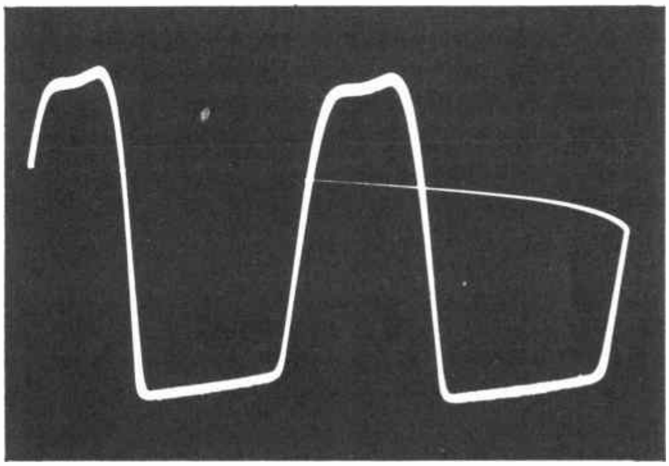

Fig. 12-C.

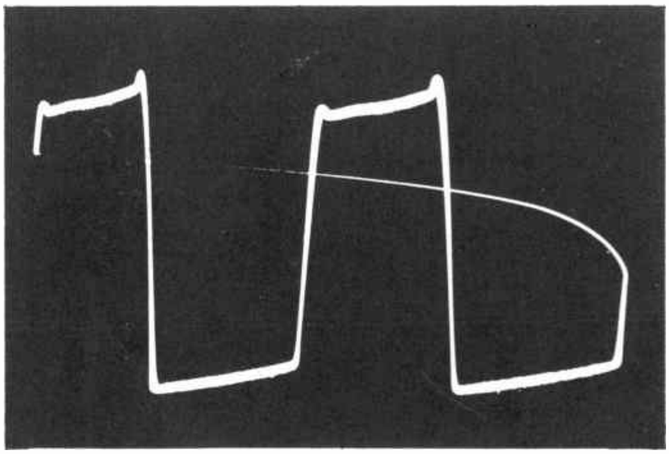

Fig. 12-D.

Fig. 12. Action in a limiter employing the principle of plate current saturation.

positive current alternations commence to ~~flatten. This is due to low screen voltage.~~ Plate current cannot increase beyond the value corresponding to the small electron flow pulled from the cathode by the very weak screen voltage. When screen voltage is pulling all the electrons of which it is capable, plate current can increase no more regardless of how positive the grid may become.

When grid signal voltage is increased to 5 volts r-m-s, the plate current curve has the form at D. Note that peak-to-peak swings of plate current are no greater than at C, because the small screen voltage can pull no more electrons under any conditions. Once the grid input voltage rises to a value causing limiting as at C, amplitude of plate current and voltage can increase no further. Should grid signal voltage become amplitude modulated to higher values, as at the left in Fig. 11, the excess amplitude modulation is cut off and cannot appear in the plate circuit of the limiter. This is complete limiting.

Partial limiting may be accomplished by using grid-leak bias for the limiter tube. When signal input to the limiter is from a two-winding transformer, as at A of Fig. 13, biasing capacitor Cg and biasing resistor Rg usually are between the low side of the secondary and ground or the tube cathode. When input to the limiter is from a single-winding coupler, as at B, grid biasing capacitor Cg is used also as a blocking capacitor to protect the limiter grid from positive plate voltage on the preceding tube. Biasing resistor Rg then is between the limiter grid and ground or the cathode. Limiting action is essentially the same with either of these grid biasing methods.

With grid-leak bias, very weak signal voltages on the limiter grid cause no limiting action. Sine-wave input causes moderately amplified sine-wave output, just as at A of Fig. 11. The remainder of the action with grid-leak bias is shown by Fig. 14. For these traces, from a pentode tube, plate voltage again is 100, but screen voltage has been raised to 30. Negative grid bias voltage varies proportionately to grid input voltage as is true whenever grid-leak bias is employed.

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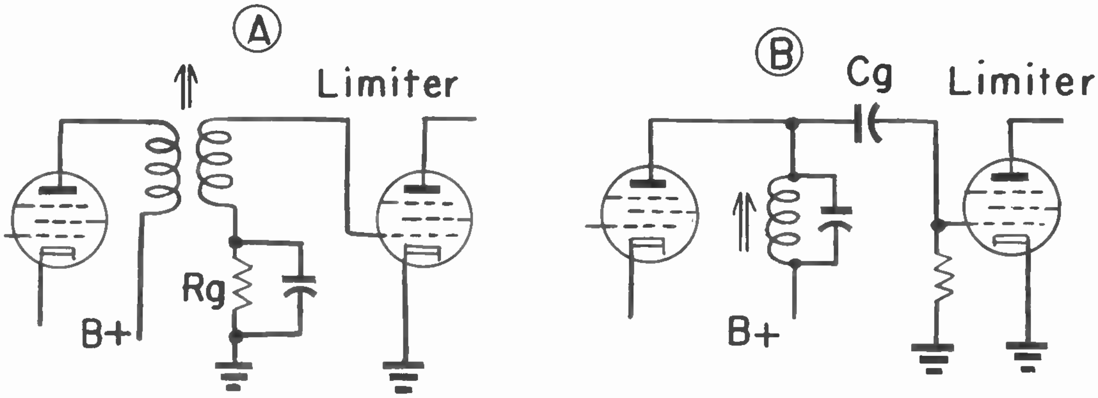

Fig. 13. Grid-leak biasing connections for limiter tubes.

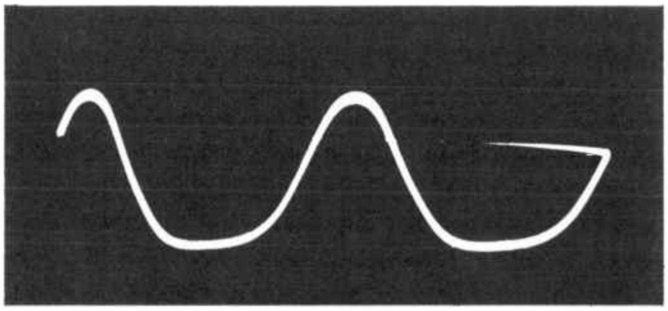

Fig. 14-A.

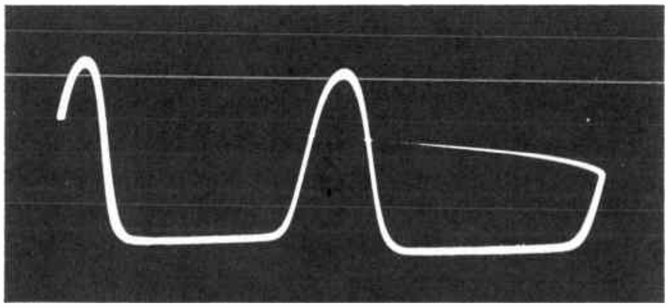

Fig. 14-B.

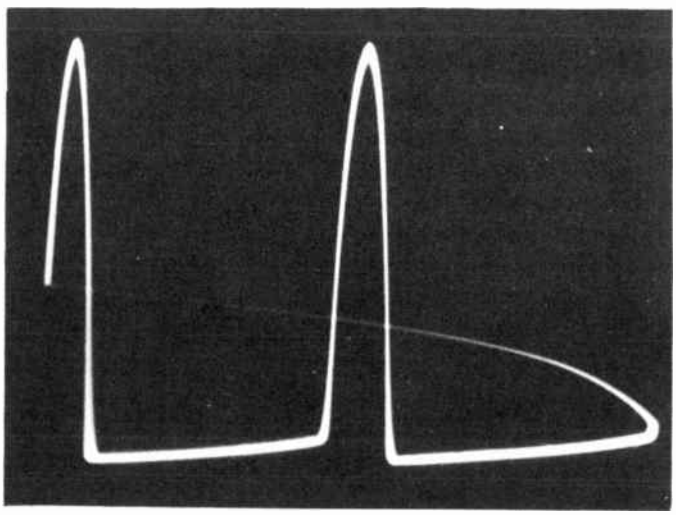

Fig. 14-C.

Fig. 14. Action in a limiter employing the principle of grid-leak biasing.

When grid signal input is increased to about 0.3 volt r-m-s we commence to see the effect of grid-leak bias as a slight cutoff at the bottom of plate current alternations, as at A of Fig. 14. With grid input raised to 1 volt r-m-s there is a decided cutoff effect, as at B. Further increases of r-m-s grid voltage make the cutoffs more and more pronounced as the grid-leak bias becomes more strongly negative. Positive loops of plate current continue to increase, as at C.

Waveforms of limiter outputs, as in Figs. 12 and 14, are badly distorted in relation to grid input voltages, which are approximately sine-wave. This distortion is not harmful, because we are not interested in reproducing good waveforms. So long as output frequency and variations of frequency are exactly like input frequency and its variations or deviations, this is all that matters in frequency modulation.

Relations between signal voltage at the limiter grid and peak-to-peak plate current, with grid-leak bias, are shown by Fig. 15. For very small input signal voltages, where the curve rises sharply from zero, there is amplification but no limiting. When limiting commences, and thereafter, the peak-to-peak plate current increases are only moderate with large increases of grid signal voltage. This is partial limiting.

The strength (amplitude) of the 4.5-mc signal reaching the limiter grid must be of some certain minimum value to cause limiting. This is evident from Fig. 15, also from the oscilloscope traces of plate current. For all greater input signal voltages there will be

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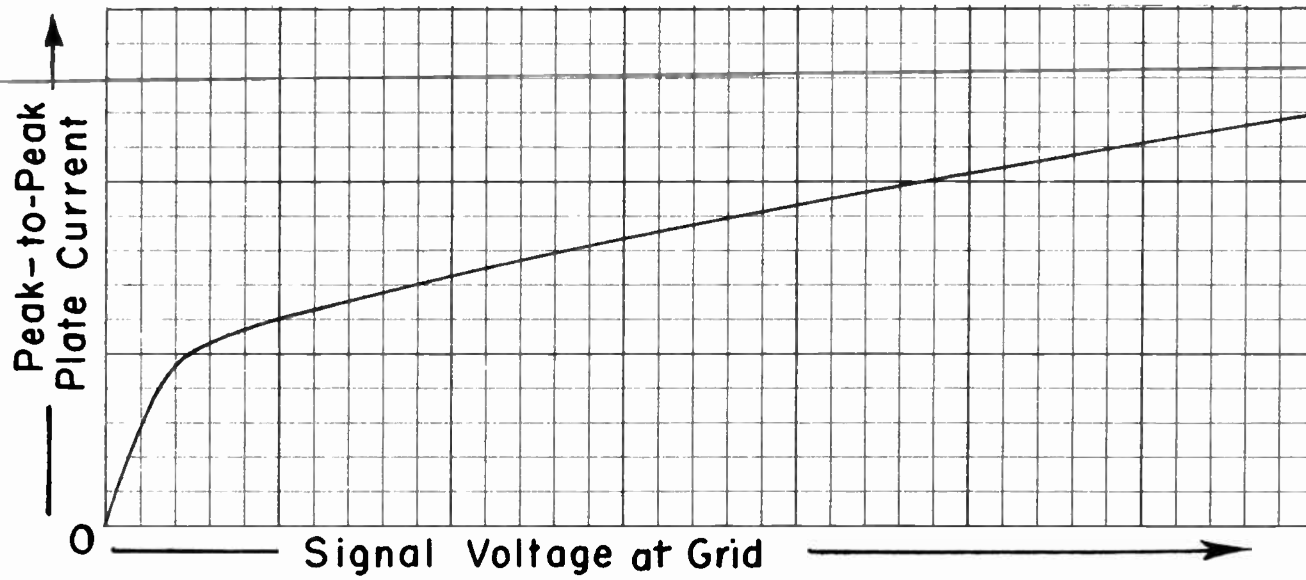

Fig. 15. With grid-leak limiting, plate current is varied but little by large increases of grid voltage above the value at which limiting commences.

limiting and removal or decided reduction of amplitude modulation. Maintaining a required minimum of limiter input signal is no great problem in television, for with any received signals strong enough to produce pictures there almost always is ample strength for sound. Sound signals as well as video signals are held at fairly constant strength by automatic gain control acting in the i-f amplifier section of the receiver.

When a limiter tube is serving its purpose, this tube is not increasing amplitude of the f-m sound signal to any important extent. Amplitude at the limiter output should be little if any greater than at the input. The limiter tube acts as an amplifier (for amplitude) only when limiter input signal voltage is too weak to cause limiting action.

With grid-leak bias for a limiter the time constant of the biasing capacitor and resistor usually is at least as long as the interval between cycles of the 4.5-mc sound signal, which is approximately 2.2 microseconds. Typical time constants are between 1.5 and 5.5 microseconds. This maintains the d-c negative bias very nearly equal to positive peak voltage of sound signals, or to 1.414 times the r-m-s signal voltage.

On the other hand, grid-leak bias time constant must be considerably shorter than the period of any voltage pulses likely to result from noise and interference in the audible range. This allows the grid bias to vary rapidly enough to cut off such pulses, whereas an excessively long time constant would allow excess amplitude modulation to increase the bias voltage. Then noise pulses would pass through the limiter as amplitude modulation.

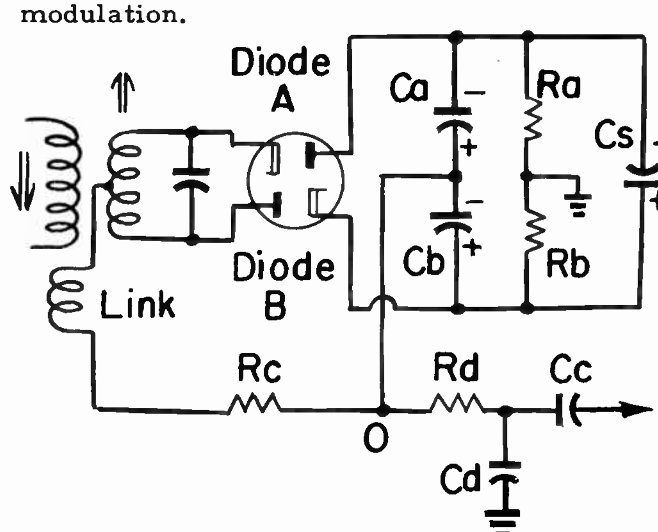

Fig. 16. A ratio detector circuit which demodulates f-m signals, and whose output is an audio-frequency voltage.

RATIO DETECTORS. The most widely used demodulator for f-m sound is called a ratio detector. One variety of ratio detector circuit is shown by Fig. 16. The transformer primary is in the plate circuit of the preceding tube, which may be one of the limiters or drivers shown earlier in this lesson.

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The secondary of the ratio detector transformer is inductively coupled to the primary. Also inductively coupled to the primary is a link coil, sometimes called a tertiary winding or third winding. One end of the link coil connects to a center tap on the secondary. The other end connects to the audio output of the ratio detector. There are separate adjustable slugs for tuning primary and secondary to the 4.5-mc intercarrier frequency.

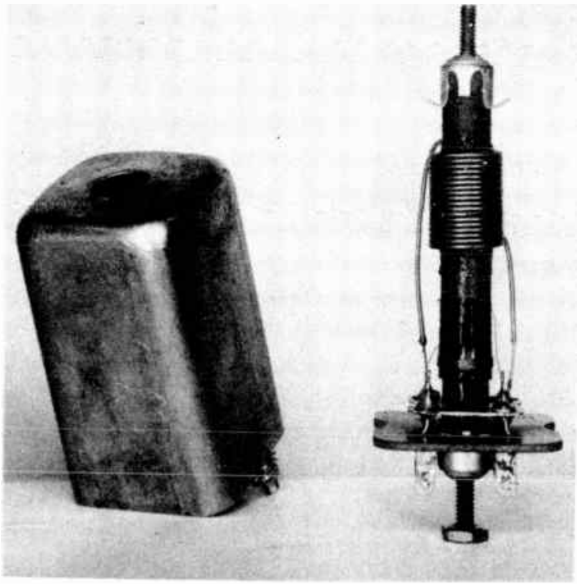

Fig. 17. A ratio detector transformer for use in an intercarrier sound system.

The entire transformer is enclosed within a grounded shield, which has been removed in Fig. 17 to show the windings. At the top of this particular unit is the secondary winding, tuned by a slug screw which would extend through the top of the shield. Down below is the primary, of very small wire. Around the bottom of the primary are the few turns composing the link coil. The primary is tuned by a slug screw extending downward, accessible from underneath the chassis.

The ratio detector tube is a twin diode. One end of the transformer secondary is connected to the plate of one diode, the other end to the cathode of the second diode. The two remaining diode elements are connected to capacitors Ca and Cb, usually of about 500 mmf each, from between which is a lead of the link coil and point O. At O appears the audio sound output of the ratio detector. Also across the diodes are resistors Ra and Rb, ordinarily of 10,000 to 20,000 ohms each, with the inner ends of these resistors to ground. The final element across the diodes is capacitor Cs, usually an electrolytic type of 2 mf to 5 mf capacitance.

Resistor Rc provides an impedance between the transformer secondary center tap and the audio output. Resistor Rd and capacitor Cd form what is called a de-emphasis filter, whose purpose will be explained later. At Cc is a blocking capacitor in the lead to the sound volume control and audio amplifier of the receiver.

You can learn to adjust or align a ratio detector and to locate and remedy its troubles without knowing how this detector changes frequency modulation to an audio signal of varying amplitude. But the action is interesting, and to satisfy any curiosity which you may have it will be explained briefly.

In the transformer secondary of Fig. 16 are two signal voltages. One comes from the primary through the link coil to the center tap of the secondary, and appears without change at top and bottom of the secondary. The other signal voltage results from inductive coupling of secondary to primary. Toward this induced voltage the secondary acts as a series resonant circuit tuned to 4.5 mc. Consequently, when signal frequency deviates below 4.5 mc the secondary increases its capacitive reactance, and induced secondary voltage lags the secondary current. With deviation to higher frequency the secondary increases its inductive reactance, and induced voltage leads the current. When there is no deviation there is neither lead nor lag.

Current and voltage from the link coil remain in phase. Therefore, deviation causes phase differences between the induced secondary voltage and voltage from the link. The out-of-phase voltages combine their amplitudes. Amplitude of the combination voltage increases or decreases proportionately to phase differences.

When f-m signal deviation is above 4.5 mc, total voltage will increase in the upper half of the secondary and to diode A of Fig.

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16. With deviation below 4.5 mc there is more combined voltage across the lower half of the secondary and to diode B. The greater the deviation in either direction, the stronger are these voltages on the two diodes.

Capacitor Ca is charged by voltage across the upper half of the secondary, rectified by diode A. Capacitor Cb is charged by voltage across the bottom half of the secondary, rectified by diode B. Instantaneous charge voltages across these two capacitors are proportional to instantaneous voltages across halves of the secondary and are proportional to deviations of frequency.

The large capacitance at Cs of Fig. 16 often is called the storage capacitor. It is charged by total voltage across the transformer secondary, because top and bottom of the secondary are connected through the diodes to top and bottom of Cs. The two diodes are so connected in the circuit that electron flow can occur only during signal voltage alternations of one polarity. The diodes act like a single rectifier. The rectified electron flow is only in the direction that charges Cs in the polarity marked.

The charge on Cs, also the charges on Ca and Cb, escape only through discharge resistors Ra and Rb. Because capacitance at Cs is so large, the time constant of this capacitor and the discharge resistors is long in comparison with periods of the 4.5-mc signal. Consequently, charge voltage on Cs builds up and remains practically equal to average amplitude of the 4.5-mc sound signal.

Time constants of small capacitors Ca and Cb, discharging through Ra and Rb, are on the order of only 5 microseconds. As a result, charge voltages on these two capacitors increase and decrease as rapidly as do the frequency deviations, and on these capacitors we have voltages varying at the deviation rate. The deviation rate is the audio frequency of sound signals being received.

Although voltages on capacitors Ca and Cb vary in relation to each other, as one voltage becomes greater while the other becomes smaller, the sum of these two voltages must remain practically constant. The sum remains constant because, while Ca and Cb are in series with each other, they are in parallel across capacitor Cs, and voltage across Cs remains proportional to average signal strength, unaffected by deviations of frequency.

Audio output, at O of Fig. 16, is taken from between capacitors Ca and Cb. When charge voltage on Ca and through Ra to ground is greater than on Cb, audio voltage from between them and at O must be positive with reference to ground. When voltage on Cb becomes greater than on Ca, audio voltage from between them must be negative to ground. This you can see from polarity markings on the two capacitors in the diagram.

Since voltage on Ca and Cb vary oppositely at the rate of deviation, and since deviations occur at audio frequency of the transmitted signal, we have at O a voltage swinging positive and negative at audio frequency. This is the desired sound signal.

As we learned before, the extent of f-m deviation in kilocycles either way from the center frequency is proportional to audio volume. The greater the deviations the greater are the variations of charge voltages on Ca and Cb, and the greater are the swings of audio voltage at O. The final result of this whole process of demodulation is to produce at point O an audio or sound signal whose frequency (pitch) is equal to the rate of f-m deviation, and whose amplitude (volume) varies proportionately to the extent of f-m deviation.

It is not the sum of charge voltages on Ca and Cb which produces the audio signal, for the sum is held constant at the value of voltage on capacitor Cs. The audio signal is produced by the changing ratio between voltages on the two small capacitors. Hence the name, ratio detector.

The ratio detector may be used without a limiter because of the large capacitance at Cs of Fig. 16. The explanation is as follows. Assume that a noise pulse voltage passes through the tube ahead of the ratio detector and acts on the primary of the detector transformer. Such a pulse has the form of a sudden but brief increase of signal amplitude.

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The tendency would be to induce a similar increase of amplitude or voltage induced in the transformer secondary.

However, the transformer secondary is connected through the two diodes to capacitor Cs, placing the capacitor effectively across the outer ends of the secondary. In the large capacitance of Cs the charge is already so great that a brief voltage pulse can cause no important addition to the total charge, and voltage on Cs shows no important increase. In other words, the large capacitor absorbs additional small charges due to brief noise pulses while its voltage remains almost exactly equal to average amplitude of the f-m sound signal. As a consequence, the ratio detector gives quite satisfactory immunity from noise effects even when no limiter is used ahead of the detector.

If there is gradual increase or decrease of average f-m signal strength (amplitude) the charge and voltage of Cs gradually increase or decrease. The long time constant of this capacitor and the discharge resistors is not so long as to prevent variations of charge and charge voltage with gradual changes of f-m signal strength.

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TELEVISION

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LESSON 60 — TELEVISION SOUND ADJUSTMENTS

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Lesson 60

TELEVISION SOUND ADJUSTMENTS

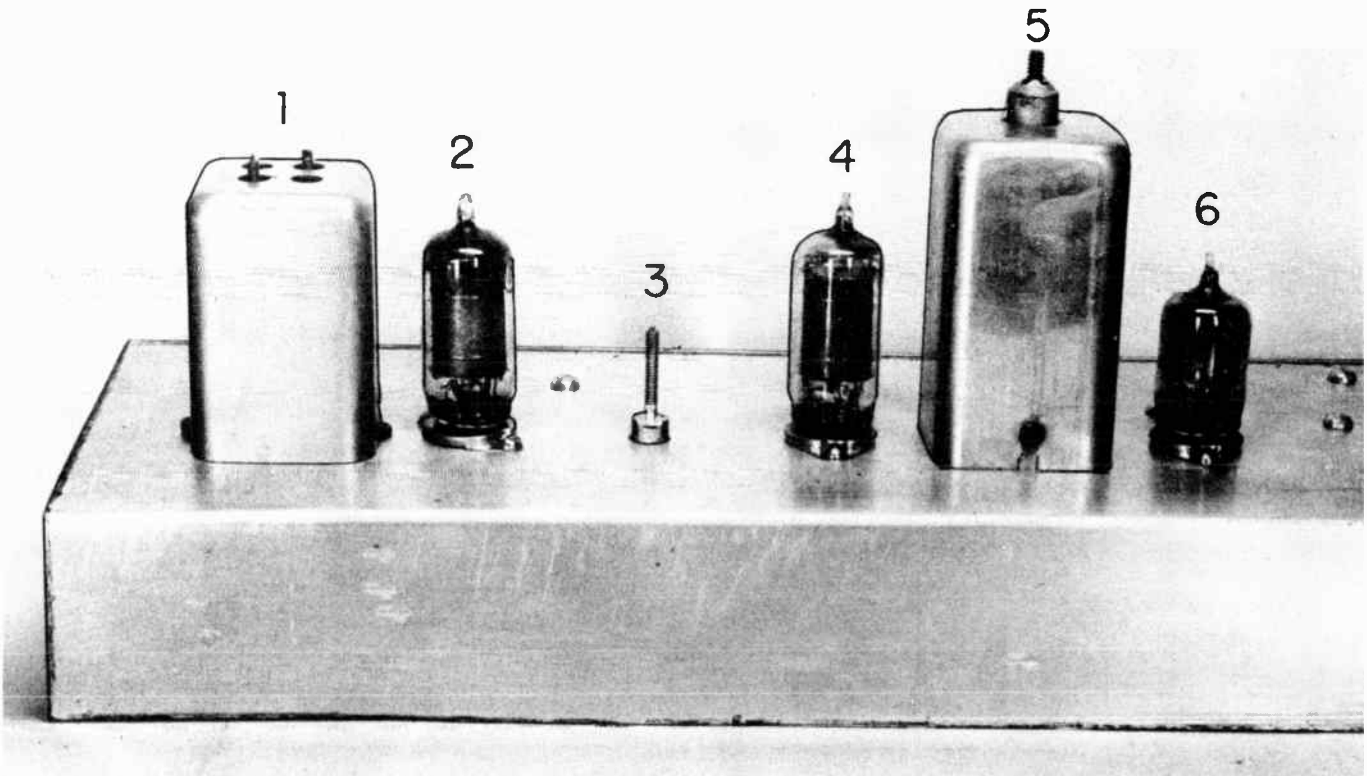

Fig. 1. The principal parts of a television f-m sound section, from takeoff through the ratio detector.

In all ratio detector circuits commonly employed one end of the transformer secondary is connected to the plate of one diode, while the other end of the secondary is connected to the cathode of the other diode. The secondary always is center tapped. A connection is made from the center tap to the audio output, usually through a link coil. Nearly always the demodulator tube is a twin diode, although there are a number of receivers in which the tube contains also a triode section used as first audio amplifier. This does not affect connections to demodulator diodes.

On the other side of the ratio detector circuit, which contains the storage capacitor and discharge resistance, there may be many modifications. These modifications do not alter the basic principle of demodulation, but they do affect the manner in which a vacuum tube voltmeter or an oscilloscope is connected during alignment of the sound section.

The principal parts of a sound section built on a separate small chassis are pictured by Fig. 1. From left to right the units are: 1. Takeoff transformer with separately tuned primary and secondary. 2. Pentode tube used as 4.5-mc amplifier. 3. Adjustment for a single-winding interstage coupler. 4. Pentode tube operated as a limiter. 5. Ratio detector transformer. 6. Twin-diode ratio detector tube.

Fig. 2 is a view underneath the sound chassis. The parts and their connections are arranged for convenient changes when checking the actions of various combinations of amplifier, limiter, and demodulator circuits. At the far right are discharge resistors, center-connected capacitors, and storage

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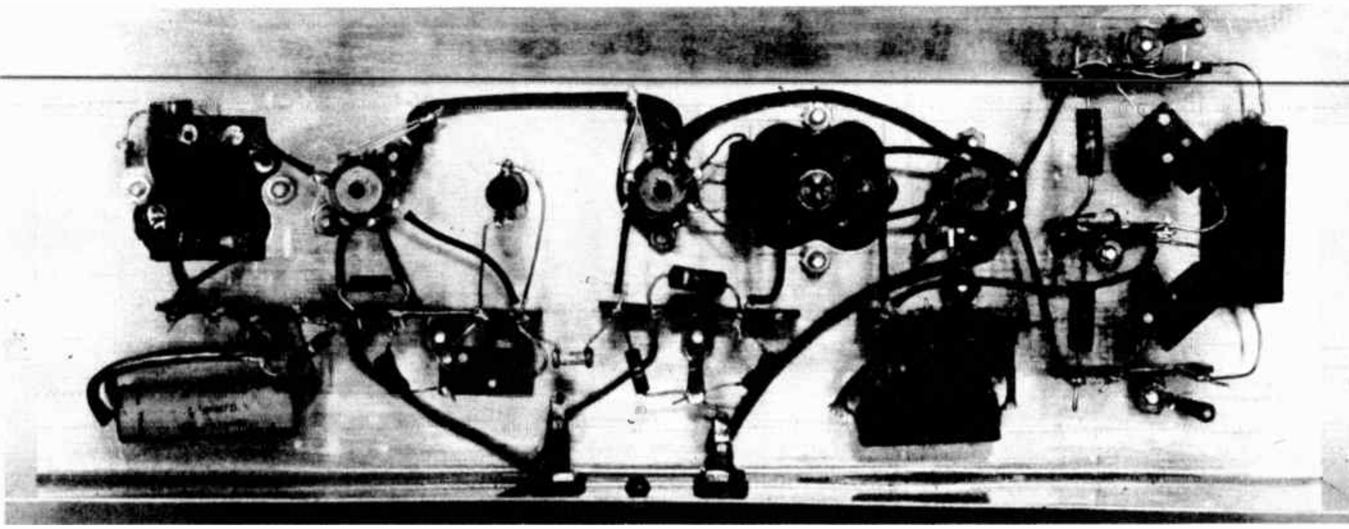

Fig. 2. The parts mounted underneath the chassis of the sound section.

capacitor for a ratio detector circuit.

Fig. 3 shows the same ratio detector circuit examined in the preceding lesson, reproduced here so that we may refer to it during alignment instructions given in this lesson.

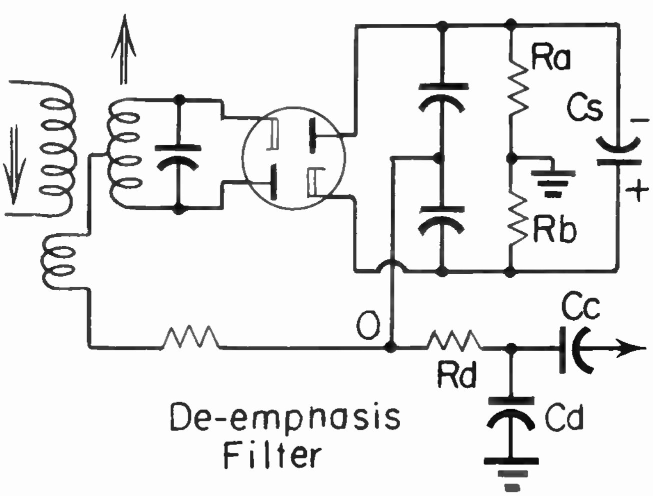

Fig. 3. Ratio detector circuit with discharge resistors balanced to ground.

One modification of the ratio detector circuit is shown by Fig. 4. There are no changes in the transformer, or in the connection from the link coil to the audio output point O and to the mid-connection between two small capacitors. The chief change is that the formerly grounded mid-connection between discharge resistors Ra and Rb now is a test point marked P on the diagram. Instead of a center ground we now have grounds on the cathode of one diode, on one

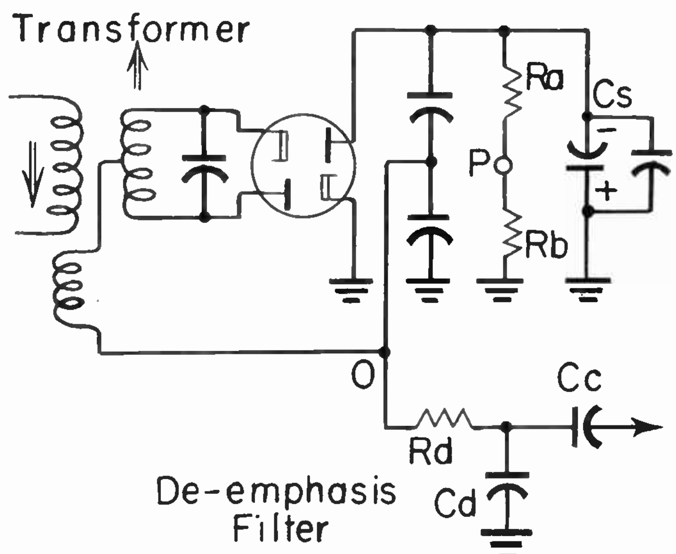

Fig. 4. One side of the capacitor-resistor section of this ratio detector is grounded.

small capacitor, on resistor Rb, and on the positive side of storage capacitor Cs. Instead of these separate grounds, a diagram might show a common connection with one ground. Modifications such as these and others may be noted on service diagrams or by tracing actual wiring connections from the demodulator tube socket or from the storage capacitor.

Storage capacitor Cs usually is an electrolytic type, but may be paper. Polarity of an electrolytic capacitor must be observed in making connections. The positive terminal of the capacitor always is connected to the cathode of one diode, while the negative side

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is connected to the plate of the other diode. You should find it easy to remember how such connections must be made. Electrons must flow away from the side of a capacitor which is made positive, and can flow only toward and into the cathode of a tube. Electrons must flow into the side of a capacitor which is negative, and can flow only away from the plate of a tube.

An electrolytic or paper capacitor of large capacitance may have considerable inductance, due to the method of winding the plates and dielectric. To bypass the resulting inductive reactance at high frequencies there may be a ceramic or mica capacitor of about 0.005 mf connected across the storage capacitor.

DE-EMPHASIS FILTER. In circuits for nearly all ratio detectors and other f-m demodulators are de-emphasis filters. Such a filter consists of a resistor in series with the audio output from the demodulator and a capacitor from audio output to ground. These units are marked Rd and Cd in Figs. 3 and 4.

A de-emphasis filter is needed for the following reason. Signal strength or amplitude at the transmitter is increased proportionately to audio modulation frequency, from about 400 cycles up to the high limit. This is done to reduce noise effects. Although noise of an electrical nature is quite uniformly distributed throughout the range of audio frequencies, the most bothersome effects are hissing sounds produced by the higher audio frequencies. Boosting the signal strength at these higher frequencies raises it with respect to noise voltages and thus improves the ratio of signal to noise.

The de-emphasis filter at the receiver is a so-called low-pass type, which passes lower frequencies freely while attenuating higher frequencies. This brings the strength of higher-frequency audio voltages down to about the same strength as those for lower frequencies. Since most of the objectionable noise is at higher audio frequencies, much of such noise is removed before it can go to the audio amplifier of the receiver.

The time constant of the de-emphasis resistor and capacitor should be, theoretically, about 75 microseconds. The number of microseconds is found by dividing by one million the product of resistance in ohms and capacitance in mmf. Actual time constants in television sound sections range from about 35 to 100 microseconds, with an average of 70 to 75 microseconds.

ALIGNMENT OF SOUND SECTIONS. From the sound takeoff all the way through the primary of the demodulator transformer we wish to bring the amplitude of the f-m signal voltage as high as possible for a given strength of input voltage. We wish also to have the response centered at the center frequency of the sound section, and to have equal gains at frequencies equally below and above the center frequency. This means that the circuits should be aligned to produce the type of response shown at A of Fig. 5.

The object of transformer secondary adjustment is to produce an audio output voltage meeting the three requirements illustrated by the response at B. First, audio amplitude should vary equally with equal f-m deviations below and above the center frequency. Second, audio voltage should swing positive with deviations above the center frequency, and negative with deviations below the center frequency. Third, audio output voltage should be zero when the f-m signal passes through its center frequency.

The response at A of Fig. 5 is secured by correct adjustments from the sound takeoff to and including the primary of the demodulator transformer. This is the response desired in the sound signal before demodulation. All of the adjustments for attaining this response normally are made with a single setup of test instruments, and without having to change any of the instrument connections.

The response at B of Fig. 5 is the result of demodulation. It is attained by correct adjustment of the demodulator transformer secondary, after the primary has been correctly adjusted. For making secondary adjustments it normally is necessary to change the connections of a VTVM or oscilloscope used as an audio output indicator.

Sound alignment commences at the adjustably tuned circuit which immediately

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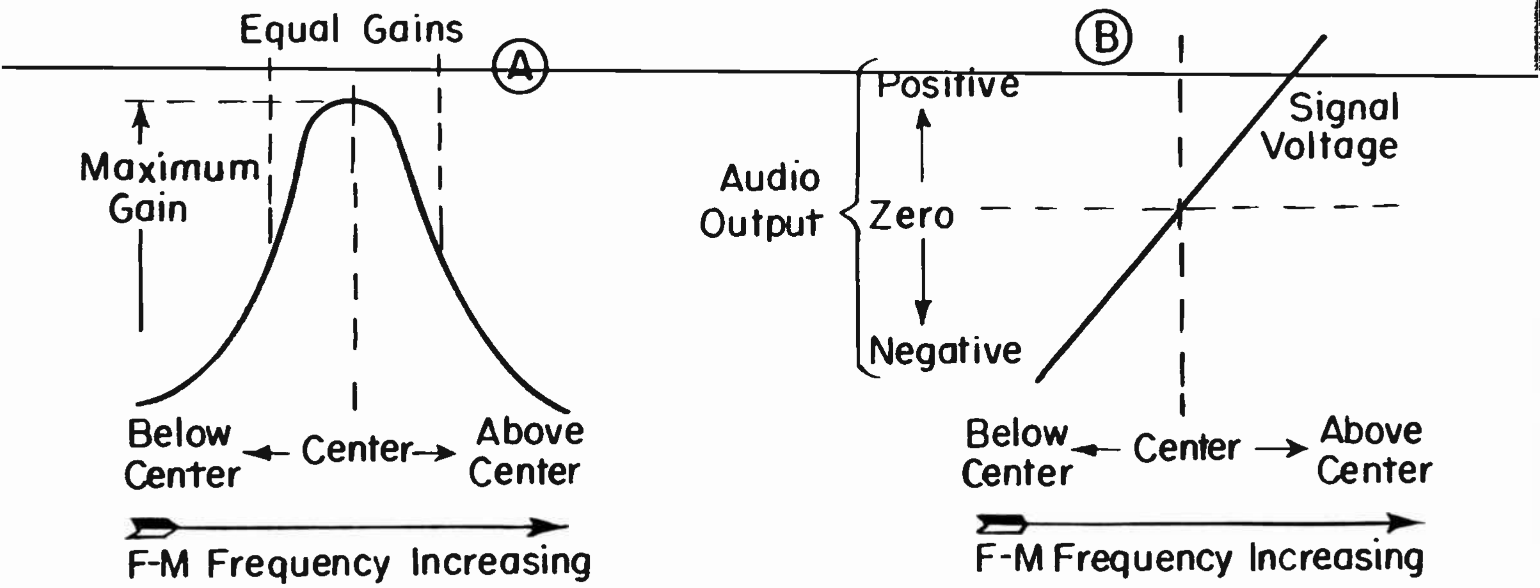

Fig. 5. These frequency responses illustrate the objects of alignment in sound circuits ahead of the demodulator, and of alignment in the demodulator.

follows the point of sound signal takeoff, which will be at the video detector or in the video amplifier for intercarrier sound systems. Remaining tuned couplings from here to and including the primary of the demodulator transformer then are aligned in order.

The secondary of the demodulator transformer is adjusted last. Otherwise its alignment would be upset by any later changes in adjustments of preceding tuned circuits.

Steps preliminary to alignment are, in general, the same as for i-f alignment. The channel selector should be set where no nearby station operates. It is advisable to disconnect the antenna or transmission line, and to short the antenna terminals to each other or to ground. If sound signals from a test generator will come through any tube or tubes affected by automatic gain control, disable this control.

A complete alignment of a sound section may be made with an r-f signal generator and a vacuum tube voltmeter. A complete alignment may be made also with an oscilloscope used in connection with a sweep generator and marker generator. Many technicians align everything preceding the secondary of the demodulator transformer with the r-f generator and VTVM, then use the scope with sweep and marker generators for aligning the transformer secondary. We shall commence our work with the r-f signal generator and VTVM.

SIGNAL GENERATOR FOR ALIGNMENT WITH VTVM. The r-f signal generator must be capable of tuning precisely to 4.5 mc when working on intercarrier sound systems, or to precisely the sound intermediate frequency for dual or split sound systems. It is highly desirable to have crystal control for the center frequency, or to calibrate the generator tuning with a fundamental or harmonic crystal frequency close to the one desired.

The need for accuracy may be illustrated by an example. Total frequency swing or deviation both ways for television sound is only 50 kc or 0.050 mc. An error of half this amount would allow the peak of response at the edge, not at the center, of the required pass band. This would be an error of only 0.025 mc. At a center frequency of 4.5 mc an error of 0.025 mc represents only 1/18 of one per cent. With generally available service signal generators, accuracy of 1/18 of one per cent or better is obtainable only with crystal control or crystal calibration.

The high side of the r-f signal generator is connected to points marked on Figs. 6 and 7, with the low side to chassis ground. When the sound takeoff is from a point between the video detector and a video amplifier the generator connection may be made to (A) the

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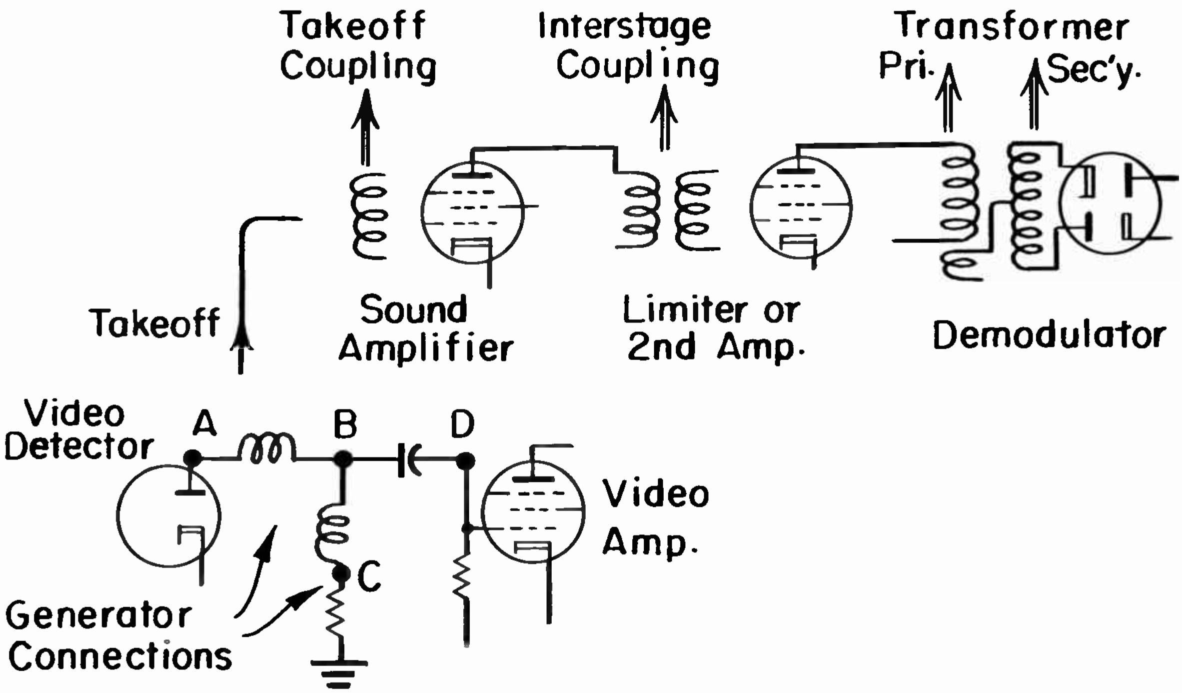

Fig. 6. Points of signal generator connection when the sound takeoff is from the output of the video detector.

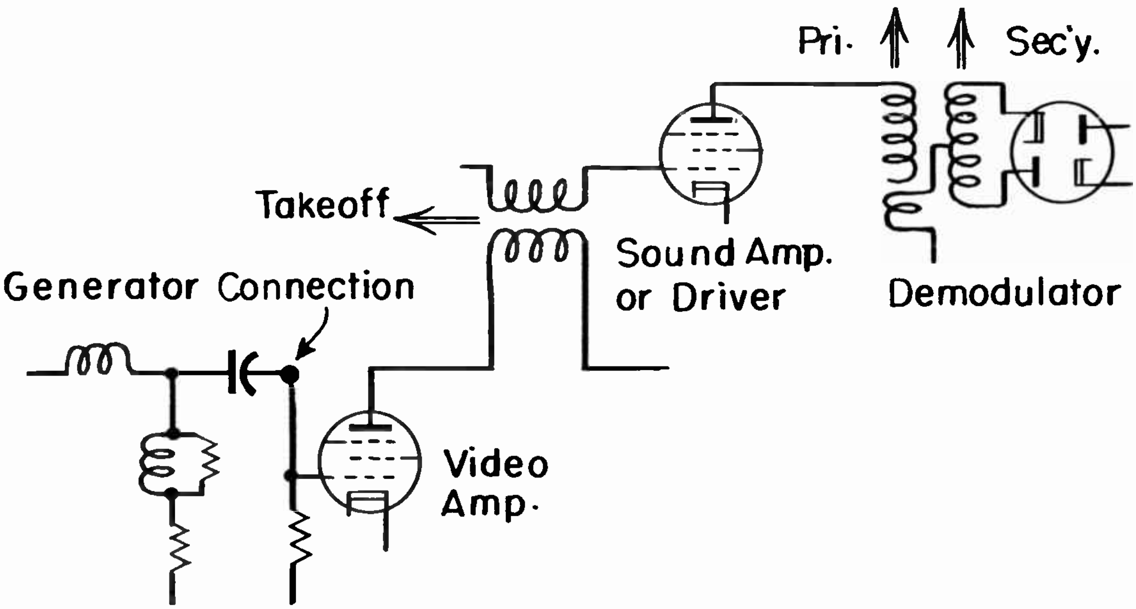

Fig. 7. When sound takeoff is from the output of a video amplifier, the signal generator is connected to the grid of this amplifier.

video detector output, (B) beyond a peaker between detector and video amplifier, (C) to the high side of the video detector load resistor, or (D) to the grid of the video amplifier. The connection at B usually is satisfactory.

The signal generator must not be connected ahead of the video detector, because this detector will not pass both polarities of the signal voltage. Never connect the generator at a point from which its signal voltage would have to pass through any 4.5-mc intercarrier beat trap to reach the sound takeoff. Obviously, such a trap would prevent getting sufficient signal voltage into the stages to be aligned.

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(Always have a fixed capacitor of 0.001 to 0.01 mf in series with the high-side lead from the signal generator. Make this a rule no matter where the generator connection is made.) The capacitor is not always needed, but it can do no harm and will be there for those connections which require d-c blocking.

Fig. 7 shows only a single sound amplifier or driver between the sound takeoff and the demodulator transformer, with the takeoff connection from the output of a video amplifier tube. For such circuits connect the r-f generator to the grid of the video amplifier which precedes the takeoff.

The one connection of the generator is used during alignment of any tuned takeoff coupling, of any sound interstage coupling, and of both primary and secondary of the demodulator transformer. The couplings may be of types shown in our diagrams or of any other types.

Transformers or other coupling elements in the sound system sometimes are so far out of adjustment that it is difficult or impossible to get a generator signal voltage from connection points in Figs. 6 and 7 all the way through the demodulator. Then we may resort to stage-by-stage alignment, in much the same fashion employed for alignment of i-f amplifiers.

For stage-by-stage alignment connect the r-f generator to the grid of the tube which precedes the last coupling, or the coupling nearest the demodulator. Adjust this last coupling. Move the generator connection to the grid of the tube next in order toward the sound takeoff. Adjust the coupling which is in the plate circuit of this tube. Proceed similarly until the generator connection has been moved back to one of the points indicated in Figs. 6 or 7.

VTVM CONNECTIONS. The vacuum tube voltmeter always is connected to that portion of the ratio detector circuit which includes the storage capacitor, discharge resistance, and audio output. When instructions say to connect the meter to or across some certain resistor or capacitor, the connection may be made anywhere on a wire lead running without interruption to or from the point specified.

Usually it is convenient to make connections to lugs on the demodulator tube socket, or to one side or the other of the storage capacitor. This large capacitor is easily located underneath a chassis. Polarities will be positive at some points and negative at others; use the polarity reversing switch of the VTVM to obtain up-scale indications.

Many test connections require that neither lead from the VTVM be grounded. Both terminals of the meter often are connected to points which are positive or negative with reference to chassis ground. If your VTVM normally rests on a metal covered shelf or bench, insulate its case from the shelf or bench during sound alignment.

Before proceeding to connect the VTVM we shall examine some other common modifications of the ratio detector circuit in order to identify various points of connection.

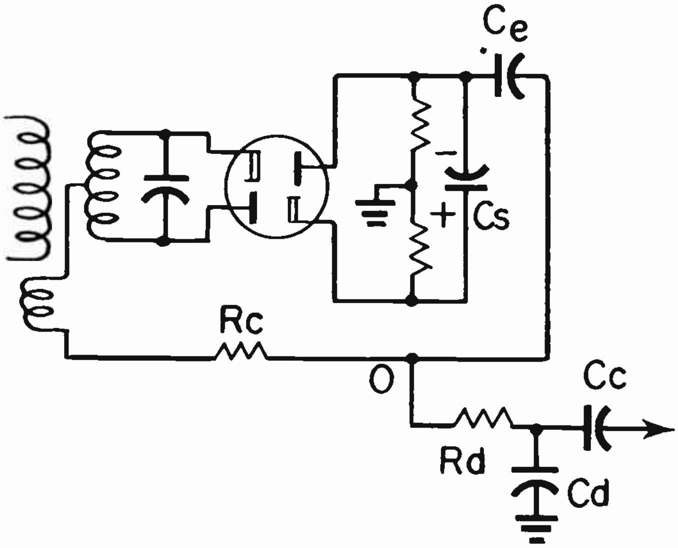

Fig. 8. Ratio detector circuit with a ground connection between discharge resistors, but no small series-connected capacitors.

The circuit shown by Fig. 8 is widely used in television receivers. Again the demodulator transformer is unchanged. On the other side of the demodulator circuit we no longer find the two small capacitors with a mid-connection to the audio output. There are, however, two discharge resistors with a ground connection from between them. Storage capacitor Cs may or may not be bypassed by a smaller capacitance. The link coil connects to the audio output point O, from which

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one line runs to the de-emphasis filter and another line through a small capacitance at Ce to one side of the storage and discharge circuit. There may or may not be a resistor at Rc.

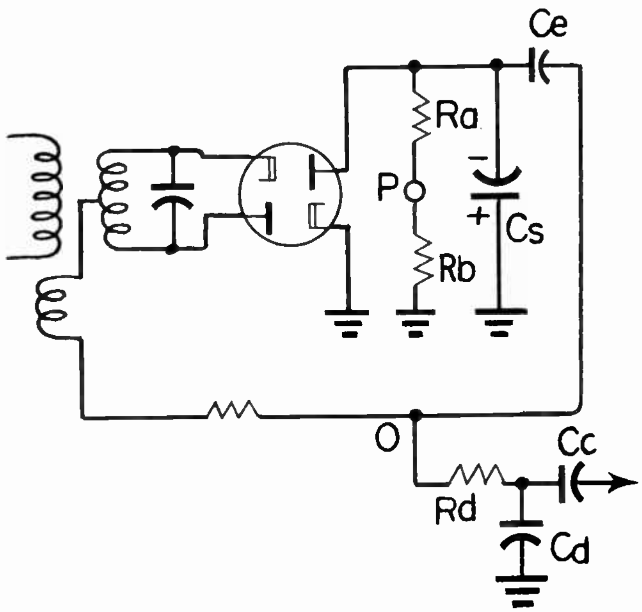

Fig. 9. Ratio detector with ground on one side and without small series-connected capacitors.

Fig. 9 shows still another modification of the ratio detector circuit. The arrangement here is generally similar to that of Fig. 8 except that the ground connection has been shifted from between the two resistors to one side of the circuit. At the former ground connection is a test point marked P on the diagram.

One more modification of the ratio detector is shown by Fig. 10. A single undivided discharge resistor is in parallel with the storage capacitor. One side of this portion of the circuit is grounded. Audio output, point O, is at the connection from the link coil to the de-emphasis filter. The broken lines show a temporary test connection which will be explained later.

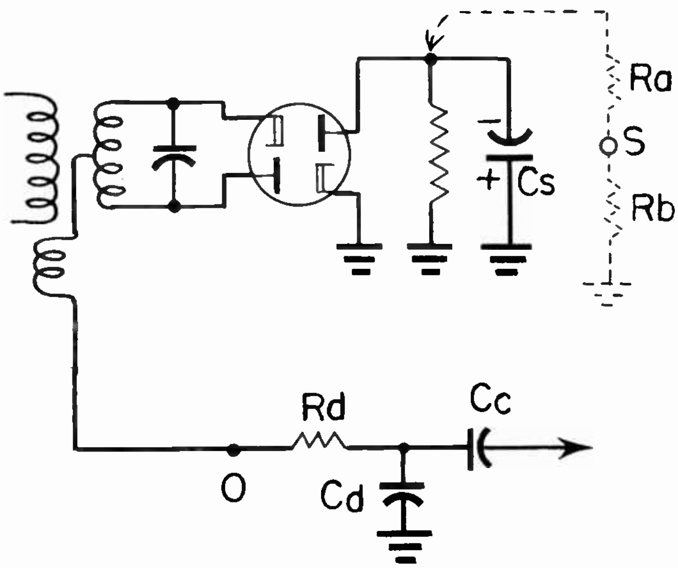

Fig. 10. The discharge resistor of this ratio detector is not tapped or divided.

ALIGNMENT OF TAKEOFF, STAGE COUPLINGS, AND DEMODULATOR PRIMARY. For adjustment of all tuned couplings from the sound takeoff to and including the primary of the demodulator transformer the VTVM is connected to the various ratio detector circuits as specified in the accompanying table. Similar connections would be made on circuits which are in general like these five common types.

Having connected the r-f signal generator and VTVM as directed, proceed with alignment as follows.

1. Signal generator.

Use without audio modulation.

Tune precisely to the center frequency, which is 4.5 mc for intercarrier sound systems, or is the sound intermediate for dual sound systems.

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VTVM CONNECTIONS FOR ALIGNING TAKEOFF, INTERSTAGE COUPLINGS, AND DEMODULATOR PRIMARY

Meter Connection Points	Circuits Shown By				
	Fig. 3	Fig. 4	Fig. 8	Fig. 9	Fig. 10
Across storage capacitor marked Cs on circuit diagrams.	X	X	X	X	X
Across either discharge resistor, or across either section of a divided discharge resistance.	X	X	X	X	
Across either small capacitor of pair which parallels storage capacitor.	X	X			
Across capacitor Ce between a-f output and line to diode plate.			X		
From ground to junction P between discharge resistors.				X	
From ground to a-f output, ahead of capacitor Cc.					X

2. VTVM

Use as d-c voltmeter, on range of not more than 10 volts maximum.

3. Commencing at the sound takeoff, adjust for maximum VTVM readings all tuned couplings, in order, to and including demodulator transformer primary. Use generator output such that meter readings at no time exceed 5 or 6 volts. The output is kept below the point which causes limiting action.

The demodulator primary will tune rather broadly, with maximum or near maximum meter voltage over a considerable range of adjustment. Final close adjustment of the primary will be made when adjusting the secondary of the demodulator transformer.

When adjusting a double-tuned transformer which does not produce two voltage peaks, align the secondary and then the primary for maximum voltage. Work back and forth between these adjustments for highest voltage on VTVM.

When adjusting overcoupled interstage transformers, which are capable of producing two separated voltage peaks, proceed as follows. Shunt the primary with about 300 ohms resistance while peaking the secondary. Then remove the primary shunt, shunt the secondary with the same resistance, and peak the primary. If resistance so low prevents obtaining distinct voltage peaks on the VTVM, increase the resistance. Go as high as 15K ohms if necessary.

ALIGNMENT OF DEMODULATOR TRANSFORMER SECONDARY. Connection of the r-f signal generator will remain as described earlier in this lesson. Connect the VTVM as follows, referring to diagrams of circuits specified.

Figs. 3 and 8.

Connect VTVM between ground and a-f output at a point ahead of any blocking capacitor Cc in line to audio amplifier and volume control. Connection may be on either side of de-emphasis resistor Rd in diagrams.

Figs. 4 and 9.

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One side of VTVM to junction between resistors Ra and Rb, point P on diagrams. Other side of meter to a-f output, on either side of resistor Rd, ahead of any blocking capacitor Cc in line to audio amplifier and volume control.

Fig. 10

As shown by broken lines on the diagram, connect two 100K resistors in series from the high side of the storage-discharge circuit to ground. Connect one side of the VTVM to the junction between these two resistors. Other side of meter to a-f output, on either side of Rd, ahead of any capacitor Cc in line to audio amplifier and volume control.

Note: The series-connected 100K resistors may be used also while adjusting takeoff, interstage couplings, and demodulator primary. Connect VTVM from ground to the junction between the two resistors.

Before adjusting the secondary of the demodulator transformer it will be well to understand a little more about performance of the demodulator circuit. Were applied frequency to be varied from far below to far above the center frequency, the frequency response of the demodulator would be as shown by Fig. 11.

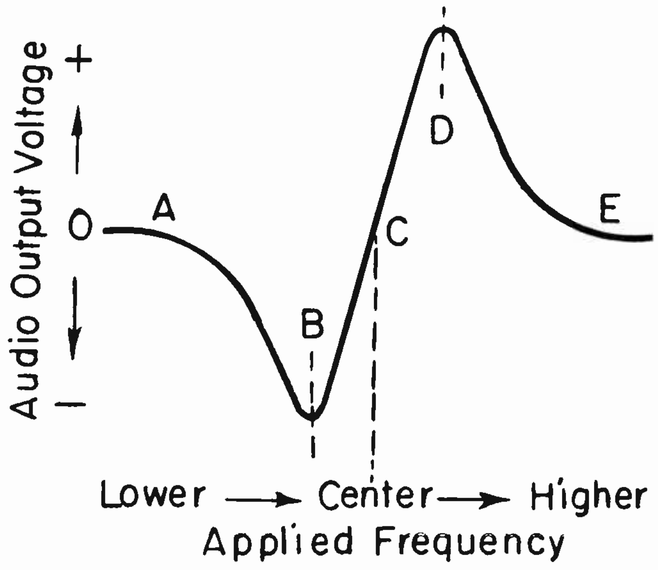

Fig. 11. Frequency response and audio output voltage of an f-m demodulator when applied frequency varies both below and above the center frequency.

At very low frequencies the response, or audio output voltage, is zero. As frequency increases, the voltage commences to go negative, at A. With further increase of applied frequency the voltage reaches a negative peak at B. Then the voltage becomes less negative, and at the center frequency becomes zero, at C. As applied frequency goes higher than the center frequency, audio output voltage commences to go positive and reaches a positive peak at D. With still further increase of frequency the voltage drops back to zero at E. Note that the response at B of Fig. 5 is part of the center section of the complete response of Fig. 11.

When the secondary of the demodulator transformer is tuned or adjusted for resonance at the center frequency, audio output voltage will be zero. If the secondary adjustment is changed far enough in one direction the secondary will be resonant at the frequency denoted as B in Fig. 11, and audio voltage will be at a peak negative value. With the adjustment changed in the opposite direction, secondary resonance will cause a positive peak voltage at frequency D.

If secondary adjustment can be varied through a sufficiently wide range it will go beyond the positions producing positive or negative peak voltages, and far enough to reach the zero voltages indicated at A and E of Fig. 11. Such a range of adjustment allows tuning the secondary for any of three different zero voltages, of which only the one at C is correct.

Now we shall proceed with adjustment of the transformer secondary, assuming that the r-f signal generator and VTVM have been connected as previously directed. The steps are as follows.

1. Signal generator

Use without audio modulation.

Tune precisely to center frequency, which is 4.5 mc for intercarrier sound, or the sound intermediate frequency for dual sound systems.

2. VTVM

Use as d-c voltmeter, on the lowest range.

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The object of secondary adjustment is only to identify the zero voltage at C of Fig. 11, not any particular values of other voltages until a final check. Therefore, if your VTVM has a zero-center dial, adjust the instrument to use this dial. If there is no zero-center dial, set the zero adjuster, while no voltage is applied, to bring the pointer exactly to 1 volt, 2 volts, or other easily identified dial position, and consider this as zero voltage during adjustments.

3. Turn the secondary adjuster far enough one way to obtain a peak voltage in one polarity (B or D of Fig. 11), with voltage dropping when the adjuster is turned on beyond the peaking position. Then turn the adjuster far enough in the opposite direction to obtain a voltage peak of opposite polarity, with a drop beyond the peak.

4. Turn the secondary adjuster back to a position about midway between the two peaking positions, then turn very carefully for exact zero between the peaks. This correct zero may be recognized because voltage swings rapidly from positive to negative with small movement of the adjuster. At either incorrect zero (A or E of Fig. 11) the voltage changes slowly with adjuster movement, and will not swing to both polarities.

5. Make the final zero adjustment with generator output high enough to cause fairly high voltage readings on both sides of the center zero reading. Turn the secondary adjuster back and forth through the zero position, to make sure of a correct setting.

6. Without disturbing the transformer secondary adjuster, tune the signal generator away from the center frequency until obtaining a peak voltage. Note the voltage value and, if possible, the frequency. Tune the generator the other way from center frequency to obtain a voltage peak of opposite polarity. Note this voltage, also the frequency if it can be read with accuracy.

7. The difference between the two peak voltages of opposite polarities should be no more than 25 to 30 per cent. The two peaking frequencies should be about equally above and below the center frequency. If these conditions are not satisfied, make slight readjustments of the demodulator transformer primary, not the secondary. After each primary readjustment, reset the secondary for zero voltage. Work back and forth between secondary and primary adjustments for most nearly equal peak voltages and frequency differences.

8. Disconnect the signal generator and VTVM. Tune in a station program. Advance the contrast control to its normal position for picture reception. If there is noticeable buzzing sound, try making slight readjustments of the demodulator transformer secondary to reduce the buzz.

OTHER METHODS FOR F-M SOUND ALIGNMENT. The methods which have been explained for alignment of sound sections by means of a signal generator and VTVM are those most often employed. As you might expect, there are other methods employing other instruments or employing the same instruments in other ways. Some of the more useful variations of alignment procedures will be explained in following paragraphs.

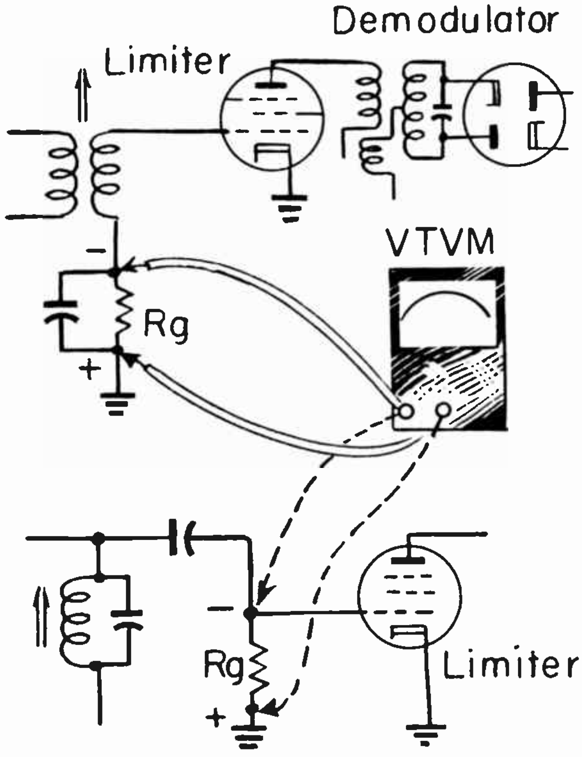

Fig. 12. Maximum bias voltage indicates correct alignment.

VTVM Across Biasing Resistors. - Alignment of sound takeoffs and of interstage couplings preceding the demodulator trans-

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former may be carried out with the VTVM connected across a grid biasing resistor as in Fig. 12. The meter here is connected across biasing resistors Rg in the grid circuits of limiter tubes. In the upper diagram the grid resistor is at the bottom of an interstage transformer secondary, and in the lower diagram the resistor is part of a grid-leak biasing circuit.

Use the VTVM as a d-c voltmeter, on a low range. The r-f signal generator is connected as explained for Figs. 6 and 7. Adjust all couplings which are ahead of the VTVM connection for maximum voltage on the meter. The greater the strength or amplitude of any signal voltage reaching a tube having grid-leak bias, the more negative becomes the bias voltage. It is this negative bias voltage that is indicated by the VTVM.

If a final sound amplifier tube has cathode bias it may be possible to align preceding couplings with the VTVM connected across the cathode resistor. Average plate current and cathode current tend to increase with stronger applied signals. However, the change of current in the bias resistor and of voltage across this resistor may not be sufficient to cause definite peak readings on the VTVM.

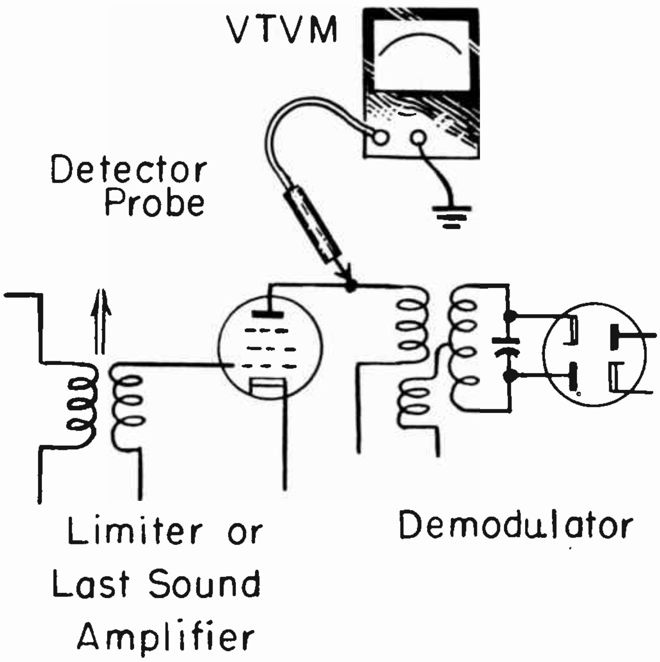

Fig. 13. A-c plate voltage increases when alignment is correct

VTVM With Detector Probe. - Another method of aligning sound takeoffs and sound interstage couplings which precede the demodulator transformer is illustrated by Fig. 13. A detector probe on the VTVM is connected to the plate of a limiter or a last sound amplifier. The signal generator is connected as in Figs. 6 or 7, and is used without audio modulation.

A-c signal voltage at the plate of a limiter increases almost directly with amplitude and gain of signal voltage coming to the limiter, until limiting action commences. Therefore, when the tube to which the VTVM is connected is a limiter, the output of the signal generator must be kept below a value that causes limiting. This precaution is not necessary when the tube is operated as an amplifier, not as a limiter. Couplings which precede the limiter or final amplifier tube are adjusted for maximum voltage indications.

Modulated Signal Generator and Output Meter. - Fig. 14 illustrates a method of aligning all sound couplings, including both the primary and secondary of the demodulator transformer, by using a modulated r-f signal generator and an audio output meter or a-c voltmeter.

The high side of the signal generator is connected through a capacitor to any of the points in the circuits of video detector or video amplifier, as explained earlier in connection with Figs. 6 and 7. The generator is tuned accurately to the f-m center frequency, just as with other methods of alignment. Tone modulation is used during all steps of alignment.

The output meter, or an a-c voltmeter, is of the type whose operation and use were explained in the lesson on "Receiver Alignment". In that lesson we used an output meter and a modulated r-f signal generator for aligning a superheterosyne receiver designed for standard broadcast reception. The meter may be connected to the voice coil of the speaker as at A in Fig. 14, or to the plate of the audio output amplifier as at B. When the connection is to a plate circuit it is necessary to use a series capacitor whose voltage rating is higher than maximum plate voltage, as explained in the earlier lesson. Capacitance may be 0.01 to 0.1 mf.

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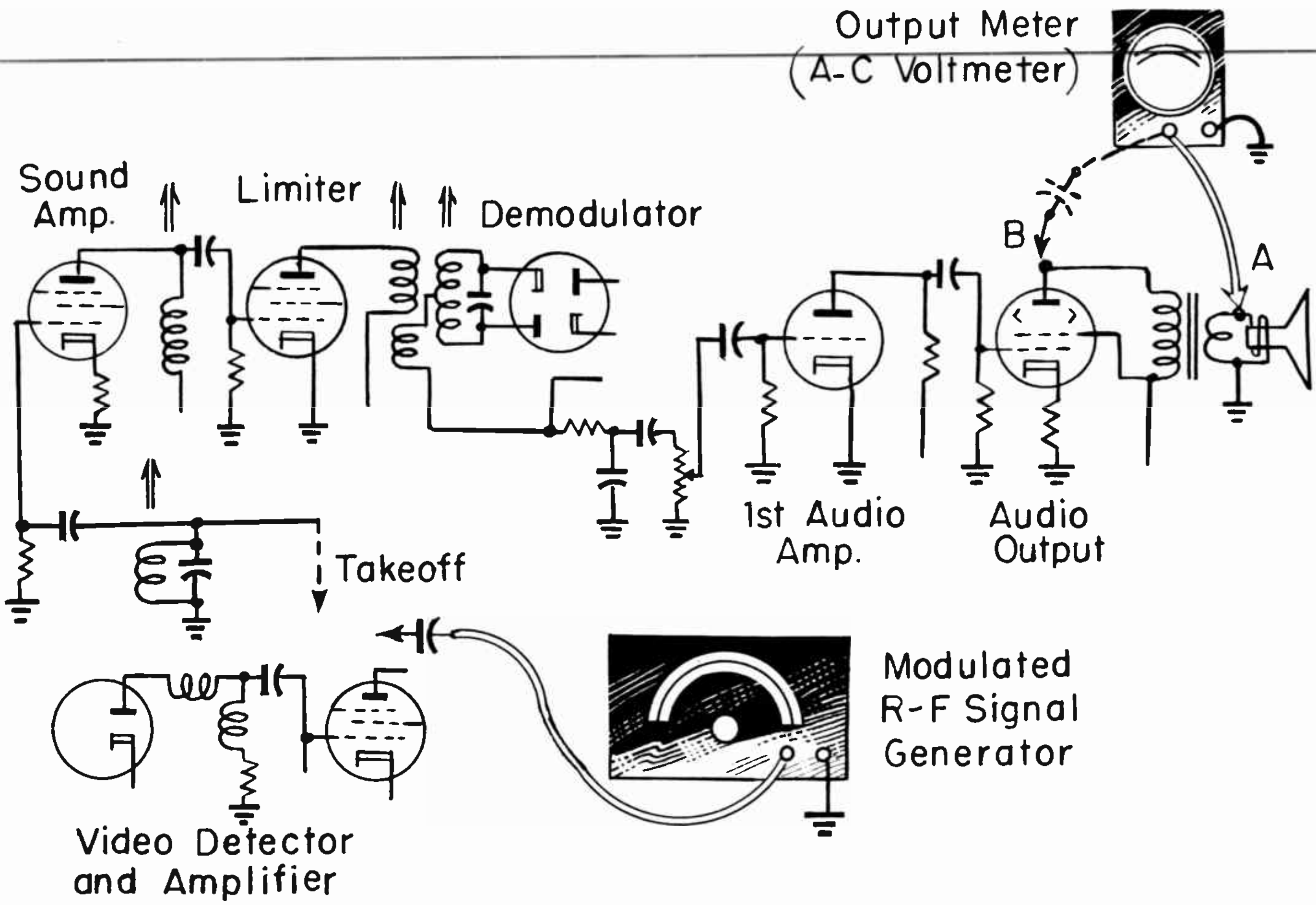

Fig. 14. The output meter and modulated generator used for television sound alignment in somewhat the same way as for standard broadcast receiver alignment.

To make the alignment proceed as follows.

1. Set the audio volume control of the television receiver for maximum volume.

2. Adjust the signal generator for high output.

3. Detune the secondary of the demodulator transformer, one turn of the slug screw usually being enough. The amplitude modulated tone from the signal generator should be heard from the speaker, and the output meter should indicate voltage.

4. Decrease the signal generator output until the meter reads about one-third scale on the lowest voltage range. Keep the generator output as low as gives definite voltage peaks in following steps, this to prevent limiting action.

5. Adjust all tuned couplings, from takeoff to and including the primary of the demodulator transformer, for maximum meter voltage. Reduce the generator output as alignment proceeds.

6. Adjust the secondary of the demodulator transformer for minimum or zero meter voltage. Increase the generator output until voltage comes only to a minimum, not to zero, with any secondary adjustment. Adjust the secondary carefully for lowest possible voltage reading.

Alignment Without a Generator, Using a VTVM. - With many receivers it is possible to make an excellent alignment of the entire sound section by using a regularly transmitted television signal instead of a signal generator, and by using a VTVM as an output indicator. The steps are as follows.

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LESSON 60 – TELEVISION SOUND ADJUSTMENTS

1. Tune in a channel on which pictures and sound are good in your locality. Adjust all receiver controls for the best possible picture quality, without regard to sound quality.

2. Turn off the receiver, but do not disturb any of its controls.

3. Connect the VTVM in exactly the same manner described earlier in this lesson, the exact connections depending on the kind of demodulator circuit in the receiver.

4. With the VTVM connected for alignment of all tuned circuits from sound takeoff to and including the primary of the demodulator, proceed to adjust all these elements for maximum reading on the VTVM. This, of course, is with the receiver turned on.

5. With the VTVM connected for alignment of the demodulator transformer secondary, adjust the secondary for minimum or zero voltage on the VTVM.

6. Disconnect the VTVM and try the receiver for normal program reception. Advance the contrast control, and if this causes a buzzing sound with the control no higher than for normal reception, make a slight readjustment of the demodulator secondary to reduce or eliminate the buzz. With many of the more recent sound systems there will be no buzz, and no readjustment of the secondary will be needed.

4.5-MC TRAP ADJUSTMENT. A common method for aligning or adjusting a 4.5-mc trap is illustrated by Fig. 15. The 4.5-mc test signal is fed from a signal generator through the trap to a vacuum tube voltmeter equipped with a detector probe.

The trap most often is in position A, or somewhere between the plate of the final or only video amplifier and the signal input to the picture tube, which may be at the grid or at the cathode. In other cases the trap, at B, is between the output of the video detector and the grid of the first or only video amplifier. In still other cases the trap, at C, may be on the cathode lead of a video amplifier. When there are two video amplifiers the trap may be between them. Where the trap is located makes no great difference, so long as test signal voltage goes from the generator through the trap to the VTVM.

Adjustment usually is easiest with the generator connected to the video detector

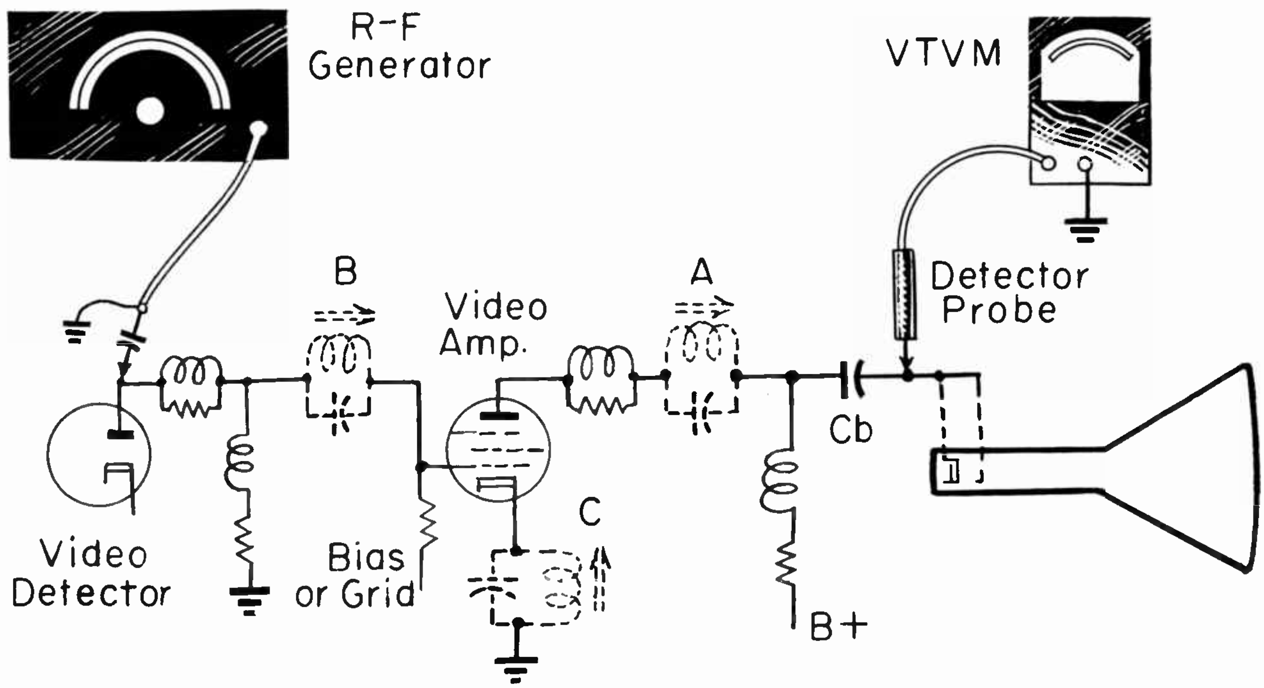

Fig. 15. Adjustment of 4.5-mc traps by use of a detector probe on the VTVM.

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output, as shown, although this connection may be on the other side of a peaker, or at the high side of the detector load resistor. Wherever the connection is made, use a series capacitor of about 1000 mmf on the high-side of the generator.

Connect the detector probe on the VTVM preferably to the picture tube signal input element. If you are sure that the probe will withstand d-c plate voltage on the video amplifier, the probe may be connected on the amplifier side of capacitor Cb. When there are two video amplifiers, with a trap between video detector and first amplifier, the probe may be connected to the plate of the first amplifier.

Do not connect the VTVM without a probe to an amplifier plate circuit for measurement then would be of d-c plate voltage and the 4.5-mc signal voltage would not be indicated.

It seldom would be satisfactory to use the a-c voltage function of the VTVM. On this function, most meters are insensitive to frequencies as high as 4.5 mc. Using a tone modulated signal does not help.

The procedure is as follows.

1. Use the signal generator without tone modulation. A modulated signal would, however, make no noticeable difference in test indications.

2. Tune the generator very precisely to 4.5 mc.

3. Commence with highest output from the generator and continue using high output.

4. Commence with a VTVM range of 10 volts or more, then drop to the lowest range for final adjustment.

5. Advance the contrast control at least as far as for normal picture reception, and somewhat higher during final adjustment.

6. Adjust the 4.5 mc trap for minimum or zero reading of the VTVM. This minimum or zero will be obtained between two higher voltages as the trap adjustment is turned one way and the other.

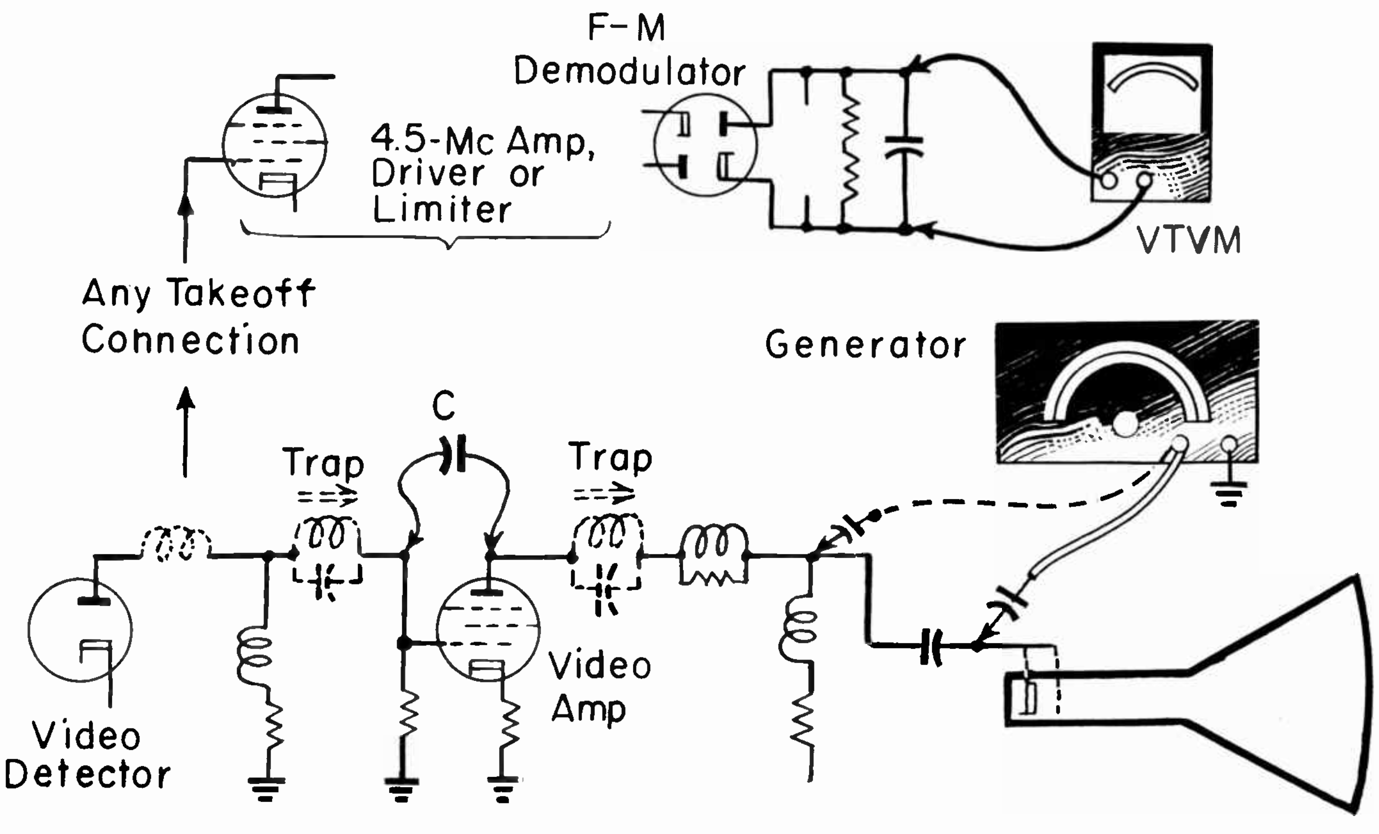

Fig. 16. Adjusting a 4.5-mc trap with a d-c output signal taken through the f-m demodulator.

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Fig. 16 illustrates a different method for adjusting the 4.5-mc trap. The test signal is fed through the trap to the sound takeoff, thence through the intercarrier sound section, and to a vacuum tube voltmeter used for indicator.

The generator is used unmodulated, is tuned precisely to 4.5 mc, and is connected through a capacitor of 1000 mmf or more to a point which is on the picture tube side of the 4.5-mc trap. Do not make this generator connection directly to the trap, but keep at least one peaker and possibly one or more capacitors between them - as a help to prevent detuning of the trap circuit.

If any video amplifier tube will be between the signal generator connection and the sound takeoff it must be bypassed. Remove the tube from its socket, then, as at C on the diagram, connect a fixed capacitor of 100 or more mmf from plate to grid lugs on the tube socket or between socket openings on top of the chassis.

Use the VTVM as a d-c voltmeter, without a detector probe. Connect the meter to the same points in the f-m demodulator circuits that would be used when aligning the sound circuits from takeoff to and including the demodulator transformer primary. That is, connect the meter where there will be an unbalanced d-c voltage at the center frequency of 4.5 mc, do not connect it to the audio output of the demodulator.

Test procedure is the same as with the method previously described. The contrast control may be advanced, although with many circuit arrangements it will make no difference. The 4.5-mc trap is adjusted for minimum voltage reading on the VTVM, between the higher voltages with the adjuster turned one way and the other.

It is possible to make an approximately correct adjustment of 4.5-mc traps with no instruments, using only a regularly transmitted television signal. The grainy and lined appearance due to the beat voltage first should be emphasized as much as possible. This may be done by advancing the contrast control, also by turning a fine tuning control slightly away from its position for best reception. Then the 4.5-mc trap is adjusted for minimum beat effect in the picture. There is least effect when horizontal trace lines appear straight and continuous from one side to the other of the picture tube screen. This will be accompanied by disappearance of the irregularly weaving vertical or sloping lines.

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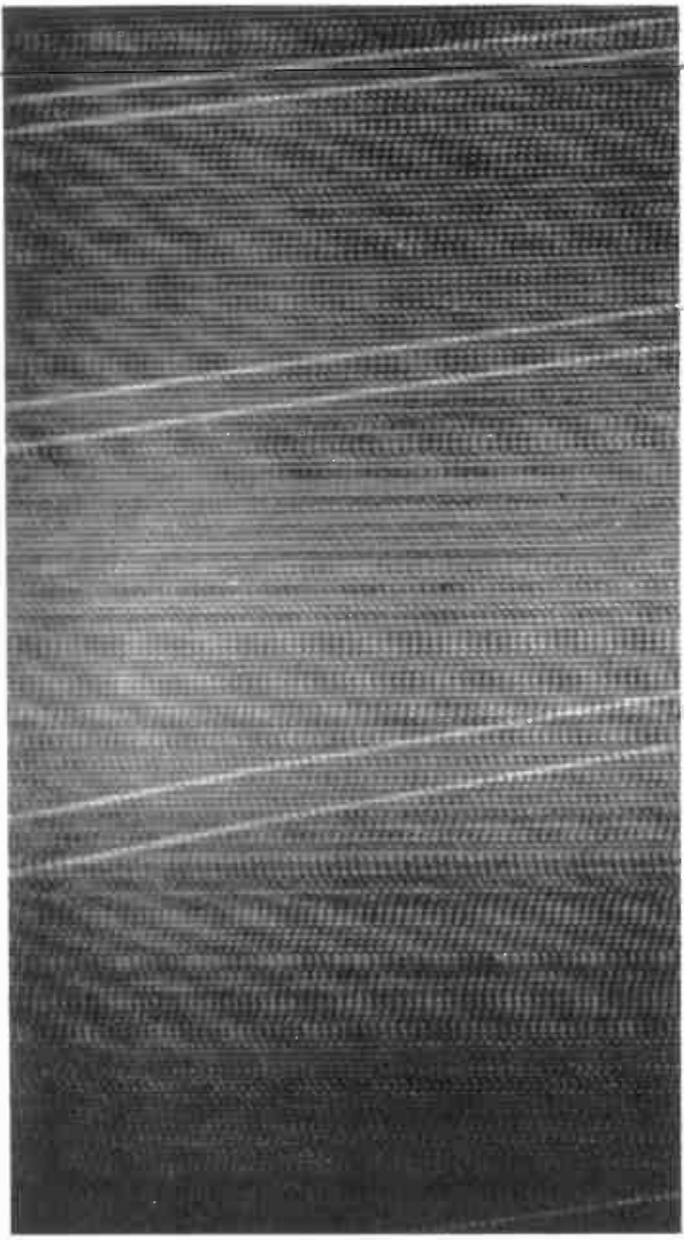

Fig. 17-A

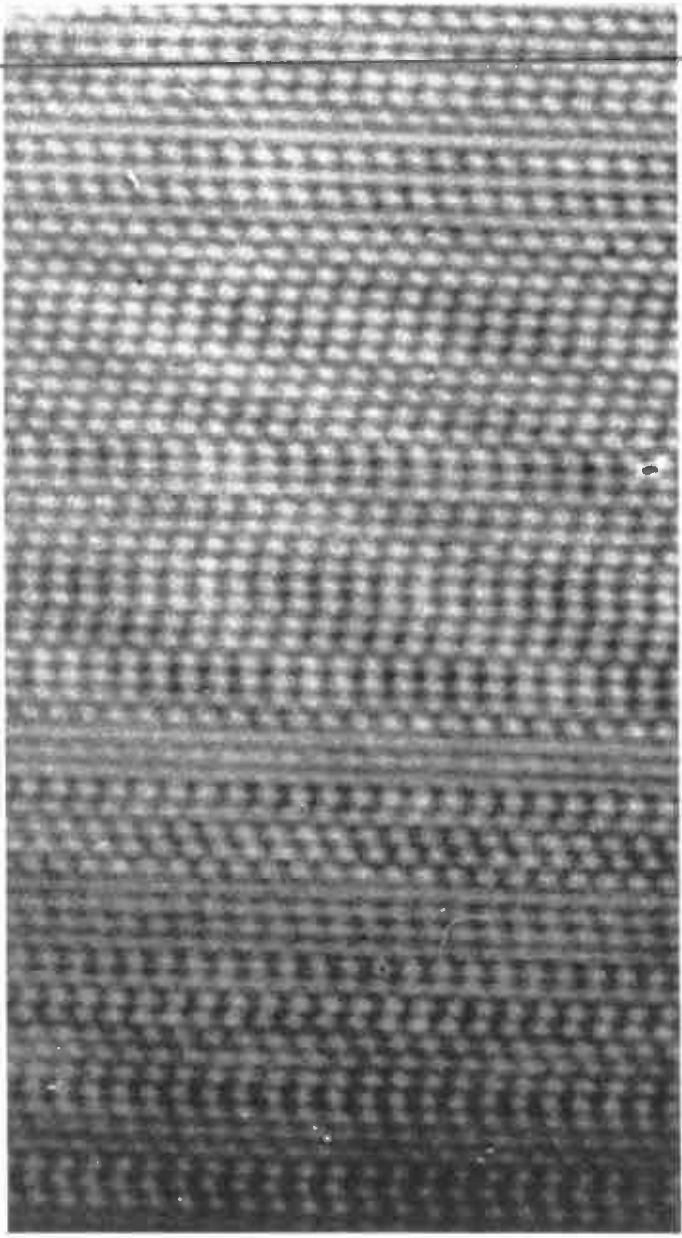

Fig. 17-B

Fig. 17. This is the effect on a raster, also on pictures, of allowing a 4.5-mc voltage to reach the grid-cathode circuit of the picture tube.

Fig. 17 will help you to recognize the effect of 4.5-mc voltage. At A is a view of a fairly large area of the picture tube screen, and at B is an enlargement of a small area. The effect illustrated was produced by a signal generator operating at 4.5 mc, and shows only the raster, not a televised picture. The same broken horizontal traces and irregular vertical lines appear on pictures suffering from the beat effect.

Should you wish to see this effect for yourself, to be sure of recognizing it, proceed thus: Connect the 4.5-mc signal generator to the video detector output, as explained earlier. Short circuit the trap terminals on each other, provided the trap does not connect to ground. Advance the contrast control beyond the setting for normal reception. Turn the brightness somewhat lower than for picture reception. Look at the result in a dimly lighted room.

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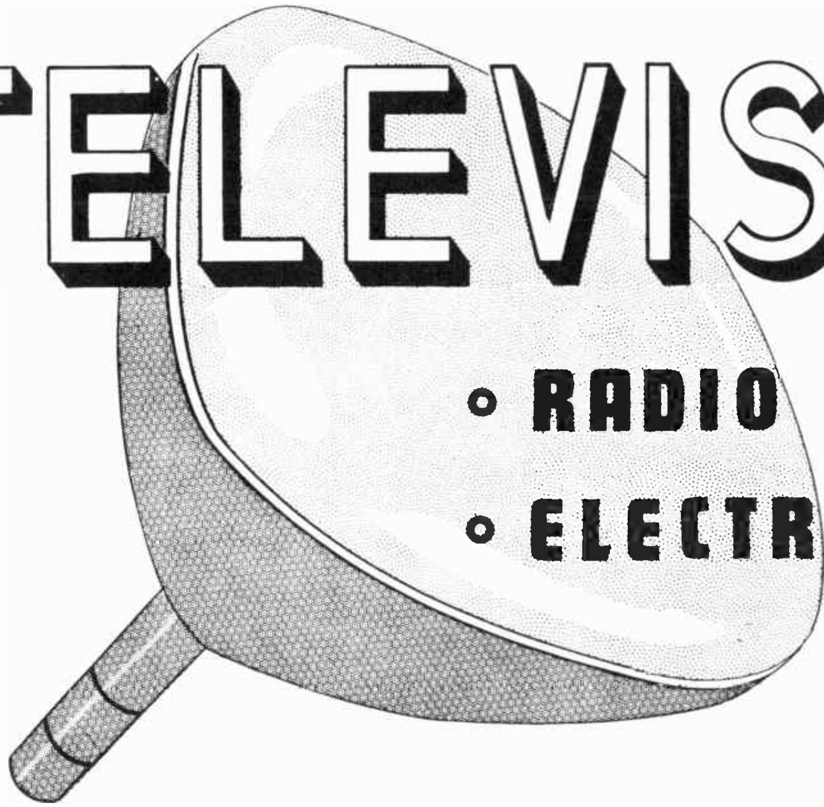

• RADIO
• ELECTRONICS

LESSON 61 – SOUND ALIGNMENT WITH THE OSCILLOSCOPE

Coyne School

practical home training

Chicago, Illinois

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Lesson 61

SOUND ALIGNMENT WITH THE OSCILLOSCOPE

Although the ratio detector is the most popular type of f-m demodulator, several other circuits are in use for the same purpose. One is the discriminator, used in the sound sections of most early television receivers and in a number of current models, also in many f-m broadcast receivers.

The most widely used discriminator circuit is shown by Fig. 2. There are two diode rectifiers, usually in the form of a twin diode tube but often in other combination tubes. Instead of connecting the transformer secondary to one diode plate and one diode cathode, as in a ratio detector, both ends of the discriminator transformer are connected to diode plates. Both diode cathodes are connected to the audio output side of the discriminator circuit. It is this different connection of diode elements that chiefly distinguishes discriminators from ratio detectors as they appear on service diagrams.

The discriminator transformer includes a primary and a center-tapped secondary which are inductively coupled. In addition to the f-m signal voltage induced in the secondary through inductive coupling, another f-m voltage is brought from the primary circuit into the secondary. In most discriminator circuits this other (in-phase) voltage from the primary is applied to the center tap through a small capacitor, C in the diagram.

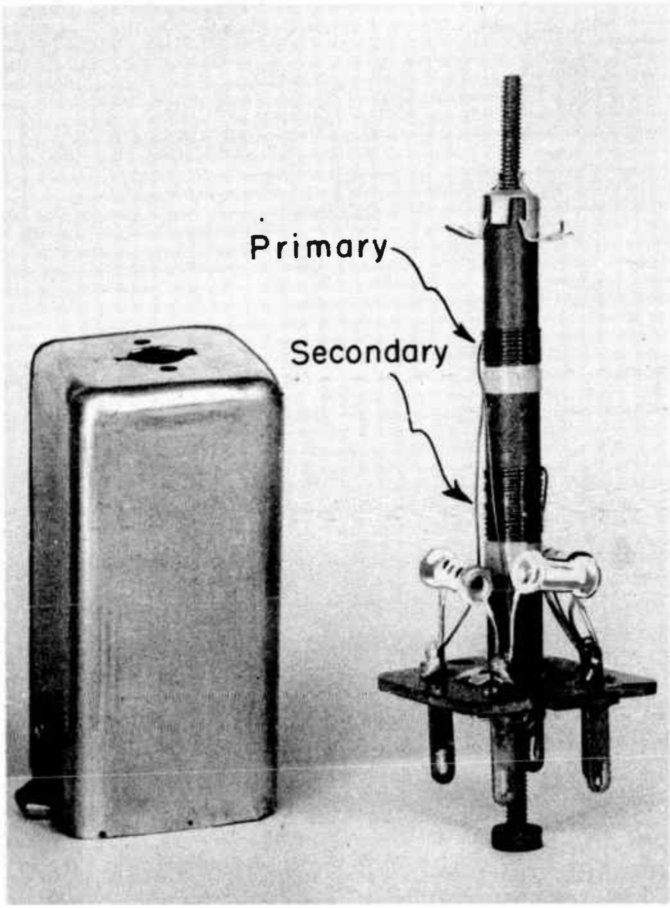

Fig. 1. A discriminator transformer removed from its shield.

In a few discriminator circuits the in-phase voltage from the primary is brought to the secondary center tap from a link coil

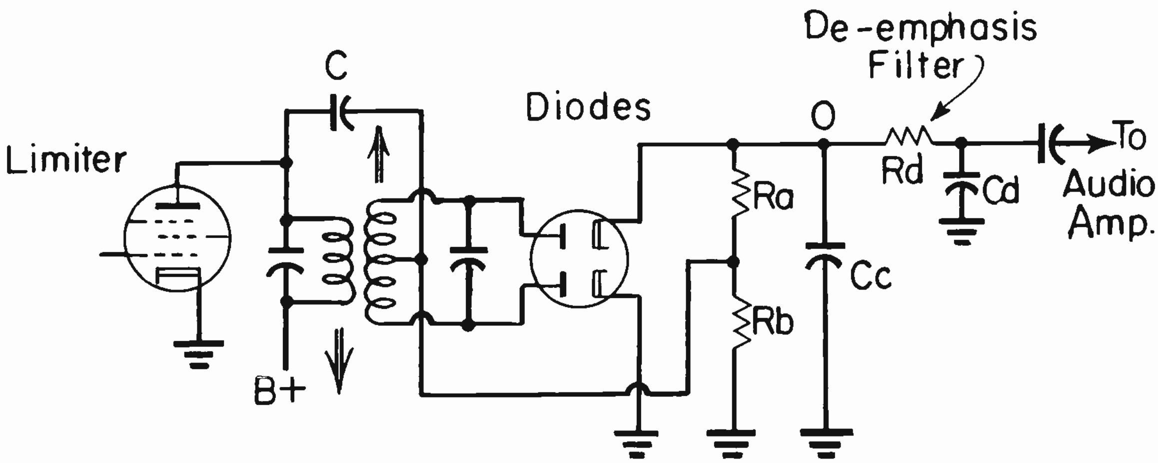

Fig. 2. A common form of discriminator circuit.

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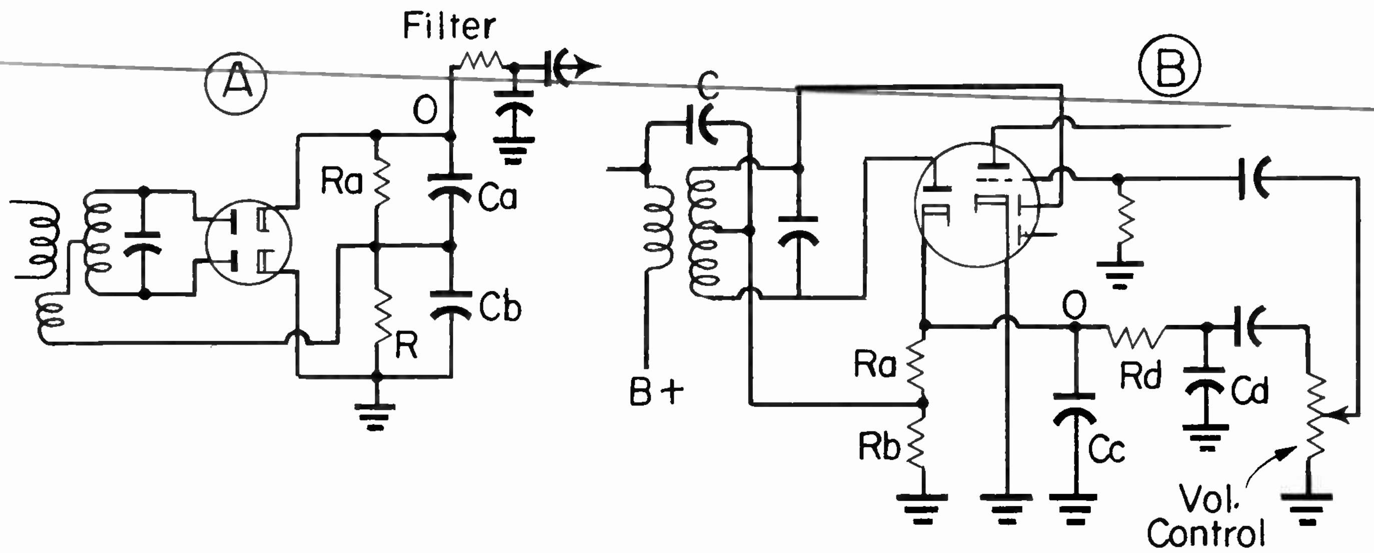

Fig. 3. Some modifications of the discriminator circuit.

inductively coupled to the primary, just as in a ratio detector transformer, and as shown at A of Fig. 3.

Diagram B of Fig. 3 shows an f-m demodulator tube combined with a triode audio amplifier in the form of a triple-diode-triode. There are two cathodes. One cathode, in connection with its associated diode plate, is used only for demodulator action. One of the diode plates on the other cathode is used for the demodulator circuit. This second cathode acts also with the grid and plate of the triode audio amplifier. Combination tubes of this general type may be used for ratio detectors as well as for discriminators.

On the output side of the circuit of Fig. 2 are load resistors Ra and Rb, usually of 100K to 120K ohms each. To the mid-connection between these resistors comes a lead from the center tap of the transformer. You will see these resistors also in Fig. 3. Across the two resistors usually is a single capacitor Cc, although two series connected and mid-tapped capacitors sometimes are used here, as at A of Fig. 3. Capacitance may be from 100 mmf to as much as 500 mmf.

The small capacitance or capacitances across the discriminator load resistances do not act like the large storage capacitance of the ratio detector. The discriminator capacitance will charge and discharge at the deviation frequencies. It is not large enough to maintain a fairly constant charge voltage with sudden changes of input amplitude, as in the ratio detector circuit.

The audio voltage output point is marked O on all our discriminator diagrams. Following this point is the de-emphasis filter, whose connections and action are the same as explained in connection with ratio detector circuits. In diagram B of Fig. 2 the audio circuit is complete all the way from point O through the de-emphasis filter, the audio volume control, and the triode audio amplifier.

So far as phase shifts with frequency deviations and the combining of out-of-phase voltages, action in the discriminator transformer is the same as in the transformer of a ratio detector. When deviation is to frequencies higher than the center frequency there is greater combined voltage across the upper half than across the bottom half of the transformer secondary, with connections shown by our diagrams. Deviation to lower frequencies causes more voltage across the bottom than across the top half of the secondary.

Voltage across the upper half of the transformer secondary causes one-way electron flow as shown by full-line arrows in Fig. 4. This one-way flow and its direction result from one-way conduction in diode A. Voltage across the bottom half of the transformer secondary causes one-way electron flow as shown by broken-line arrows, as determined by one-way conduction in diode B.

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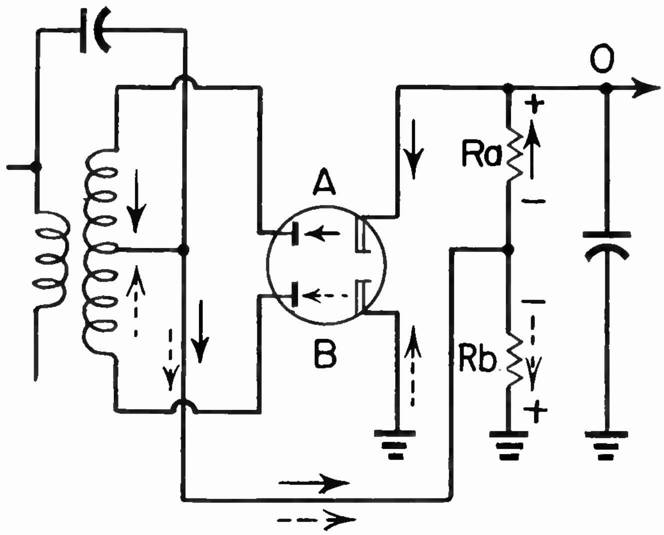

Fig. 4. Electron flows in the discriminator circuit.

Deviation to higher frequencies causes more electron flow and greater voltage across resistor Ra than across resistor Rb. Note that polarities across these two resistors are opposite and tend to cancel each other, due to opposite directions of electron flows. With greater voltage across Ra the net voltage or the difference between voltages must be positive at audio output point O, because the top of Ra is positive, and is toward point O. Consequently, deviation to higher frequencies causes audio output voltage to swing positive with reference to ground.

Deviation to lower frequencies makes voltage across resistor Rb greater than across Ra. Then the net voltage or the difference between voltages will have the polarity of resistor Rb. The end of Rb toward audio output point O is negative. Therefore, the lower deviation makes audio output voltage swing negative with reference to ground. When there is no deviation, and applied frequency is the f-m center frequency, currents and voltages in resistors Ra and Rb are equal. Net voltage is zero, and audio output voltage goes through zero. The final result of demodulation in the discriminator is the same as in the ratio detector, but is obtained in a different manner.

While a discriminator will demodulate f-m signals it will also demodulate variations of signal voltage amplitude, or will demodulate an a-m signal. Sudden changes of amplitude in incoming signals can cause variations of audio output voltage. The explanation follows.

Assume that a certain frequency deviation is producing 3 volts across resistor Ra and 1 volt across Rb. Audio voltage will swing positive by the difference, which is 2 volts. Any increase of amplitude in the applied f-m signal will increase currents and voltages proportionately in both halves of the discriminator circuit. Assume that voltages across the load resistors are doubled in this manner, and become 6 volts on Ra and 2 volts on Rb. Now the difference is 4 volts, and audio voltage swings positive by 4 volts instead of the former 2 volts. Thus audio output voltage is varied by amplitude of an f-m signal voltage reaching the discriminator.

Because the discriminator is sensitive sudden change or modulation of amplitude it always is preceded by a limiter. The limiter is needed to remove or greatly reduce sudden changes of signal amplitude, such as caused by noise.

DISCRIMINATOR ALIGNMENT WITH VTVM. A discriminator may be aligned by using either a vacuum tube voltmeter or an oscilloscope as the output indicator. The chief difference between aligning a sound section containing a discriminator and one containing a ratio detector is in the points at which you connect the VTVM or scope.

For discriminator alignment with a VTVM the meter is used as a d-c voltmeter, without a detector probe.

The signal generator is a constant-frequency r-f or marker type used without tone modulation. The high side of the generator is connected through 1000 mmf or greater capacitance to any of the points used when aligning a ratio detector sound system, as described in the preceding lesson.

During adjustment of the discriminator transformer primary and of all preceding couplings as far back as a tuned sound takeoff, the VTVM must indicate changes of amplitude or gain in the amplified f-m signal voltage at the center frequency. A d-c voltage varying with gain appears across either

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one of the load resistors, Ra and Rb on our diagrams. Therefore, the VTVM might be connected across either load resistor during this portion of the alignment process.

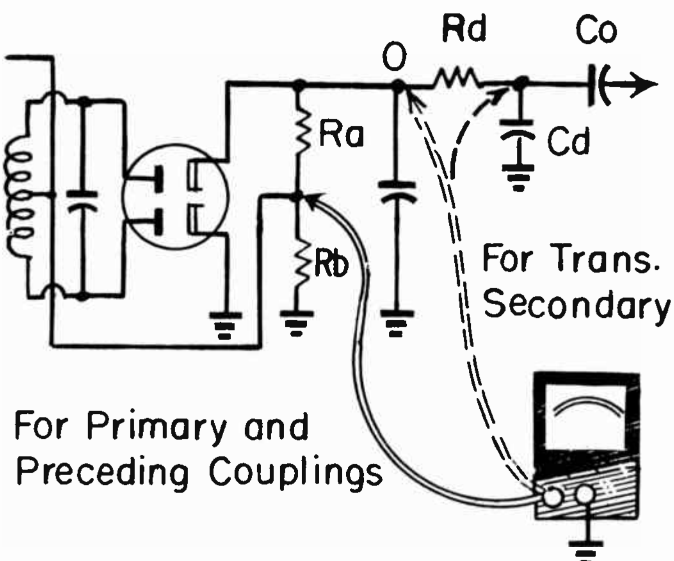

Fig. 5. Connection of a VTVM to the discriminator output for adjustment of the transformer and all the preceding couplings.

To obtain most stable and dependable voltage readings, connect the high-side of the VTVM to the mid-connection between the two resistors, as in Fig. 5, and connect the low side to ground. The high-side connection may be anywhere between the resistor junction and the lug or terminal on the transformer for its secondary center tap. The meter now is across resistor Rb. With this connection of the meter, adjust any tuned sound takeoff, all sound interstage couplings, and the primary of the discriminator transformer, each for maximum voltage reading. Use the weakest generator output that allows distinct voltage indications.

For adjustment of the discriminator transformer secondary the VTVM must indicate zero voltage when the input signal is at center frequency, because audio output voltage should be zero at this frequency. Such a voltage appears across the two load resistors in series, or, in our diagrams, between the top of resistor Ra and the bottom of Rb.

In practice, as shown by Fig. 5, connect the high side of the VTVM to audio output point O on the diagrams. Connect the low side to ground. It would do as well to make the high-side meter connection on the other side of resistor Rd in the de-emphasis filter. Do not make this connection to any point beyond capacitor Co, which goes to the volume control and audio amplifier. D-c voltage would not get through this capacitor.

With this connection of the VTVM, adjust the discriminator transformer secondary for a zero voltage reading which occurs between positive and negative voltages as the secondary adjuster is turned one way and the other from the zero-voltage position. Make this adjustment just as though you were working with a ratio detector transformer secondary.

Instead of connecting the VTVM to a point between the two load resistors for alignment of transformer primary and preceding couplings, the meter may be connected to the audio output for all adjustments. Then, to begin with, detune the transformer secondary slug one or two turns. This will allow meter readings while adjusting the transformer primary and preceding couplings for maximum voltage. Next, without changing the meter connection, adjust the transformer secondary for the zero voltage reading which occurs between positive and negative voltages as the adjuster is turned one way and the other.

After the primary and secondary of the demodulator transformer are adjusted by any method which employs a VTVM make this final check. Leave the VTVM connected to the audio output. Tune the signal generator far enough above the center frequency to obtain a peak VTVM voltage of one polarity, and note this voltage. Then tune below the center frequency for a peak voltage of opposits polarity, and note this voltage. The two peak voltages should be equal within 25 to 30 per cent at most. Otherwise make slight readjustments of transformer primary and secondary to more nearly equalize the peaks. This was done also when aligning ratio detectors.

We aligned ratio detector sound sections without a signal generator, with only a received television signal as the source of f-m voltage and a VTVM as output indicator. This method, outlined in the following para-

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graph, may be used with a discriminator sound section.

Tune the receiver for best picture reception on any channel. Turn off the receiver and, without changing its controls, connect the VTVM as in Fig. 5. With a connection to the mid-point between resistors Ra and Rb, turn on the receiver, then adjust preceding couplings and the primary of the demodulation transformer for maximum voltage. Shift the VTVM connection to the audio output and adjust the secondary for zero reading, and for least buzzing sound when the contrast control is advanced.

For alignment of only a tuned sound takeoff and an interstage coupling between the first sound amplifier and the limiter, the VTVM may be connected across the limiter grid resistor, as mentioned for alignment of ratio detector sound systems. Then the takeoff and the coupling ahead of the limiter are aligned for maximum voltage on the VTVM.

SOUND ALIGNMENT WITH THE OSCILLOSCOPE

Instead of using a constant-frequency signal generator and VTVM, the entire sound section or any part of it may be aligned with sweep and marker generators as signal sources and with an oscilloscope as output indicator.

The sweep generator must be capable of operating at a sweep width at least as narrow as 1 mc or 1000 kc, and preferably even narrower. The marker generator must be accurate to at least the degree specified earlier for constant-frequency r-f generators. This means crystal control or crystal calibration.

Connect sweep and marker generators to the same points used for the r-f generator when the output indicator is a VTVM. Make the sweep connection through about 10 to 100 mmf capacitance, and the marker through 2 to 20 mmf.

When sound takeoff is from the video detector output, connect the generators to the video detector output circuit. If takeoff is from the plate circuit of a video amplifier, connect the generators to the grid of that amplifier. Do not connect the generators ahead of the video detector, on the video i-f amplifier side, for the detector would not pass both polarities of the generator voltage. The generator connections specified remain unchanged for all adjustments, including the primary and secondary of the demodulator transformer.

Stage-by-stage alignment, if necessary due to extreme misadjustment, may be carried out in the same general manner as for i-f amplifiers. First, for adjustment of primary and secondary of the demodulator transformer, connect the generators to the grid of the tube which precedes this transformer. Then move the generator connection back, stage-by-stage while adjusting couplings, until reaching the sound takeoff.

ALIGNMENT OF TAKEOFF TO DEMODULATOR PRIMARY. For alignment of a sound takeoff, any and all sound interstage couplings, and the primary of a ratio detector transformer, the oscilloscope may be connected in either of the ways shown by Fig. 6. Either method may be used with any ratio detector circuits which have been shown in lesson diagrams.

At A a detector probe is attached to the vertical input of the scope. The probe is placed on the demodulator diode plate pin that is connected to the secondary of the ratio detector transformer. If you are in doubt, check the pin numbers of the two diode socket lugs which are connected to the transformer, look up the basing of the demodulator tube, and make your connection to the diode plate, not to the cathode. The actual connection may be at the tube socket, the transformer terminal, or anywhere between.

With the method illustrated at B of Fig. 6 we do not need a detector probe on the scope. One side or the other of the storage capacitor Cs must be temporarily disconnected and left free during adjustments. Were the storage capacitor left connected it would absorb or smooth out the 60-cycle sweep variations and no useful trace would appear on the scope.

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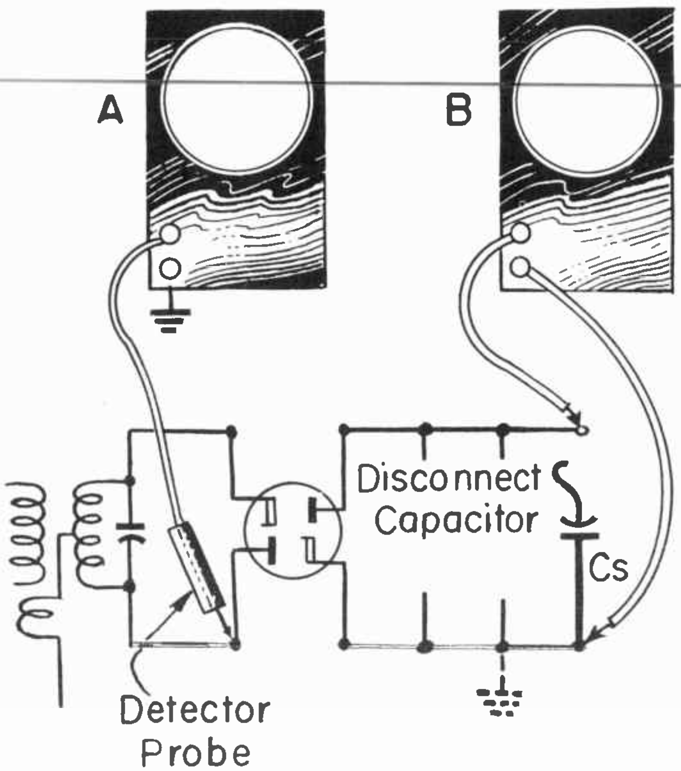

Fig. 6. Oscilloscope connections for aligning the ratio detector transformer primary and all preceding couplings.

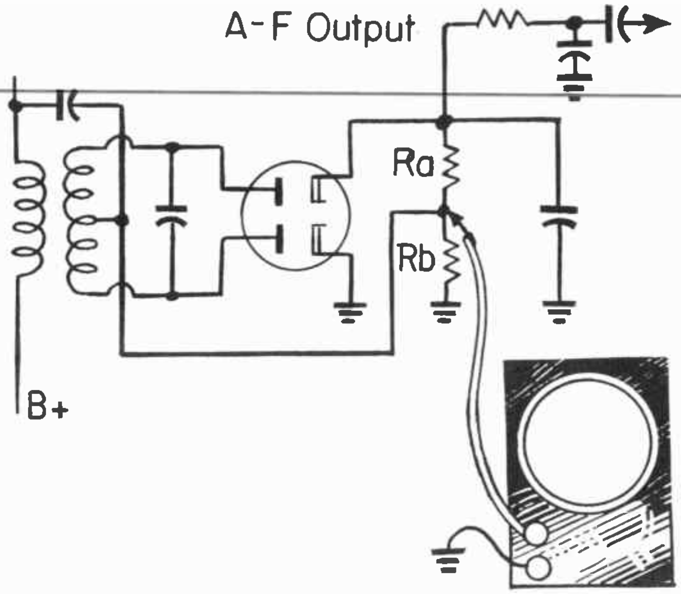

Fig. 7. Oscilloscope connection for alignment of the discriminator primary and all preceding couplings.

If the diode-cathode side of the storage capacitor circuit is grounded, connect the low side of the scope to ground. Otherwise the scope case must be insulated from all grounds, and the scope may be connected either way around. While the storage capacitor is disconnected, scope connections may be made anywhere along conductors running between capacitor terminal points and diode socket lugs.

When the demodulator is a discriminator the scope connection is made as in Fig. 7 for alignment of everything from takeoff to and including the primary of the discriminator transformer. Connect the high side of the scope vertical input to the junction between the two load resistors, and the low side to ground. This places the scope across load resistor Rb in the diagram, which is grounded at one end. Results will not be as good with the scope across the other, ungrounded, load resistor, although this connection could be used. Note that no detector probe is used on the vertical input of the scope.

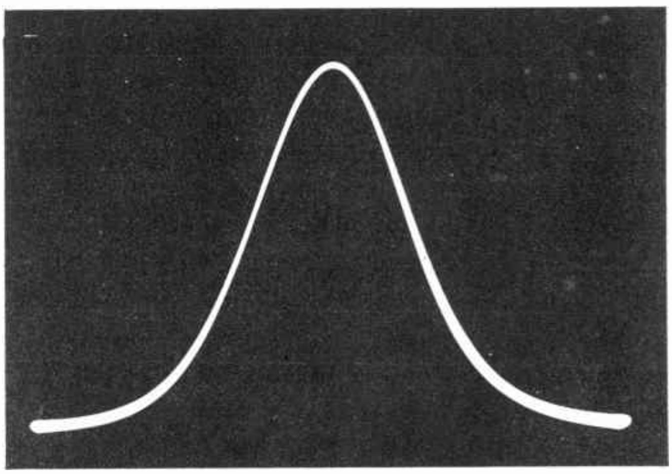

Fig. 8-A

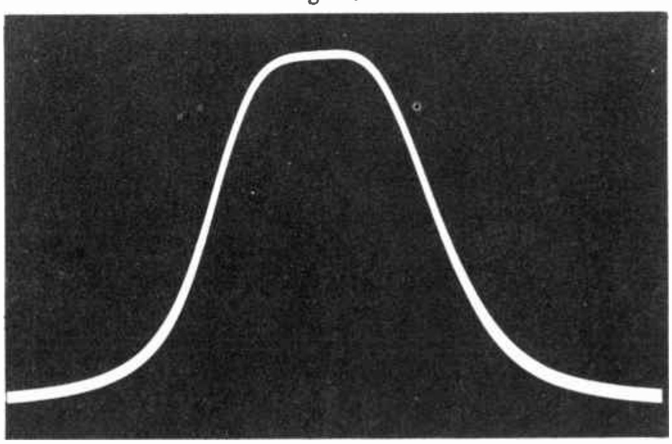

Fig. 8-B

Fig. 8. Typical frequency responses of circuits from the sound takeoff to and including the demodulator transformer primary.

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With sweep and marker generators and the oscilloscope connected according to instructions, turn on the instruments and receiver for a reasonable warmup time. Then it should be possible to bring onto the scope screen a response trace of the general form illustrated by Fig. 8. At A the response is rather broadly peaked (the entire sweep is 200 kc) while at B the response is slightly flat-topped. Proceed in this manner.

1. If possible, use synchronized sweep voltage on the scope. If synchronized sweep is not available, use the internal sweep at 60 cycles.

2. Adjust generator sweep width for about 1 mc. Set the attenuator for high output. Tune the generator center frequency back and forth around 2 to 5 mc until a curve of some kind appears on the scope screen.

3. Reduce sweep generator output until the trace is about half of screen height.

4. With internal sweep there will be two or more response curves. Use the horizontal gain and position controls of the scope to enlarge and center one complete response.

5. Adjust generator sweep width to obtain a complete response with flat parts at zero gain on both sides. This is shown by Fig. 8.

6. During following adjustments keep vertical gain of the scope at maximum. Reduce sweep generator output to prevent excessive trace height. It is best to keep sweep generator output low enough to prevent limiting. You can tell when there is no limiting by the fact that small changes of sweep generator output then cause proportional changes of trace height.

7. Try out the marker generator in producing marker pips on the trace. Pips may be excessively wide when using a narrow sweep, with which each cycle of marker frequency extends over quite a bit of the total sweep. Sharpen the marker by using a bypass capacitor from the high side of the scope vertical input to ground. This may require capacitance of 0.01 to 0.10 mf.

8. Commence with adjustment of a tuned takeoff, if one is used. Follow with adjustment of interstage couplings, and finally of the demodulator transformer primary. Obtain a response as nearly as possible of the following description.

A. Maximum gain or maximum trace height, with other requirements satisfied.

B. The peak, or the center of a flat top, must be at the f-m center frequency, which would be 4.5 mc with intercarrier sound, or the sound intermediate frequency for dual sound.

C. The top of the response may be broadly peaked, flat-topped, or slightly double peaked, as shown by Fig. 9. If there are two peaks, the valley between them must be very shallow, dropping to not less than about 90 per cent of maximum peak height.

D. Opposite sides or skirts of the response should be symmetrical, slopes should be of the same form in opposite directions.

E. Desirable band width requirements, shown by Fig. 9, are as follows. Gain or trace height should be practically uniform to more than 25 kc each side of the f-m center frequency, for a total width of more than 50 kc. Total width may be 100 to 150 kc at 90 per cent of maximum height, may be 200 to 250 kc at 70 per cent of maximum height, and may go to 350 kc or more half way down the slopes.

With interstage transformers of the double-tuned variety, it is usual to adjust the secondary and then the primary of each transformer as you come to it. Should response peaks become abnormally high or ragged, regeneration and oscillation are indicated. Turn off the receiver, reduce the sweep generator output, and begin over again.

DEMODULATOR SECONDARY ADJUSTMENT. For alignment of the secondary in the demodulator transformer, whether you have a ratio detector or a discriminator, connect the vertical input of the scope between the audio output point and ground, without a detector probe. This connection may be ahead of the de-emphasis filter resistor, it

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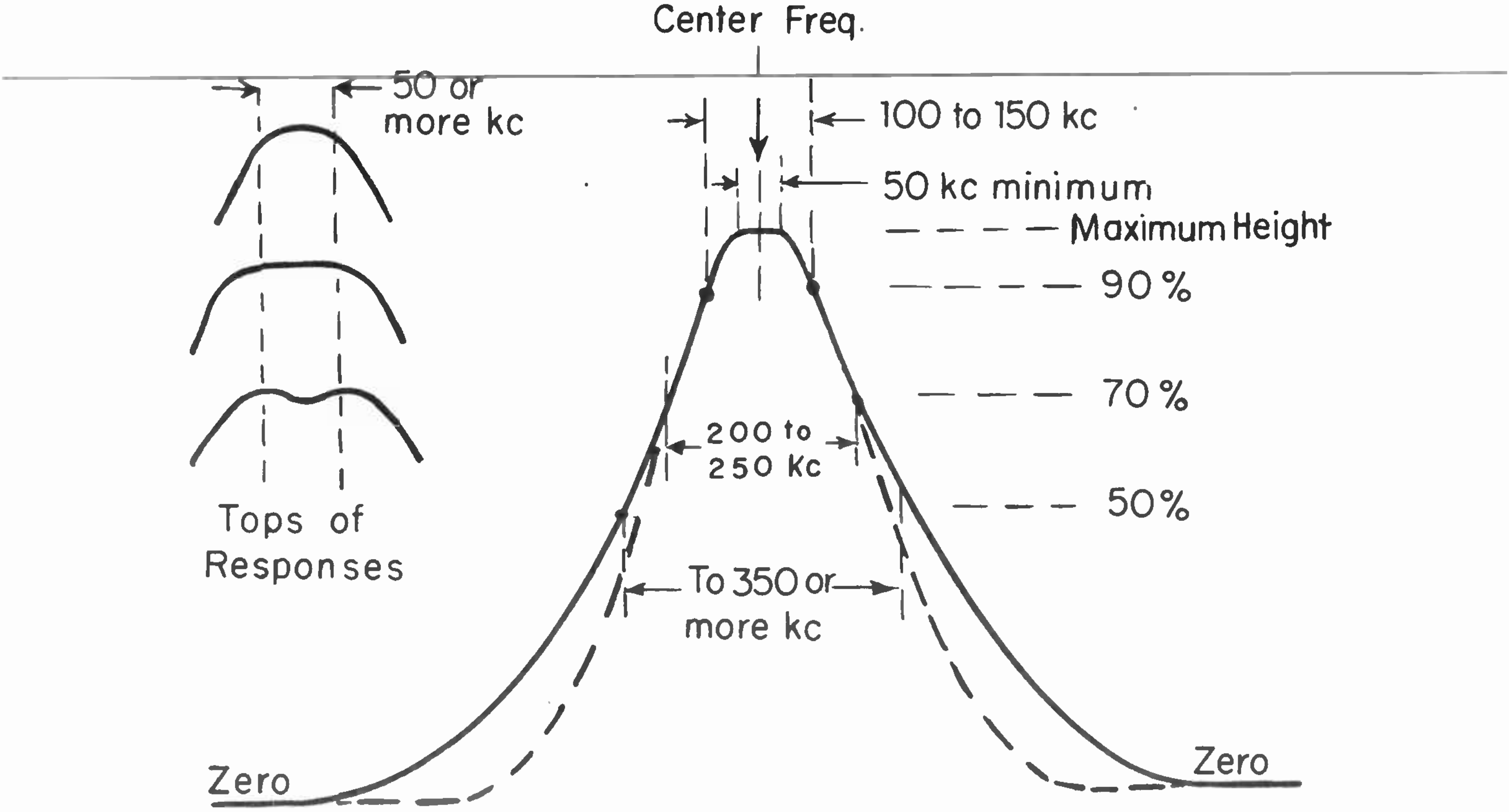

Fig. 9. Characteristics of the frequency response for all circuits from takeoff through the demodulator transformer primary,

may follow this resistor, or may be beyond the capacitor in the lead going to a volume control and audio amplifier. Use the connection giving the cleanest scope curve with least displacement of forward and return traces when using synchronized sweep.

After completing adjustments of circuits preceding the demodulator secondary it usually is necessary only to shift the scope connection in order to have an "S-curve" appear on the screen. Otherwise a slight readjustment of sweep generator center frequency should bring such a curve into view.

A complete S-curve appears as in Fig. 10. Assuming that sweep frequency increases from left to right, the curve shows this performance: At the flat portion of the trace on the extreme left the sweep frequency is so low that the demodulator tube and circuit provide zero gain. The trace commences to go negative where sweep frequency becomes high enough for the demodulator to provide some gain. At the negative peak there is maximum gain in this polarity.

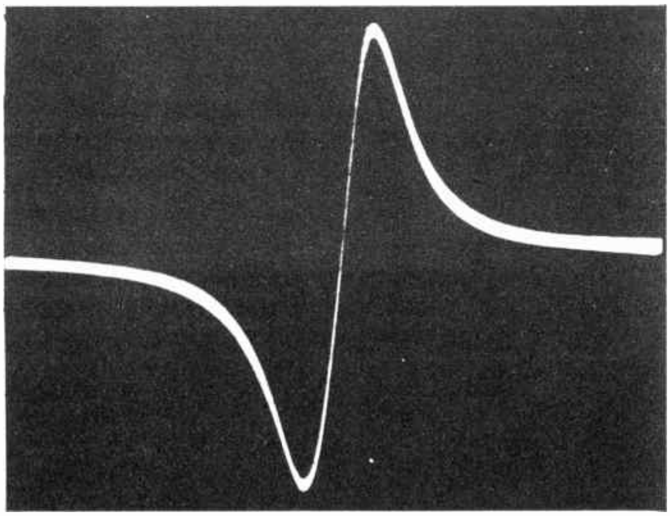

Fig. 10. An S-curve produced at the audio output of either a ratio detector or a discriminator.

Now we come to the action which allows f-m demodulation. With sweep frequency still increasing, gain decreases and the response goes from negative toward zero gain, at the center. When sweep frequency becomes equal to f-m center frequency the

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gain of the demodulator circuit is zero, and the trace reaches zero.

Increase of sweep frequency above the f-m center frequency results in an increase of gain in positive polarity. At a sweep frequency as far above center as that below center for a negative peak, we have a positive peak. With still further increase of sweep frequency the demodulator circuit loses sensitivity or gain, and response drops back to zero at the right-hand end of the trace.

Program sound signals utilize only a small portion of the S-curve. The useful part of the response extends only from the center zero, at f-m center frequency, as far as signal frequency deviations below and above this point. Television deviation goes only to 25 kc below and 25 kc above the center frequency.

The complete procedure for adjustment of the demodulator transformer secondary is as follows.

1. Adjust sweep width for more than 1 mc to begin with. Set the sweep generator attenuator for high output. Tune the generator center frequency back and forth near the f-m center frequency until some kind of S-curve appears on the scope.

2. Adjust vertical gain of the scope for maximum. Reduce sweep generator output for satisfactory trace height. Reduce sweep width to widen the S-curve, while readjusting sweep center frequency to keep the entire curve on the screen.

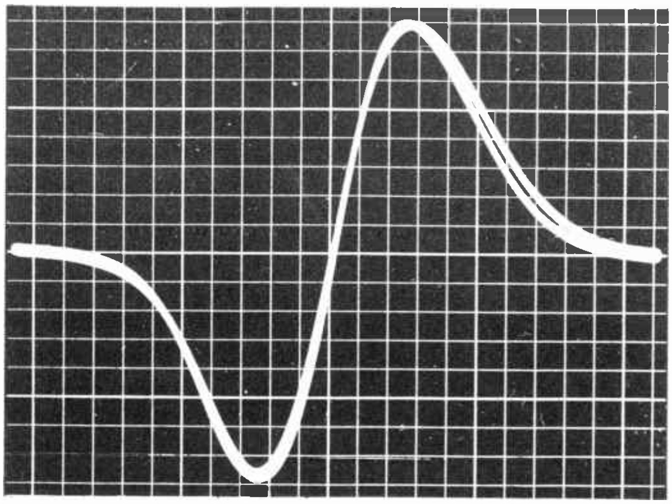

Fig. 11. With a graduated scale, the point of zero gain on the slope of the S-curve is in line with zero gains on opposite sides of the curve.

3. It is advisable to use a transparent ruled and graduated scale in front of the scope screen. Use the vertical position control to bring both outer zeros of the trace onto the same horizontal line of the scale, as in Fig. 11. Then this horizontal scale line crosses the central slope of the response at the point of zero gain, a point otherwise difficult to identify.

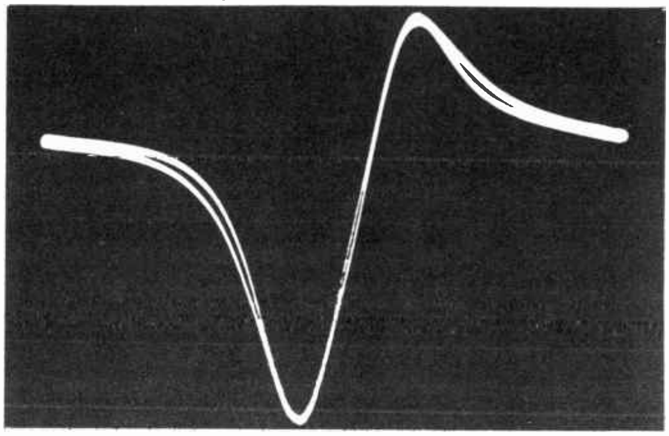

Fig. 12-A

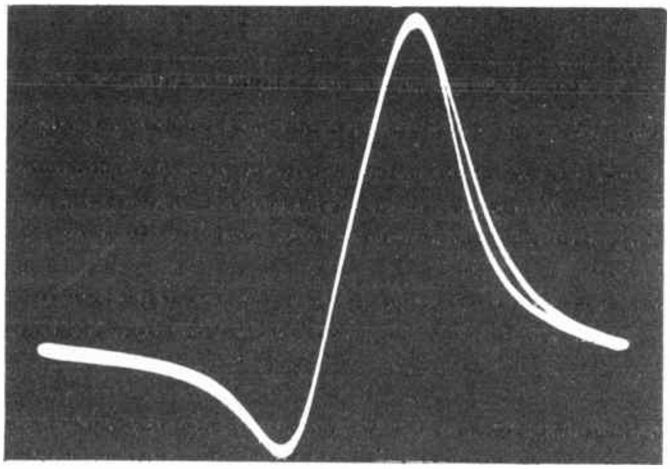

Fig. 12-B

Fig. 12. Misadjustments change the peak amplitudes and move the center of the S-curve slope away from the point of zero gain.

4. Make adjustments such that the S-curve satisfies requirements listed in the accompanying table. At the right of the requirements are three columns. The column headed I-S refers to adjustments of interstage and sound takeoff couplings. The one headed PRI refers to adjustment of the demodulator transformer primary. The column headed SEC refers to transformer secondary adjustment. A large X in any column indicates that this adjustment has a major effect on the accompanying requirement. A small x indicates a minor effect.

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S CURVE REQUIREMENTS	I-S	PRI	SEC
The two peaks should be of equal amplitudes, below and above zero. See Fig. 12, which illustrates effects of misadjustment.	x	x	X
The amplitudes or heights of peaks below and above zero should be as great as possible, indicating maximum gains.	X	x	
The central slope between peaks should be straight at least to points beyond maximum f-m signal deviations. This is affected largely by gains in circuits between sound takeoff and demodulator transformer.	X		
Frequency separation between negative and positive peaks may be from 100 to more than 500 kc in various receivers. It is affected by circuit design, by high- or low-Q, by degrees of coupling, and so on.	x	x	x
The exact center of the long slope between peaks should be precisely at the f-m center frequency, as identified by the marker generator.	x	x	X

It is difficult to see a marker pip at the center or zero-gain point of the long slope between peaks on an S-curve, because at zero gain the marker voltage gets no amplification. There are several ways of handling this problem. One method is to advance the marker generator attenuator until a pip does show, regardless of how much the S-curve is distorted or flattened. Then adjust the sweep center frequency to bring the center of the marker pip onto the vertical center line of a ruled scale in front of the CRT of the scope. Next, attenuate or turn off the marker and adjust the circuits to bring the center of the long slope to the vertical center line of the scale.

With another method the marker frequency is shifted a little below and then a little above the f-m center frequency while noting the appearance of the pip as it moves away from center toward either peak. Next, tune the marker to the exact f-m center frequency. Turn the transformer secondary adjuster one way and the other to make the pip appear first toward one peak and then toward the other. Leave the adjuster where the pip becomes zero or minimum in size, between its appearance below and above the center.

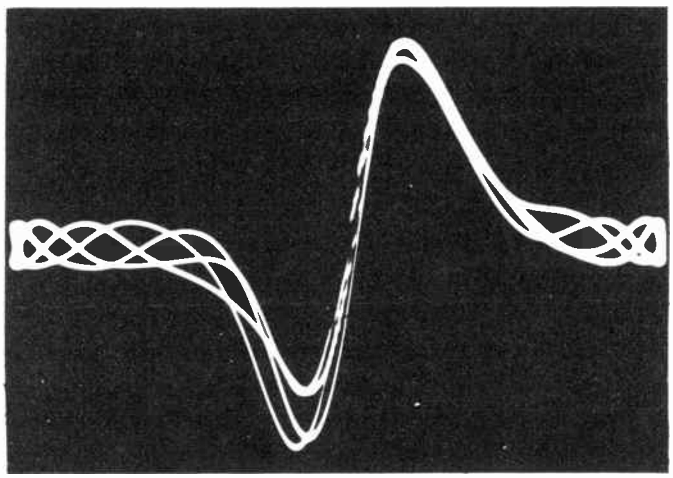

Fig. 13. Waviness on an S-curve caused by tone modulation of the marker generator while the S-curve center is not at the point of zero gain.

A better way is to use audio or tone modulation on the marker generator while the generator is tuned precisely to the f-m center frequency. So long as the transformer secondary is out of adjustment, the tone modulation will cause a continual waviness on both sides of the S-curve trace, or over the entire trace if modulation percentage is high enough. The effect is illustrated by Fig. 13.

Adjust the demodulator transformer secondary, and other sound circuits if neces-

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sary, to make the waviness disappear or reduce to a minimum. When this has been accomplished, the center of the S-curve slope is at the f-m center frequency. The waviness disappears because there is zero gain at the frequency of the modulated marker.

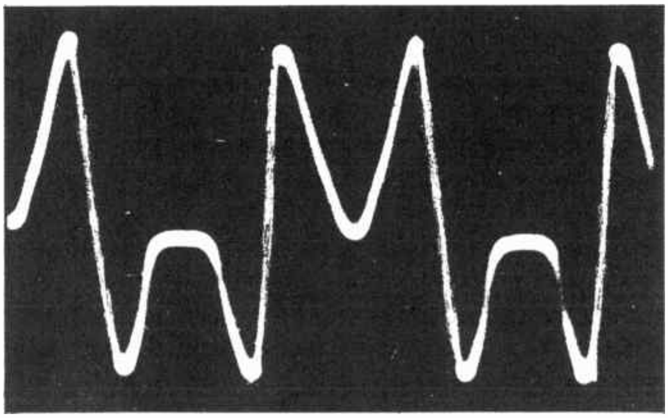

Fig. 14-A

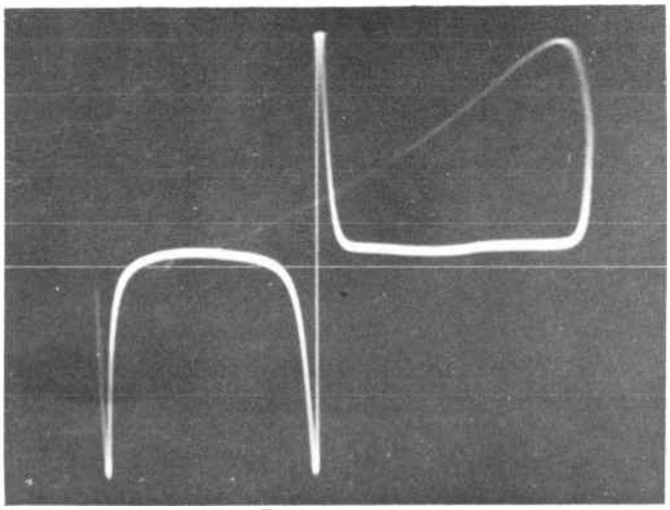

Fig. 14-B

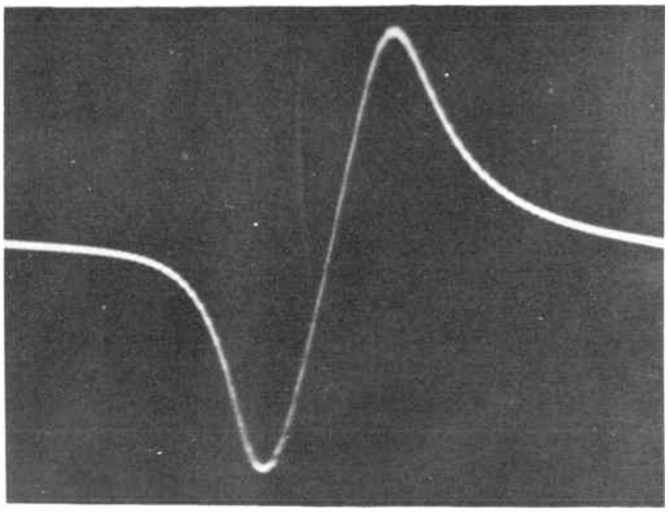

Fig. 14-C

Fig. 14. How the S-curve is produced when using internal sweep of the oscilloscope.

The whole process of demodulator transformer adjustment becomes a matter of working with primary and secondary adjusters until desired results are obtained, assuming, of course, that preceding sound circuits have been correctly aligned.

If you use internal sweep rather than synchronized sweep for the scope, commence with the sweep rate adjusted to bring one or two complete sweep-frequency cycles onto the screen. With 30-cycle internal sweep there will be two complete cycles, as at A of Fig. 14, and with 60-cycle sweep rate there will be one complete cycle (two S-curves) as at B. One S-curve of each cycle is traced while sweep generator frequency increases, and the other while sweep frequency decreases. Use horizontal gain and centering controls of the scope to widen and center one S-curve, as at C. Then proceed as outlined earlier.

ALIGNMENT WITH X-CURVES. Adjustment of the demodulator transformer sometimes is carried out by using what may be called X-curves or "crossover" curves instead of S-curves. A nearly complete X-curve is shown at A of Fig. 15, while the central portion usually employed during alignment is illustrated at B.

An X-curve is two S-curves, with one reversed and superimposed on the other. One curve is traced while sweep frequency is increasing, and the other while this frequency is decreasing. When generator sweep rate is 60 cycles, as usually is the case, horizontal sweep rate in the scope must be at 120 cycles.

A synchronized 120-cycle horizontal internal sweep rate is provided by some oscilloscopes, and is available from some sweep generators for application to the horizontal input of a scope. In any case there must be means for synchronizing and phasing this 120-cycle horizontal sweep with the 60-cycle frequency sweep rate of the generator. Attempts to use the internal sync of a scope, or to use an external audio generator for the 120-cycle sweep voltage, seldom result in satisfaction. Lack of synchronization may affect the X-curve and its crossover point in much the same manner as adjustments of receiver circuits.

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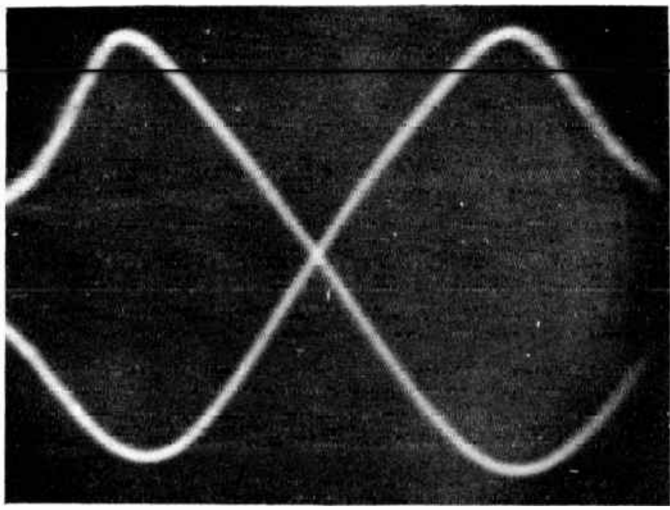

Fig. 15-A

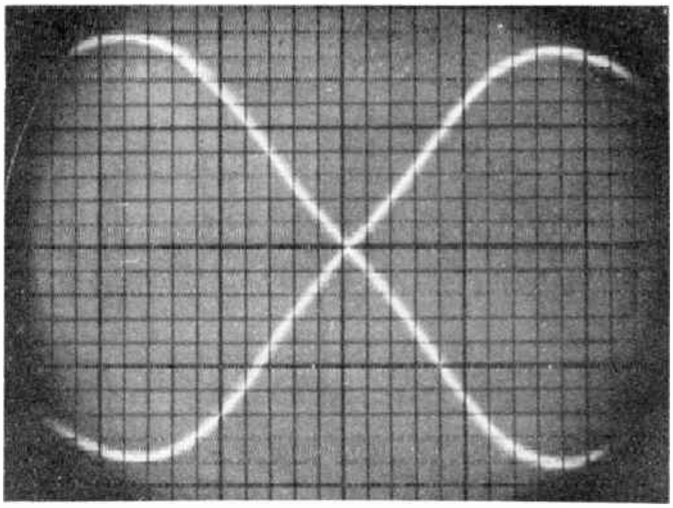

Fig. 15-B

Fig. 15. X-curves with crossovers at zero gain and at f-m center frequency.

With suitable instruments correctly adjusted, the X-curve allows rapid f-m alignment. When the crossover of forward and return traces is at the center and at the point of zero gain, and when slopes and peaks are symmetrical around the point of crossover, adjustments are correct. Transformer primary and preceding couplings are adjusted for maximum amplitudes of peaks. The crossover will moveup and down as the secondary adjustment is altered.

4.5 MC TRAP ADJUSTMENT. Because a 4.5-mc trap, when used, always is somewhere between the signal output of the video detector and the signal input to the picture tube, this trap always will have a decided effect on frequency response of the video amplifier section. Therefore, while adjusting the 4.5-mc trap, it is an advantage to watch the video amplifier response on the oscilloscope. So that you won't have to refer to earlier instructions for observing a video amplifier response, the entire process is outlined here.

1. Oscilloscope. Use a detector probe on the vertical input. Connect the probe to the signal input element, grid or cathode, of the picture tube. If the probe is capable of withstanding the d-c plate voltage it may be connected to the plate circuit of the final video amplifier at a point beyond the 4.5-mc trap. Otherwise, when connecting a probe to the plate circuit, make the connection through a series capacitor rated at 500 volts or more, and of capacitance no greater than 1000 mmf. Use the oscilloscope with synchronized sweep.

2. Sweep generator. Connect the high side of this generator through about 1000 mmf to any point at which the generator output would be connected for alignment of a sound section.

3. Marker generator. Connect the high side through about 100 mmf to the same point as the sweep generator. Tune the marker precisely to 4.5 mc.

4. Remove the final i-f (video) amplifier tube or shunt its output with about 300 ohms resistance. Otherwise the response trace may show only high-frequency pulses.

5. Remove or disable the horizontal sweep oscillator tube. Otherwise the response trace may be made fuzzy by the 15.75-kc horizontal sync pulses.

6. Remove or disable the vertical sweep oscillator tube, or else carefully adjust the vertical hold control to prevent continual up and down movement of the trace.

7. Advance the contrast control to maximum or nearly to maximum.

8. Adjust vertical gain of the scope to maximum.

9. Adjust generator sweep width to between 5 and 6 mc. Tune the generator center frequency back and forth through 4.5 mc to

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bring a response curve onto the scope. Readjust generator sweep width, and on the scope readjust horizontal size and position to bring a complete video response onto the screen. Adjust sweep generator output for suitable height of the trace.

10. Adjust marker generator output to show a marker pip on the response trace.

11. Adjust the 4.5-mc trap until the lowest point on the high-frequency side of the response is at the 4.5-mc marker.

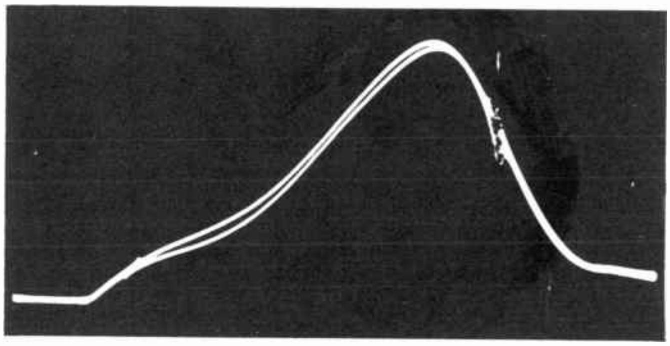

Fig. 16-A

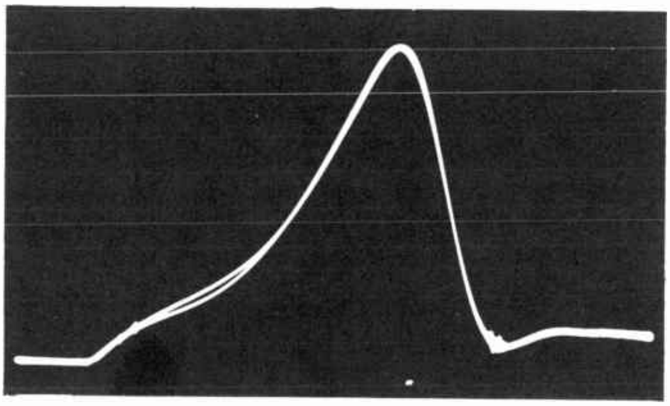

Fig. 16-B

Fig. 16. A video amplifier frequency response before and after insertion of a correctly adjusted 4.5-mc trap in video amplifier circuits.

At A of Fig. 16 is a video amplifier response set up on the screen of the scope in accordance with preceding instructions. A 4.5-mc marker pip is about half way up on the high-frequency slope of the response, because the trap has been temporarily shorted out of circuit. Since the 4.5-mc frequency is at a point of considerable gain on the response, a 4.5-mc voltage getting into the video amplifier system would cause a strong beat effect in all pictures.

The trace at B shows the result of reinserting the 4.5-mc trap and adjusting it correctly. Response or gain at this frequency has been brought nearly to zero, where the marker pip is barely visible. The 4.5-mc beat effect in pictures will be unobjectionable, yet video amplifier response remains high to nearly 4.0 mc, a desirable condition.

It would be easier to see the marker pip and the accompanying dip in the trace by viewing only that portion of the response at and near the 4.5-mc point. This may be done by reducing the sweep width to about 1 mc, by widening the trace with the horizontal gain control, and centering the 4.5-mc point with the horizontal position control of the scope.

A method more commonly used for adjusting a 4.5-mc trap is illustrated by Fig. 17. The oscilloscope is here used only as a sensitive voltmeter, in connection with a tone modulated constant-frequency generator. The steps are as follows.

1. Signal generator. Use a constant-frequency r-f or marker type generator, with tone modulation of at least 30 per cent and preferably more. Tune the generator to precisely 4.5 mc. Connect the generator high side through a capacitor to any point mentioned earlier for trap adjustment with a VTVM, just so that the generator connection is ahead of any 4.5-mc trap.

2. Oscilloscope. Use a detector probe on the vertical input. Connect the probe directly to the grid or cathode signal input of the picture tube, or, through a high-voltage protective capacitor to a video amplifier plate circuit. The scope connection must follow the 4.5-mc trap.

3. Remove the final i-f amplifier tube, which is ahead of the video detector, or shunt its output with about 300 ohms resistance.

4. If bothersome fuzziness or pulses appear on the trace, remove or disable the horizontal sweep oscillator and, if necessary, the vertical sweep oscillator. This may not be necessary, since we will be interested only in height of the scope trace, not in its form or clarity.

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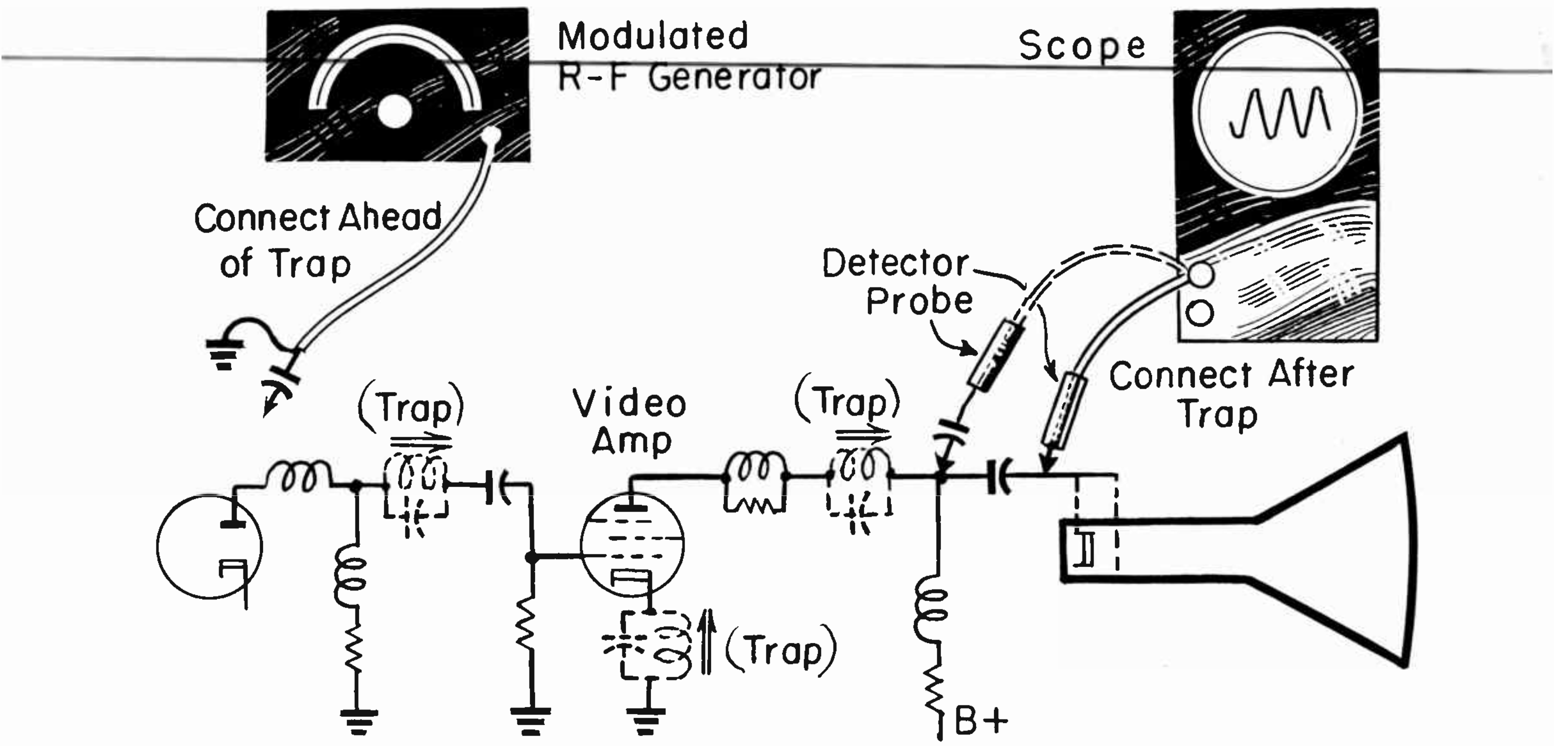

Fig. 17. Using a modulated signal voltage and a detector probe on the scope for adjustment of 4.5-mc traps.

5. Advance the contrast control to maximum or near maximum.

6. Adjust the scope internal sweep rate to bring several cycles of generator modulation onto the screen. Advance the signal generator output to obtain a high trace to begin with.

7. Adjust the 4.5-mc trap for minimum height of modulation trace on the scope. Increase signal generator output as adjustment proceeds. It is not necessary to keep the modulation waveform synchronized by readjustment of internal sweep rate, for only the height of the trace is of interest.

DUAL SOUND ALIGNMENT. The big difference between alignments of dual and intercarrier sound systems is in the center frequency employed. With intercarrier sound the f-m center frequency always is 4.5 mc. With dual sound the center frequency is the sound intermediate frequency of the receiver, which, depending on make and model, may be almost anything between 20 and 50 mc.

Other than being designed to operate at different center frequencies, ratio detector and discriminator circuits are the same for dual and intercarrier sound systems, and methods of alignment are unchanged. Methods of aligning couplings from the sound takeoff as far as the demodulator transformer are the same for both systems, other than for center frequencies employed. Amplifier tubes between sound takeoff and demodulator in dual sound systems usually are called sound i-f amplifiers. Limiters are the same for dual and intercarrier systems, other than for operating frequencies.

When using an r-f signal generator or sweep and marker generators for dual sound alignment these instruments are connected to the grid of a tube which precedes the sound takeoff. If the takeoff is from the output of the mixer tube in the tuner, as at A of Fig. 18, connect the generator to the mixer grid circuit just as for video i-f alignment.

If sound takeoff is from the plate circuit of any video i-f amplifier, as at B, connect the generator to the grid of this amplifier.

For stage-by-stage alignment of a dual sound section, make the generator connection first at the grid of the tube ahead of the demodulator transformer while adjusting primary and secondary of this transformer.

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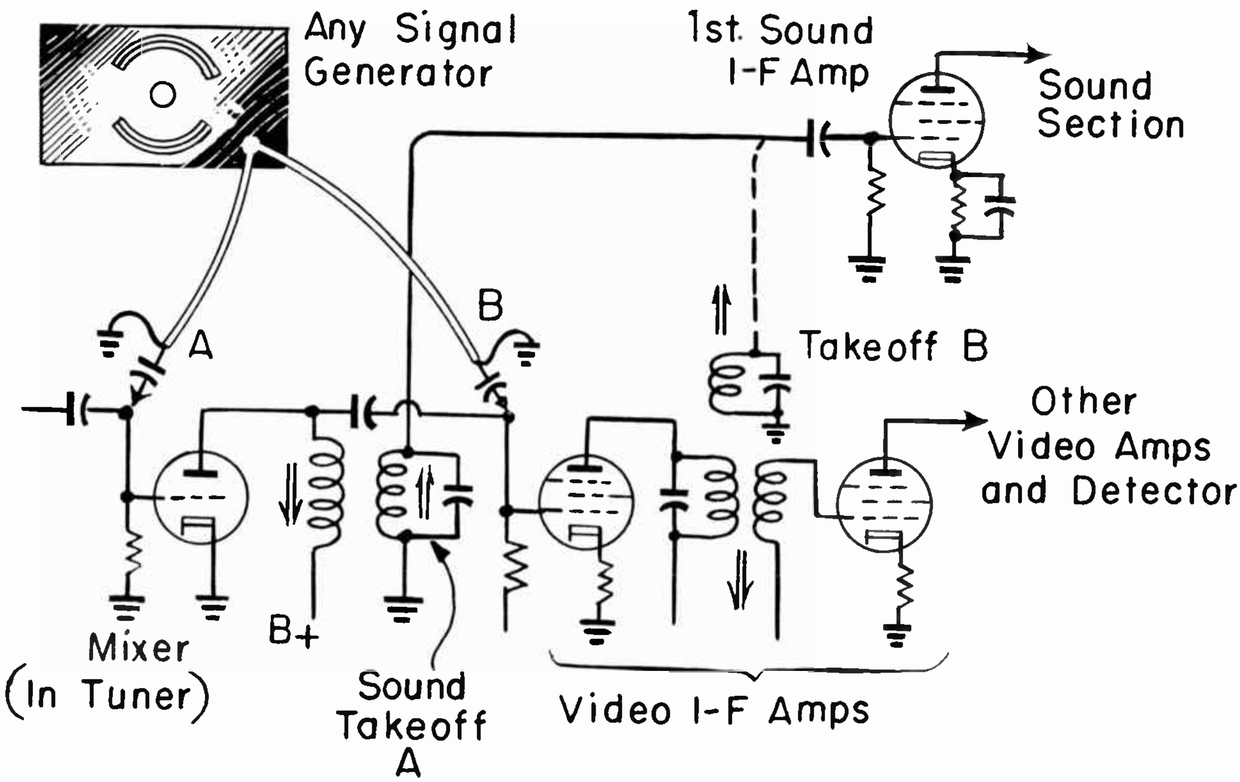

Fig. 18. Connections of the signal generator for alignment of a dual sound section.

For adjustment of the next transformer or sound interstage coupling, shift the generator connection to the tube ahead of this next coupling. Proceed thus until the generator connection is at one of the points shown in Fig. 18.

A VTVM or an oscilloscope used as output indicator is connected to the demodulator circuit in a dual sound section in exactly the same manner as for an intercarrier sound section. Such connections of the VTVM or scope allow alignment of the demodulator transformer, of all sound interstage couplings, and of any tuned sound takeoff. For alignment of only the takeoff and interstage couplings, not the demodulator transformer, the VTVM or scope may be connected across the grid resistor of a limiter tube.

You will recall that frequency from an r-f or marker type signal generator used for intercarrier sound alignment must be within a small fraction of one per cent either way from 4.5 mc. Such great accuracy is not so essential for dual sound alignment, provided all couplings and the demodulator transformer are aligned for exactly the same center frequency, whatever it may be. For instance, were the specified sound intermediate for a receiver to be 21.25 mc, performance would be essentially the same with alignment for any frequency between about 21.0 and 21.5 mc.

The thing to do is let your signal or marker type generator, also the receiver, warm up very thoroughly. Then adjust the generator as nearly as possible to the sound intermediate specified for the receiver. Complete every step in sound section alignment, from takeoff through the secondary of the demodulator transformer, before turning off the test instruments or the receiver.

Such procedure insures that all parts of the sound section are adjusted to work correctly together at the center frequency actually furnished by the generator. Any small discrepancy between generator frequency and assumed or specified intermediate frequency may be compensated for by adjustment of a fine tuning control or of r-f oscillator circuits in the tuner of the television receiver. This method cannot be followed with intercarrier sound, for there the 4.5-mc center frequency is fixed by difference between transmitter carrier frequencies, not by any adjustments within the receiver.

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TELEVISION

• RADIO
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LESSON 62 — COMBINATION AM-FM RECEIVERS

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Lesson 62

COMBINATION AM-FM RECEIVERS

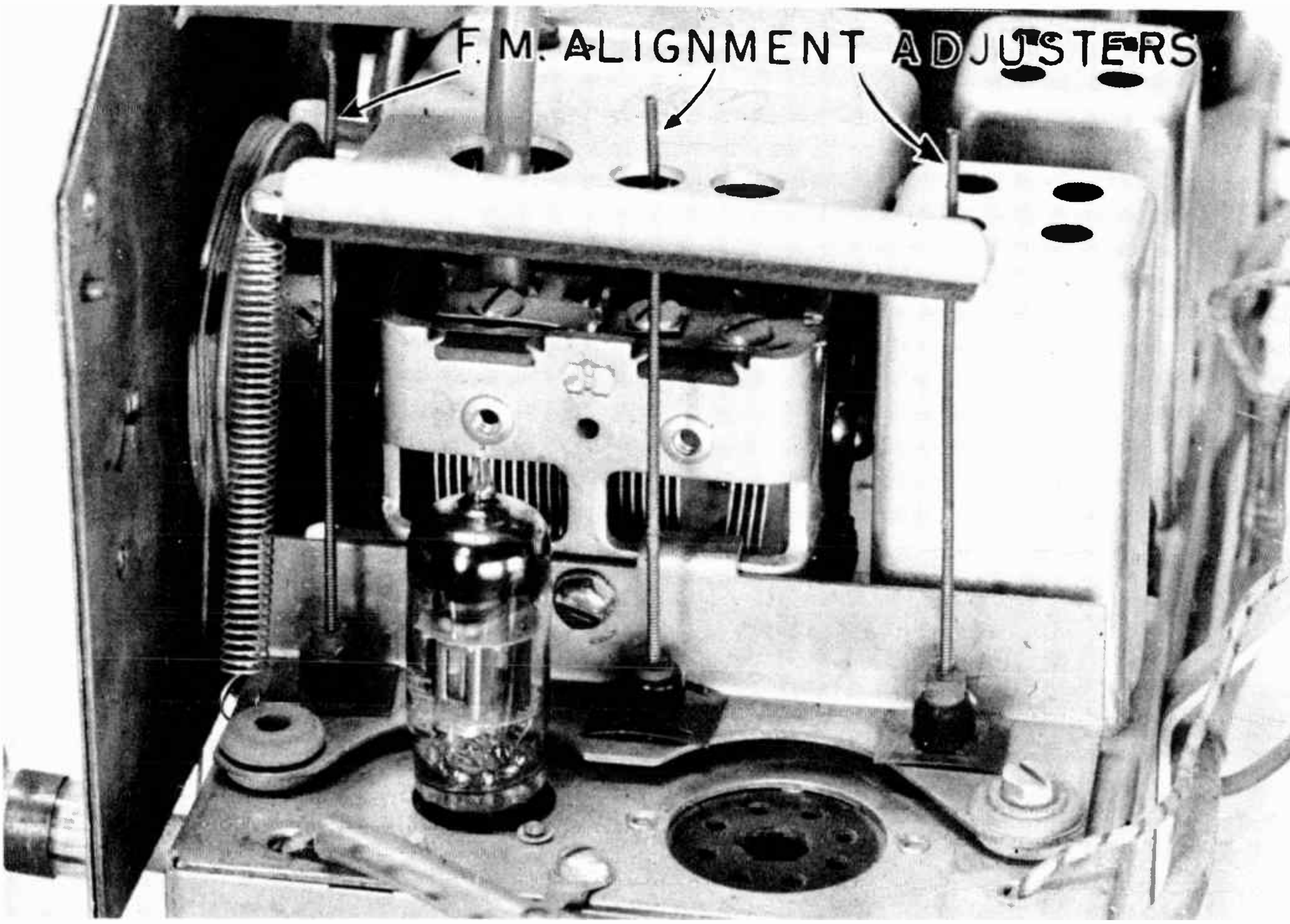

Fig. 1. Tuning for f-m reception by means of three adjustable inductors.

When first studying the principles of radio reception we worked with standard broadcast superheterodyne receivers designed to operate from amplitude-modulated carrier signals. Later we worked with amplitude-modulated video signals, for reproduction of television pictures. More recently we have been working with frequency-modulated signals for the sound portion of television programs.

Now we shall examine combination receivers which reproduce either amplitude-modulated sound from the standard broadcast band or frequency-modulated sound from the f-m broadcast band, where carrier frequencies range from 88 to 108 mc. A set of this kind, called an AM-FM radio receiver is popular by itself and also is built into the same cabinet with some television sets. The result is a receiver capable of reproducing television pictures and sound, or f-m broadcast sound, or a-m broadcast sound, and usually arranged also for operation with phonograph records.

The entire TV-FM-AM receiver employs no principles or circuits with which we are not already familiar. It merely utilizes various combinations of these principles. Other than possibly having a common low-voltage power supply, television picture and sound portions of a combination TV-FM-AM receiver are separate from the AM-FM

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broadcast portion. Consequently we need now deal only with the AM-FM portion, which may be built into the television cabinet or as a separate sound receiver.

The tuning section of AM-FM broadcast receivers is a superheterodyne type. An r-f oscillator furnishes a frequency which beats in the mixer with carrier frequencies to form the intermediate frequency. Unless you remember how all this is accomplished, read again the lessons on "The Superheterodyne" and on "Broadcast Receivers" before proceeding with this lesson. The principles employed for a-m tuning are used also for f-m tuning.

In a combination set there must be separate tunable circuits for f-m and for a-m carrier signals, also separate tuning for r-f oscillator frequencies required in the two bands. There must be two sets of i-f transformers or other interstage couplings, one set tuned for the f-m intermediate frequency and the other for the a-m intermediate. Following the i-f sections will be a diode detector for a-m signals and a separate demodulator for f-m signals. A single audio amplifier section serves for demodulated signals from both bands.

Two things are common to f-m and a-m reception in combination sets. One is the audio amplifier and speaker, which are fed from either the a-m detector or the f-m demodulator. The other common parts are tubes. It is possible to use the same converter or same oscillator and mixer for both bands. An r-f amplifier, when used, may operate in both bands. The same i-f amplifier tubes always are used for both f-m and a-m reception. To become acquainted with combinations of separate and common parts in AM-FM receivers we shall look at a few of the arrangements used in typical sets.

In Fig. 2 the signal grid of a converter is connected through switch A to either of two variable tuned circuits. One circuit tunes the dipole antenna for f-m reception. The other circuit tunes the loop antenna for a-m reception. The oscillator grid of the converter is connected through switch B to one tuned circuit for frequencies needed on the f-m band, and to another tuned circuit for frequencies needed on the a-m band. The oscillator circuits may be of any types studied earlier.

Switch C connects the plate of the converter to either of two primary windings in the first i-f transformer. One primary and its coupled secondary are tuned for the standard f-m intermediate frequency of 10.7 mc. The other primary and coupled second-

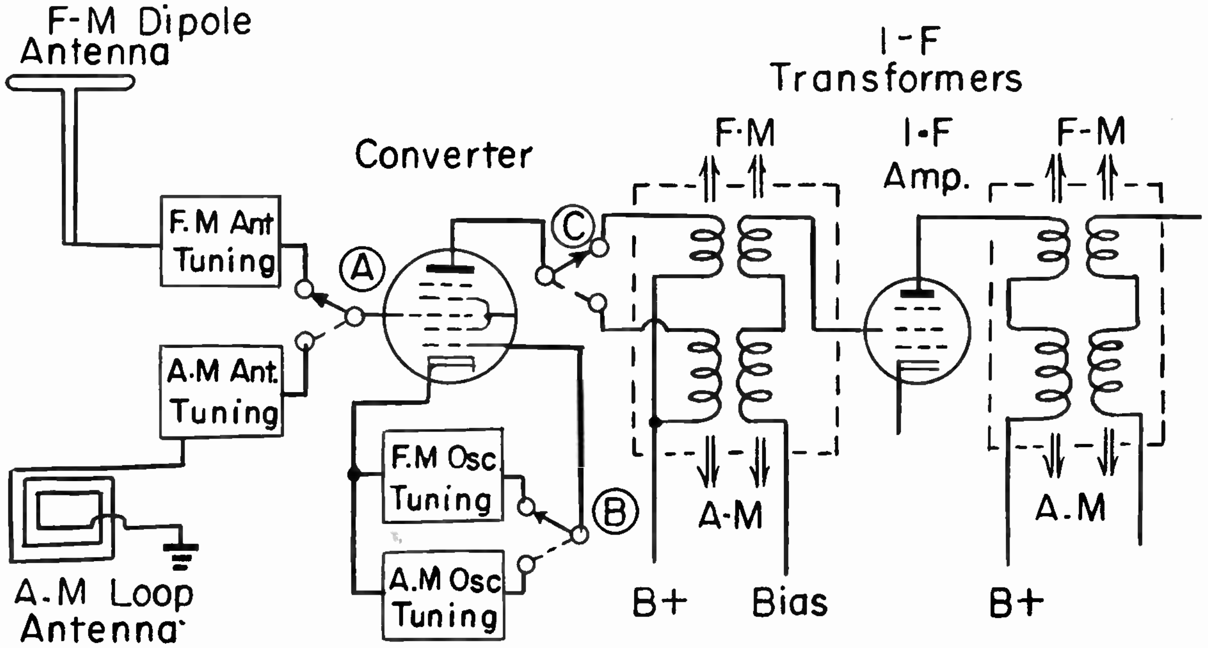

Fig. 2. Band switching at the tuner and first i-f amplifier for f-m or a-m reception.

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ary are tuned to the standard broadcast intermediate frequency of 455 kc. The secondaries of the f-m and a-m sections of the i-f transformer are in series with each other and connected to the grid of the first i-f amplifier tube. The output of this i-f amplifier goes to the second i-f transformer, which operates without band switching.

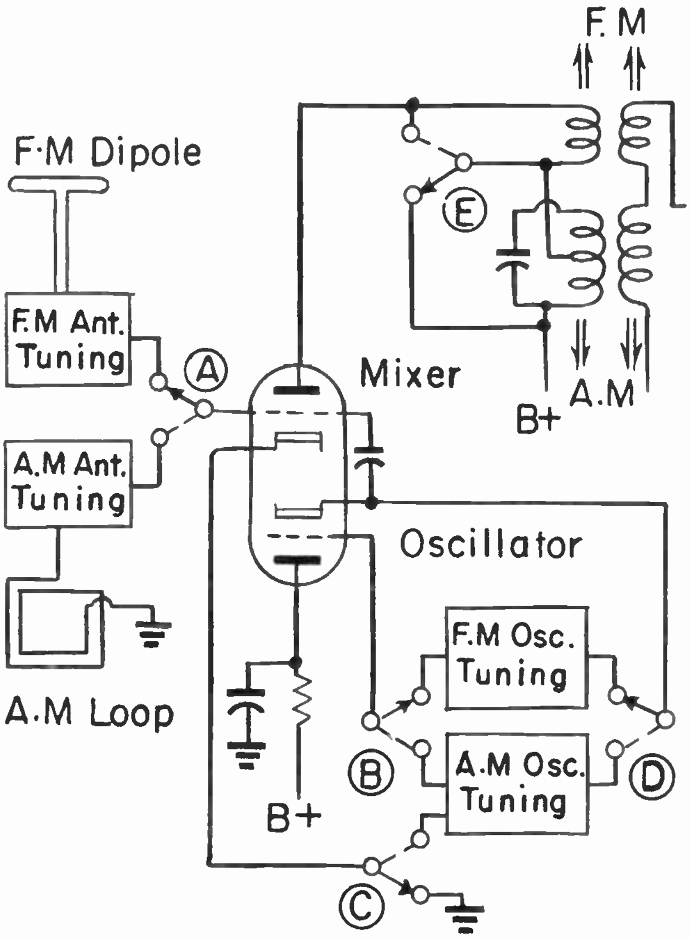

Fig. 3. A separate mixer and oscillator, rather than a converter, may be used in the combination tuner.

Instead of a converter tube, Fig. 3 shows an AM-FM tuner having a twin triode tube for mixer and oscillator. The mixer grid is connected through switch A to suitable tuning circuits and either the f-m dipole antenna or the a-m loop antenna. All switches are shown by full lines in their f-m positions and in broken lines for the a-m positions. The r-f oscillator circuits are of the Colpitts type, connected to the oscillator and mixer sections of the twin triode through switches B, C, and D.

The mixer plate is connected to the first i-f transformer. For f-m reception the a-m primary winding is shorted by switch E, and for a-m reception this switch, in its broken-line position, shorts the f-m primary winding The secondaries of this first i-f transformer are in series, as in Fig. 2, and would feed the following i-f amplifier tube and other circuits not included in the diagram.

In Fig. 4 we have an r-f amplifier tube which is used for both f-m and a-m reception. The grid of this amplifier is connected through switch A either to the tuning unit for the f-m dipole or to the tuning unit for the a-m loop antenna. Note that f-m tuning is shown as a variable inductor, while a-m tuning is by a variable capacitor. When one of the f-m circuits in a receiver is inductively tuned it is customary for all f-m circuits to be similarly tuned, as in the present diagram. All of the a-m circuits are tuned by variable capacitors in practically all combination receivers. Capacitive tuning may be used also for all the f-m circuits, this, in fact, being the general practice.

The output of the r-f amplifier in Fig. 4 is connected through switch B to either a variable inductor coupler for f-m reception or to a capacitor-tuned coupler for a-m reception. These couplers are connected through switch C to the signal grid of a converter tube. Oscillator tuned circuits and following i-f circuits are similar to those of Fig. 2. In any combination receiver there is only a single multi-scale dial for all variable tuned circuits. The fm-am switches shown separately in our diagrams are combined in a single multi-section rotary switch unit having separate positions for f-m reception and for a-m reception.

In Fig. 5 we again have an r-f amplifier, but it is used only for f-m reception. The grid of the r-f amplifier is connected through an adjustable coupling to the f-m dipole. The adjustment is a service operation, the coupling is not variably tuned for station or channel selection. The plate of the r-f amplifier feeds into a variably tuned coupling, thence through switch A, in its f-m position, to the grid of the mixer section in a twin triode.

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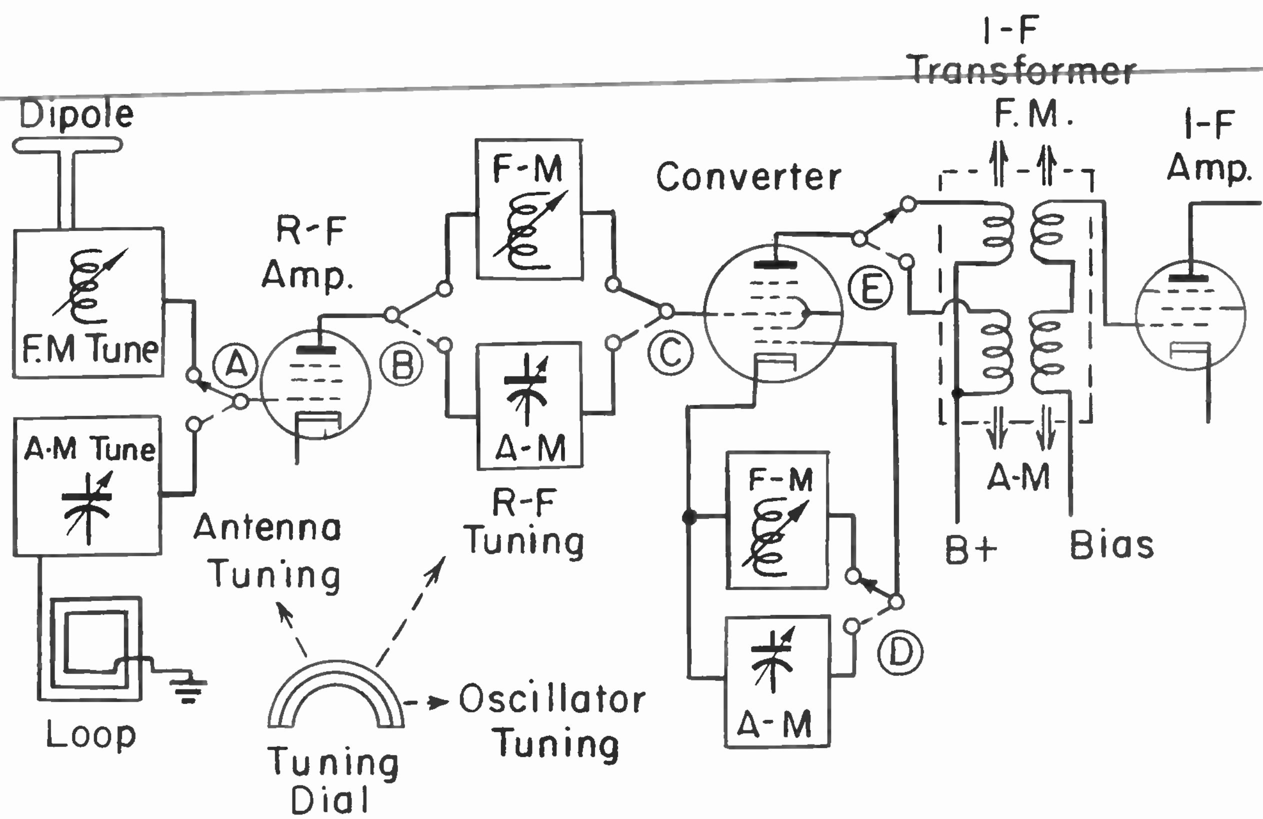

Fig. 4. An r-f amplifier stage used for reception in both the f-m and the a-m bands.

The a-m loop antenna of Fig. 5 is tuned by a variable element connected through switch A to the mixer grid. The r-f oscillator circuits are similar to those of Fig. 3, although drawn in slightly different fashion.

In service instructions for AM-FM receivers it is common practice to apply the name converter to a twin triode used as mixer and r-f oscillator. The remainder of the connections in Fig. 5 are much the same as in preceding diagrams.

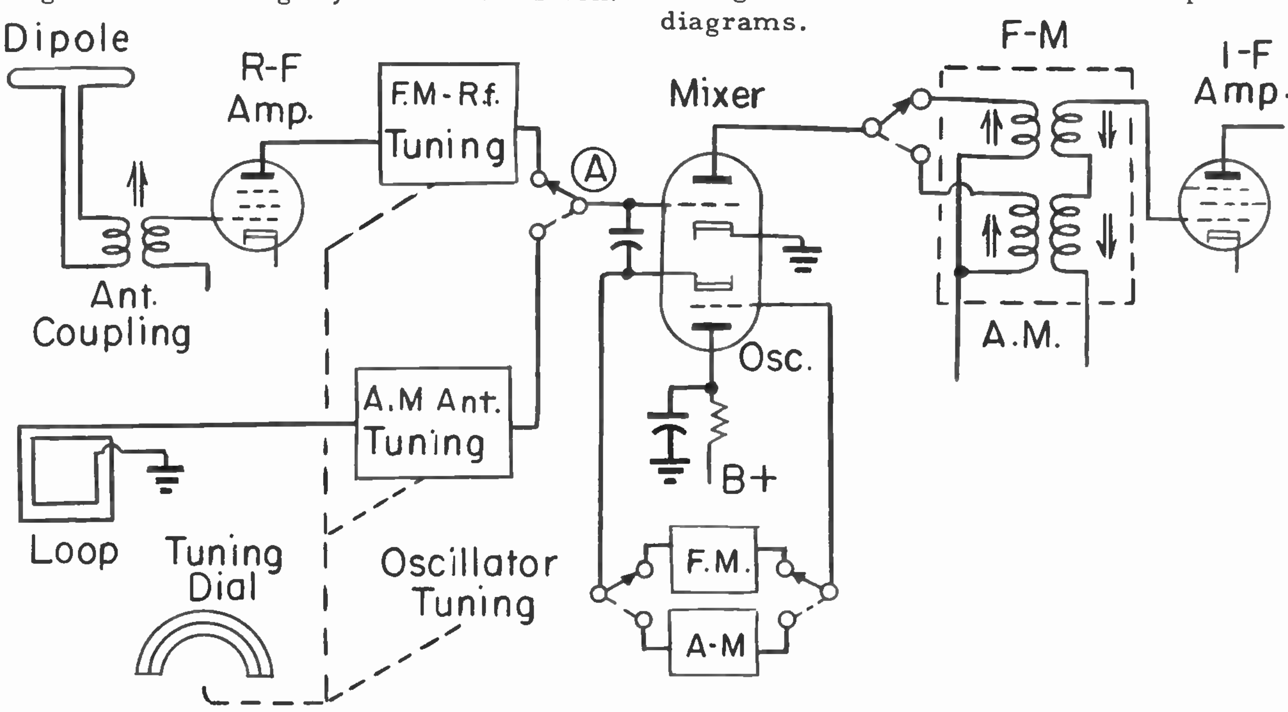

Fig. 5. The r-f amplifier stage is used only for f-m reception.

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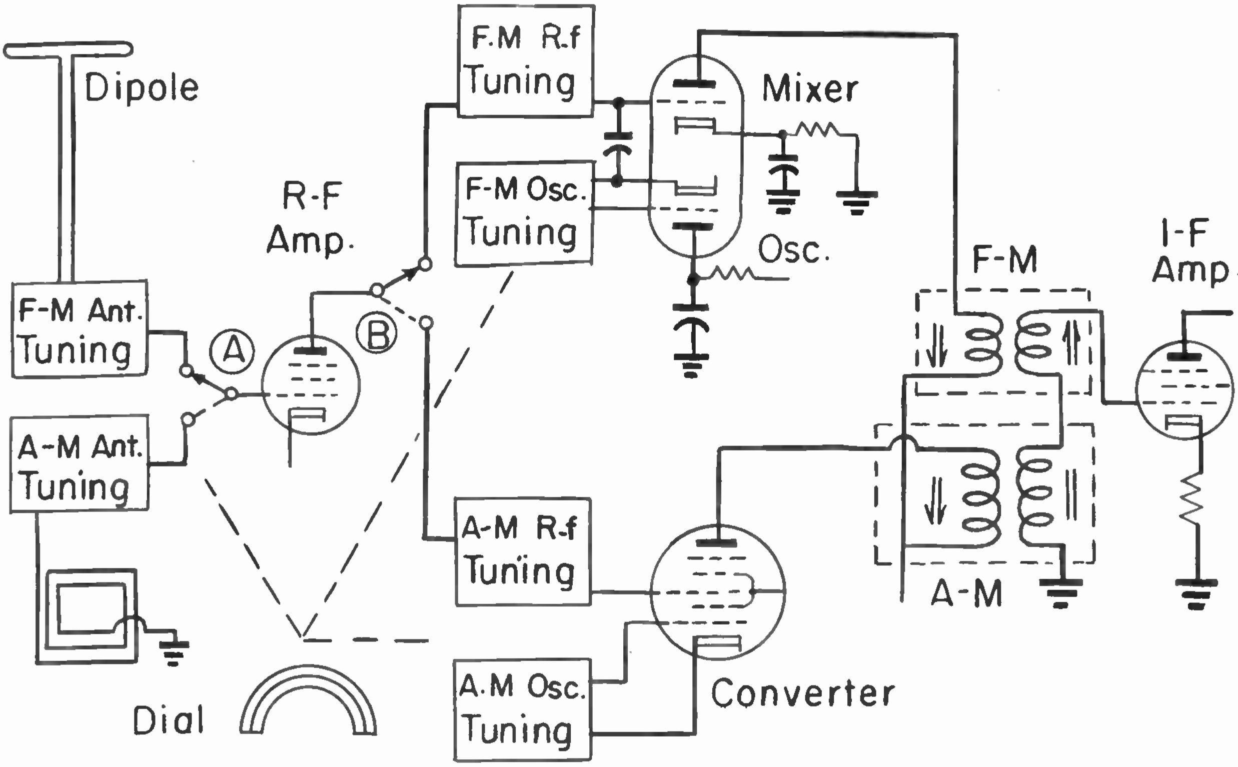

Fig. 6. A separate mixer and oscillator for f-m reception, and a converter for a-m reception.

In the f-m tuning system of Fig. 6 we have the following features. The r-f amplifier tube is connected through switch A to the f-m antenna tuner and the dipole, and through switch B to the f-m r-f tuning unit. This tuning unit connects to the grid of the mixer section in a twin triode. The mixer plate goes to the f-m i-f transformer. The oscillator section of the twin triode has its own tuned circuit.

In the a-m tuning system of this figure we find the following. Switch A connects the r-f amplifier tube to the a-m antenna tuner and loop, while switch B connects this amplifier to an a-m r-f tuning unit and the signal grid of a converter tube. The converter has its own oscillator tuning circuit. The converter plate connects to the a-m i-f transformer. Note that a twin triode mixer-oscillator is used only for f-m reception, a converter is used only for a-m reception, and an r-f amplifier is used for both f-m and a-m reception.

Fig. 7 shows some rather unusual features. One section of a twin triode is an r-f amplifier only for f-m reception, while the second section is a mixer only for f-m reception. This mixer feeds the primary in the f-m portion of the first i-f transformer. A converter tube is used as a converter (com-

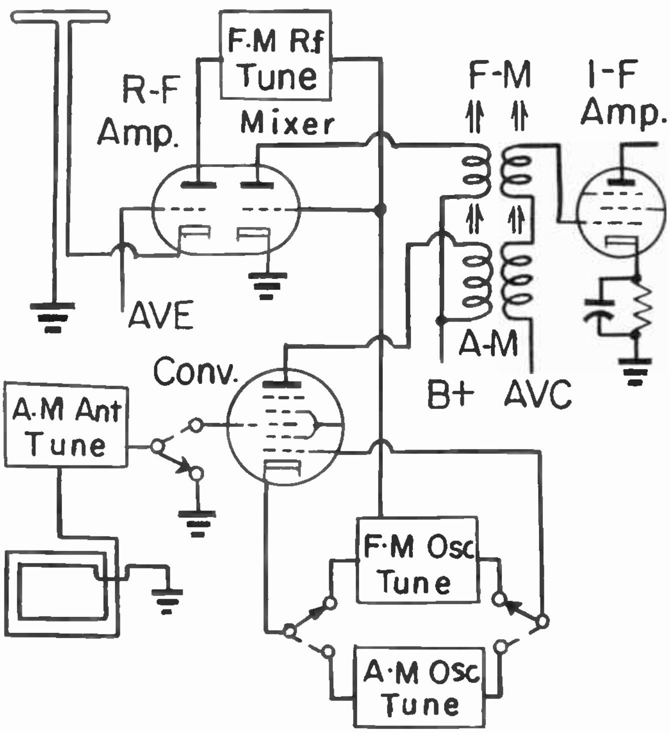

Fig. 7. Converter with separately tuned oscillator circuits for f-m and for a-m reception.

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bined mixer and oscillator) for a-m reception and is used only as an oscillator for f-m reception. The signal grid of the converter connects to the tuned loop antenna, and the plate goes to the a-m portion of the first i-f transformer. On the converter there is one tuned circuit for f-m oscillation and another tuned circuit for a-m oscillation.

We might continue almost indefinitely with examination of tuners for combination AM-FM receivers, but the circuits which have been shown illustrate that all tuners embody well known principles in different arrangements. Switch elements shown in our diagrams make the shift between variably tuned circuits for f-m and a-m reception. On these band switches will be other sections for shifting the audio amplifier between outputs of the f-m demodulator and a-m detector, also for disconnecting B-voltage from tubes not used and applying this voltage to tubes that are used for reception in each band.

√ F-M BROADCAST SIGNALS AND BANDS. As mentioned before, the f-m broadcast band of carrier frequencies extends from 88 mc to 108 mc, being just above the low band (channels 2 through 6) of the television broadcast range. Center frequencies of f-m broadcast channels are separated by 200 kc, or each channel extends over 200 kc. The total band from 88 to 108 mc covers 20 mc or 20,000 kc, and thus allows for 100 f-m broadcast channels.

Maximum deviation for f-m broadcast signals is 75 kc instead of the maximum of 25 kc allowed for television sound. The r-f amplifier circuits in an f-m broadcast receiver should tune broadly enough for good response to at least the limits of deviation.

I-F AMPLIFIERS. The present standard intermediate frequency for f-m broadcast receivers is 10.7 mc. Since this is more than half of the total frequency range in the 88-108 mc band, all image frequencies are beyond the response limits of a correctly aligned i-f amplifier system. Earlier standard f-m broadcast intermediates were 8.3 mc and 4.0 mc, used chiefly in sets built during the period when the f-m broadcast band extended from 42 to 50 mc instead of the present 88 to 108 mc.

The i-f transformers for f-m and for a-m reception may be in separate cans, with the two transformers for any one stage mounted close together on the chassis. These separate transformers look just like those used in television i-f amplifiers and sound amplifiers. On each can will be one opening or an exposed screw for primary adjustment, and another for secondary adjustment.

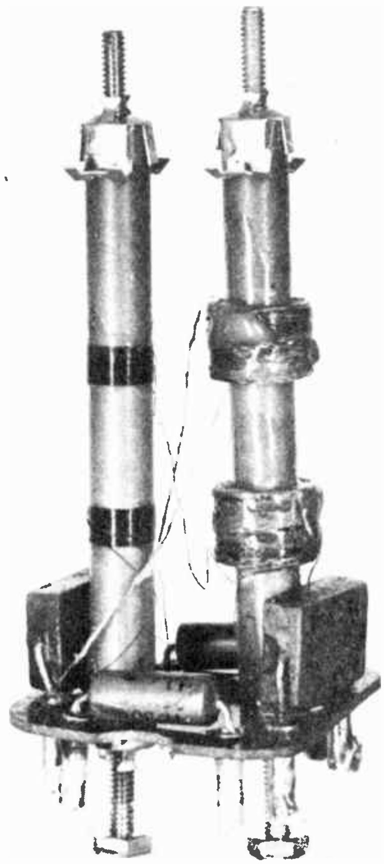

Fig. 8. A combined f-m and a-m intermediate-frequency transformer with its shield can be removed.

Both the f-m and the a-m transformers quite often are within a single can. Such construction is pictured by Fig. 8. The form carrying smaller primary and secondary windings in the f-m unit, while the form with larger windings is for a-m reception. The small capacitors mounted near the base of this transformer unit are connected across the windings, one capacitor being shunted across each of the four windings to form parallel resonant tuned circuits.

On the combination transformer illustrated the adjusting screws for both secondaries are at the top, and extend out through

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openings in the top of the can. Adjusters for both primaries are at the bottom, and would be accessible from underneath the chassis. In other transformers all four adjusters may be at the top, or all four at the bottom, or some may extend from or be reached through the sides of the shield can.

Fig. 9 shows fairly typical circuits which extend from the output of the tuner through the audio output or power amplifier tube of a combination AM-FM receiver. We shall commence at the upper left, at the line from a tuner, and trace through the circuits while noting the more important features.

The primaries of the first i-f transformers are switched for the two reception bands. Separating, shorting, or otherwise isolating f-m and a-m circuits at the tuner helps prevent difficulties in mixer or converter circuits.

The secondaries of the first i-f transformer are not switched, and neither are the primaries or the secondaries of the second i-f transformer. When f-m and a-m windings are in series, low-frequency a-m signals meet very small reactance or impedance in the f-m section and feed through this section with little loss. The f-m sections have high reactance at the high f-m intermediate frequency, and signal energy for this reception band is transferred from primary to secondary.

The i-f section of any sound receiver must provide nearly all of the selectivity, since preceding r-f, mixer, and converter stages tend to tune rather broadly. The fre-

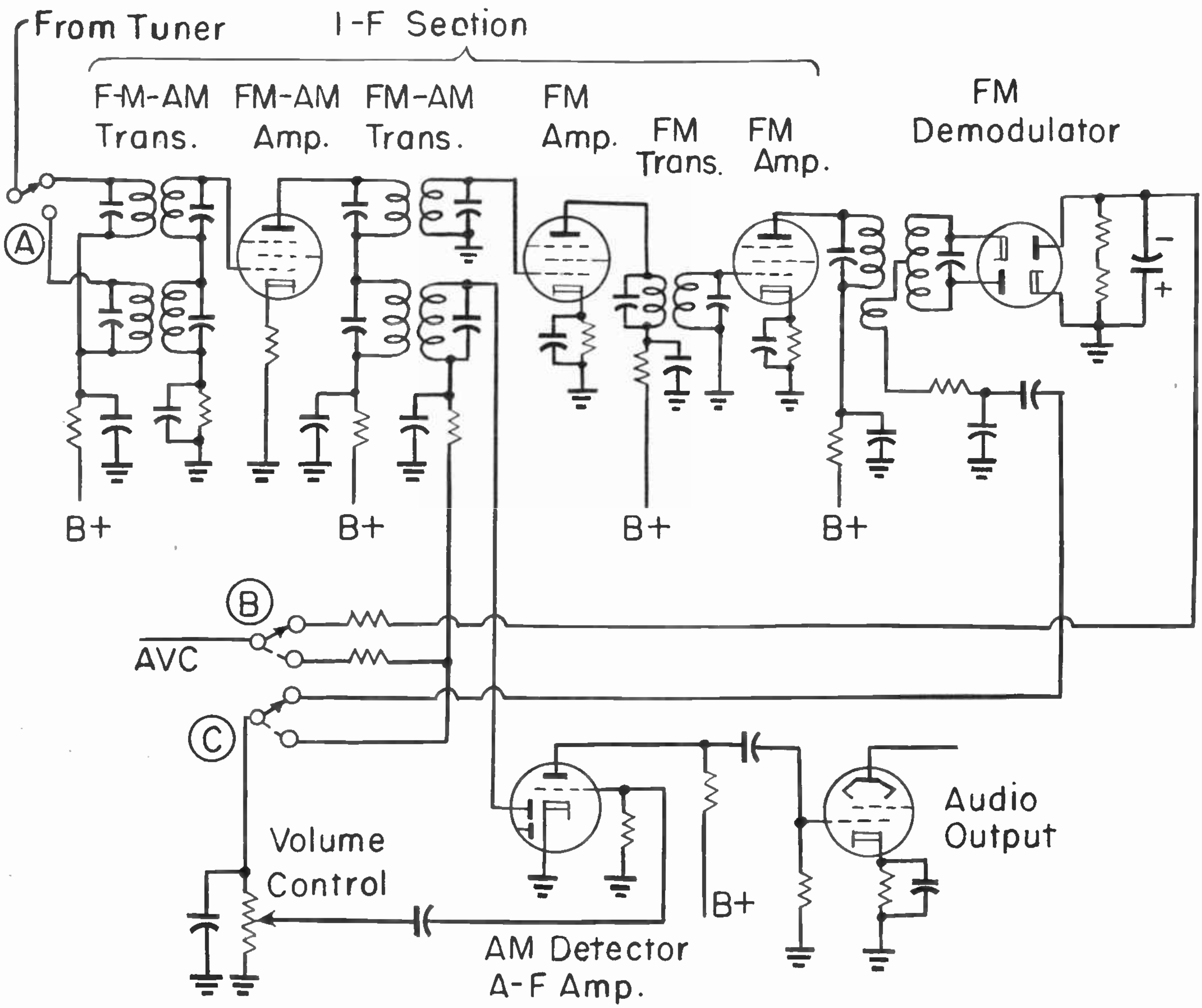

Fig. 9. The i-f, demodulator, and audio amplifier sections of a combination am-fm receiver.

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quency response of the f-m section should be quite uniform for at least 75 kc, the deviation limit, on each side of the center frequency, but should have least possible gain or response at frequencies in f-m channels below and above the one being received. The response may be moderately peaked, flat topped, or slightly double peaked, just as in the case of sound amplifier circuits for television receivers.

Returning to Fig. 9, the f-m portion of the second i-f transformer feeds a following amplifier used only for f-m reception. There is no connection between the f-m and a-m secondaries of this transformer. The f-m amplifier tube used only for f-m reception feeds through an f-m i-f transformer to a third i-f amplifier tube, also used only for f-m reception. This third tube in the i-f section might be operated as a limiter rather than as an amplifier.

Now, in tracing through the f-m i-f amplifier section of the combination set we come to the f-m demodulator. The diagram shows this demodulator as a ratio detector, but it might be a discriminator. There is no difference whatever between demodulator circuits for AM-FM receivers and for the sound sections of television receivers, although, of course, the operating frequencies are different.

Next, let's go back to the second i-f transformer. The a-m secondary of this transformer is connected between the volume control and a diode plate in the lower duodiode-triode tube used as a diode detector and a-f amplifier. These connections are electrically the same as those for the detector and first a-f amplifier in a-m broadcast receivers studied in earlier lessons. An avc voltage is taken from above the volume control through band switch B to the avc bus, just as in an a-m receiver.

For f-m reception, switch C of Fig. 9 connects the volume control to the audio output of the f-m demodulator, at a point beyond the de-emphasis filter. At the same time, switch B connects the avc bus to the negative side of the storage capacitor in the ratio detector circuit. Voltage of this capacitor varies with strength of received signals, as we learned when studying television sound systems, and thus provides a suitable negative voltage for avc purposes.

A so-called avc (automatic volume control) in an f-m receiver does not act to maintain a fairly constant sound volume with variations of strength in received signals, since volume or loudness depends on frequency deviation and not on amplitude. An avc system does tend to maintain a constant signal amplitude at the f-m limiter or demodulator.

Many combination sets use avc for a-m reception but not for f-m reception. Avc voltage for f-m reception, when used, ordinarily is taken from the negative side of the storage capacitor in a ratio detector demodulator, as in Fig. 9. In sets using a discriminator and limiter, an f-m avc voltage may be taken from the high side of the limiter grid resistor and applied to grid returns of controlled tubes.

It is in the demodulator and a-f amplifier portions of combination receivers that unusual designs and circuits most often appear. Some examples will serve to show how well known principles may be adapted to new requirements.

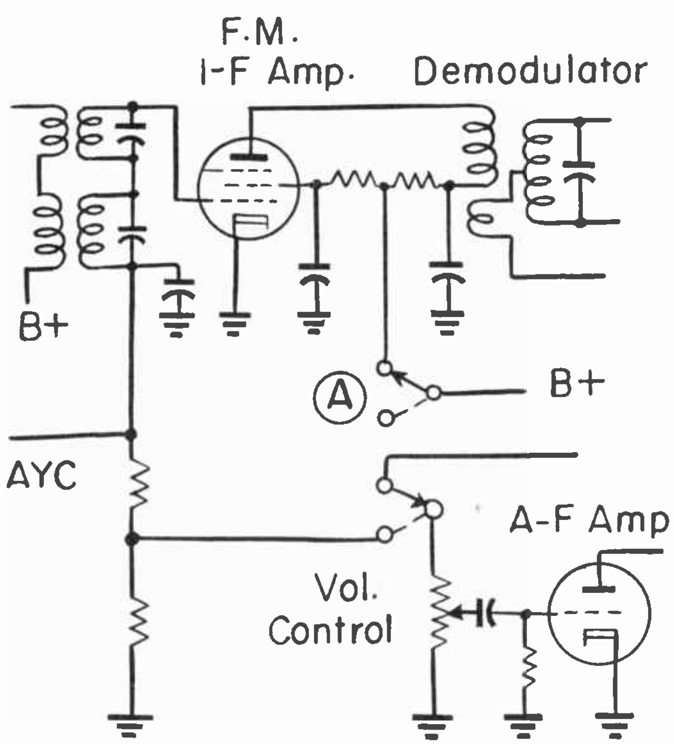

Fig. 10. A pentode used as i-f amplifier for f-m reception and as diode detector for a-m reception.

In Fig. 10 the final f-m i-f amplifier tube, which feeds into the demodulator transformer for f-m reception, is used as a diode detector for a-m reception. For f-m reception switch A carries B-voltage and current to the plate and screen of the pentode i-f amplifier. For a-m reception this switch

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cuts off the B-supply to this tube. Then the grid acts as a diode plate and the cathode as a diode cathode to form a diode detector. A-m signals are not appreciably impeded by the f-m secondary of the i-f transformer, and the circuit becomes equivalent to that for any ordinary diode detector in an a-m sound receiver.

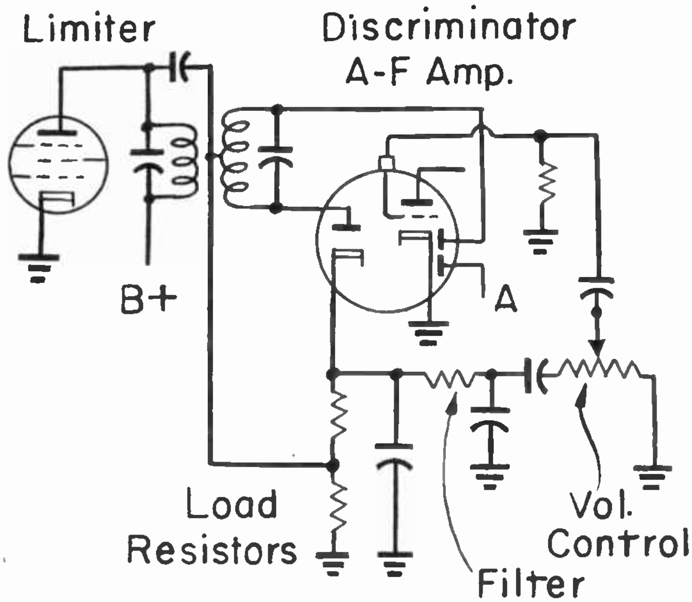

Fig. 11. A combination triple diode triode used as discriminator, amplifier and detector.

In Fig. 11 a triple diode triode tube, such as the 6S8 or 6T8 is used as an f-m discriminator, an a-f amplifier, and an a-m diode detector. There is nothing unusual about the discriminator circuit except for the positions of the diode plates employed. One of these diode plates acts with a separate cathode, and the other with the cathode used also for the triode amplifier and a-m detector. The a-m detector plate, for which circuit connections are not shown, is marked A in the diagram.

The combination tube has a top cap connected internally to the triode grid. The cap connects to the volume control in the usual manner. For a-m reception the volume control would be switched from the a-f output of the discriminator to the a-f output of the diode detector, much as in Fig. 9.

Fig. 12 shows connections for a discriminator circuit in which the transformer has a divided secondary and the plates of both discriminator diodes operate with a single cathode. The tube is called a twin-diode triode. Examples are types 6AQ7 and 7K7. The triode section of the tube is used as an audio amplifier, with its grid connected through the

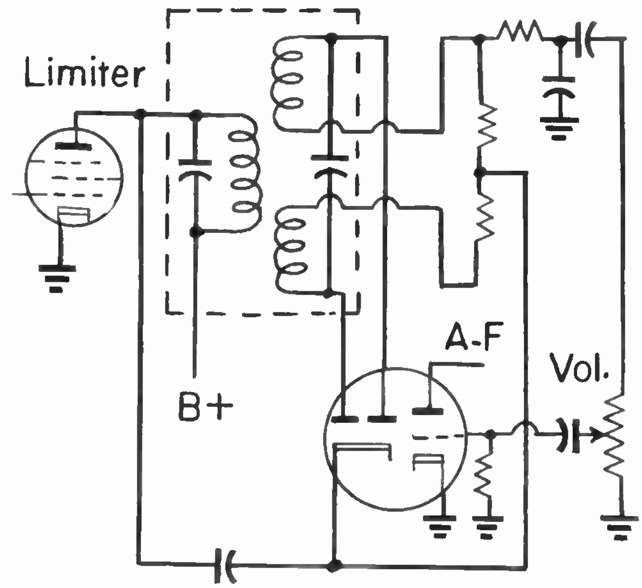

Fig. 12. An f-m discriminator requiring only a single cathode for two diode plates.

volume control to the de-emphasis filter and audio output point of the discriminator circuit.

<u>ALIGNMENT OF AM-FM RECEIVERS.</u> We need learn only a little that is new in relation to aligning a combination AM-FM set. The a-m section is adjusted just as though the f-m section were not there, other than making sure that the band switch is in its a-m position. A-m alignment methods were explained in the earlier lesson on "Receiver Alignment".

The f-m portion of a combination set consists of the tuner, the i-f amplifier, and the demodulator. Other than in the matter of operating frequencies, alignment of f-m broadcast demodulators is no different than alignment of demodulators in television sound sections. I-f amplifiers in f-m receivers are aligned like sound takeoffs and interstage couplings in television sets. The f-m tuner is aligned in about the same general way as the a-m tuner, except for test frequencies used.

Most technicians align the a-m section, then the f-m section, although there is no particular objection to reversing the procedure. F-m alignment should commence with adjustment of i-f transformers. Next comes adjustment of primary, then secondary of the demodulator transformer. Last is adjustment of trimmers on tuning circuits in r-f oscillators, r-f amplifier stages, and antenna couplings.

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ALIGNMENT OF F-M DEMODULATORS AND I-F STAGES

SIGNAL GENERATOR	OUTPUT INDICATOR		CIRCUITS ALIGNED			TYPE OF DEMODULATOR	
	TYPE	CONNECTION	I-F Or Inter-stage	Demodulator Pri	Demodulator Secy	Ratio det'r	Dis-crim
Constant-freq Unmodulated	VTVM	Demod'r output, unbalanced	x	x		x	
Constant-freq Unmodulated	VTVM	Demod'r output, audio			x	x	
Constant-freq Unmodulated	VTVM	Limiter grid resistor	x			x	x
Constant-freq Unmodulated	VTVM and det'r probe	Demod'r primary, at tube plate	x			x	x
Constant-freq Modulated	Output meter or A-c V-M	Voice coil or A-f amp plate	x	x	x	x	x
None	VTVM	Demod'r output, audio	x	x	x	x	x
Constant-freq Unmodulated	VTVM	Demod'r output, unbalanced	x	x			x
Constant-freq Unmodulated	VTVM	Demod'r output, audio			x		x
Constant-freq Unmodulated	VTVM	Demod'r output, audio	x	x	x		x
None	VTVM	Demod'r output, audio	x	x	x		x
Sweep And Marker	Scope and det'r probe	Demod'r primary, at tube plate	x	x		x	
Sweep And Marker	Scope	Demod'r output, unbalanced	x	x		x	
Sweep And Marker	Scope	Demod'r output, unbalanced	x	x			x
Sweep And Marker	Scope	Demod'r output, audio			x	x	x

In lessons dealing with television sound we became acquainted with a great many methods and modifications of methods for aligning takeoffs, interstage amplifiers, and demodulators. In the accompanying table all these methods are listed in the same order as printed in the two lessons, "Television Sound Adjustments" and "Sound Alignment

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With the Oscilloscope". You may refer to those lessons for details of any method in which you are interested while servicing.

How to go about aligning the i-f amplifier and demodulator in an f-m set depends on the types of signal generator and output indicator available. The first three columns of the table list these instruments and how they are employed for each method. The next three columns, headed "Circuits Aligned", show whether instructions in the lessons apply to i-f or interstage adjustments, or to demodulator adjustments, or to all the circuits. The last two columns show whether lesson instructions refer specifically to circuits containing ratio detectors, containing discriminators, or whether the instructions may be used for either type of demodulator.

A principal difference between alignment of f-m broadcast and television sound is in connection of the signal generators. For television sound this connection often must be made with reference to a sound takeoff, either before or after the takeoff. In an f-m receiver there is no sound takeoff, the signal for the i-f amplifier always originates at the output of a mixer or converter tube. If alignment is not too bad to begin with, the generator connection is through a small capacitor to the grid of a mixer or the signal grid of a converter, and remains there during the entire process of i-f and demodulator adjustments.

If the f-m receiver has no r-f amplifier, and the signal grid of a mixer or converter goes directly to an a-m antenna coupler, the signal generators may be connected to the f-m antenna terminals through a series resistor of about 300 ohms instead of through a capacitor.

Should i-f transformers or the demodulator transformer be badly misadjusted to begin with, stage-by-stage alignment may be necessary. Connect the generator in the usual manner to the grid of a tube preceding the transformer being aligned. Then move the connection a stage at a time until reaching the signal grid of a mixer or converter.

Connection of either a VTVM or an oscilloscope as output indicator is the same for f-m receiver alignment as for television sound alignment, as listed in the table of alignment methods.

Most of the preparation for aligning the f-m i-f section of a combination set is the same as for aligning the i-f section of a television receiver, or the a-m section of the combination set. For instance, a transformerless power supply with series heaters, and a hot chassis, requires the same precautions as to grounding or isolation as when working with any other set of this kind. A few other preliminaries are as follows.

1. Don't forget to place the band switch in its f-m position.

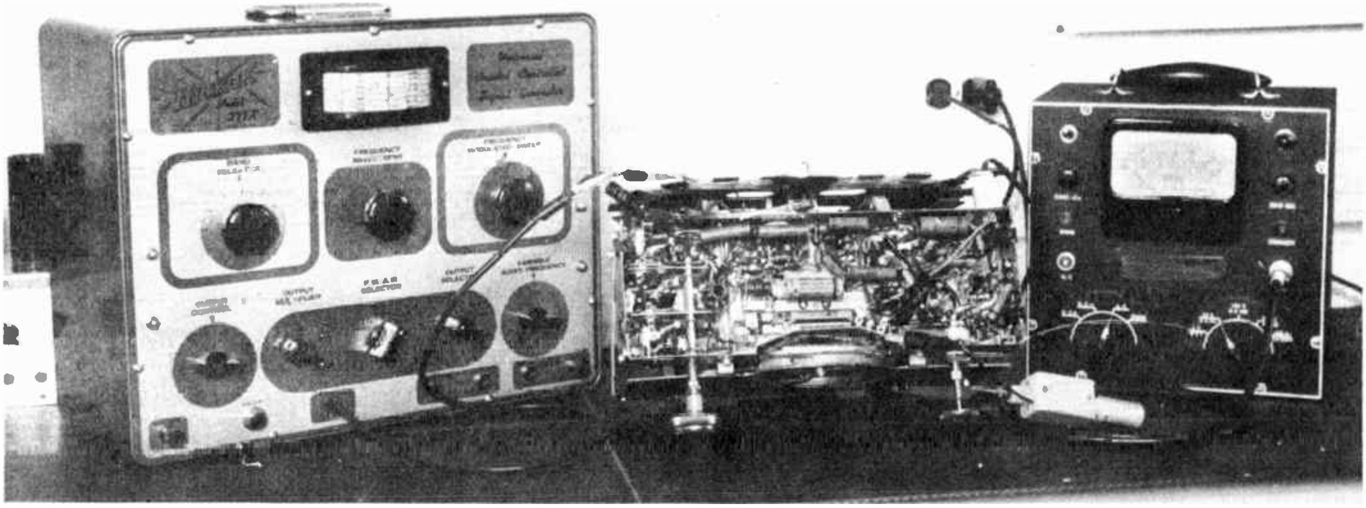

Fig. 13. Setup for alignment by means of r-f signal generator and vacuum tube voltmeter.

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2. Disconnect a line coming from a separate f-m antenna to the tuning section, and short circuit the f-m antenna terminals of the receiver on each other.

3. Place the tuning dial or pointer at a frequency not used by any nearby f-m station, preferably at a frequency near the top or bottom of the dial scale.

4. If automatic volume control or gain control is used for f-m reception, override the automatic bias voltage with fixed battery voltage. Two or three dry cells in series should provide a suitable override.

5. Tune marker and other constant-frequency r-f signal generators to the standard f-m intermediate frequency of 10.7 mc. Should you encounter sets so old as to have the 8.3-mc intermediate it is quite likely to be marked on the transformer cans or on the chassis. If in doubt, and you cannot adjust satisfactorily for 10.7 mc, try 9.3 mc. The center frequency of a sweep generator must be adjusted with reference to 10.7 mc, or to 8.3 mc on a very old receiver.

6. After connections have been made for signal generators and VTVM or oscilloscope, and after instruments and receiver are warmed up, try changing the receiver tuning one way and the other. If this causes jumps or any decided changes of VTVM reading, or causes horizontal shifting of a response trace, the r-f oscillator should be disabled during i-f alignment.

Disable the oscillator by connecting its grid to ground, from a socket lug, through about 0.001 mf. The grounding capacitor may be connected also from the high side of an oscillator tuning capacitor or variable inductor. The f-m oscillator rarely is a separate tube, so seldom can be removed from its socket to prevent bothersome effects.

It is essential that the demodulator transformer and i-f interstage transformers be aligned for precisely the same frequency. This was mentioned in connection of television sound sections, where center frequencies would be the intercarrier beat of 4.5 mc or else the sound intermediate frequency for the receiver. In f-m broadcast receivers this center frequency is 10.7 mc.

To insure alignment of demodulator and i-f amplifier for the same center frequency, all adjustments in these two sections should be completed before turning off the r-f or marker generator, or the receiver. If the actual center frequency furnished or marked by the signal generator is not precisely 10.7 mc, any slight difference or error will be compensated for when adjusting the r-f oscillator of the tuner section. The oscillator can be adjusted to provide the actual intermediate frequency for which the i-f amplifier and demodulator have been aligned.

Interstage couplings in the i-f sections of f-m or combination receivers most often are of the double-tuned type with separate slugs or possibly separate trimmer capacitors for secondary and primary windings. When using a VTVM as output indicator, most of these double tuned transformers can be satisfactorily aligned by first adjusting the secondary and then the primary for maximum output voltage.

If results of such alignment seem poor, the windings may have enough coupling to make each adjustment affect the other. Then each winding may be shunted with resistance of 300 ohms or more while the other one is adjusted for peak voltage. Sometimes it will be sufficient to commence by detuning the secondary, turning its adjuster all the way out, while adjusting the primary for maximum output. Without disturbing this primary adjustment, the secondary is aligned for peak output.

When using an oscilloscope for output indicator the procedure is like that for television sound adjustment, with the object of obtaining a response symmetrical on both sides of the center frequency.

When checking band width by means of markers on a scope response you must keep in mind that f-m broadcast deviation is 75 kc below and above the center frequency, which calls for a broader top on the curve than for television sound work. Since each f-m broadcast channel is only 200 kc wide, the skirts of a response curve must not flare too widely or else the receiver will not be selective.

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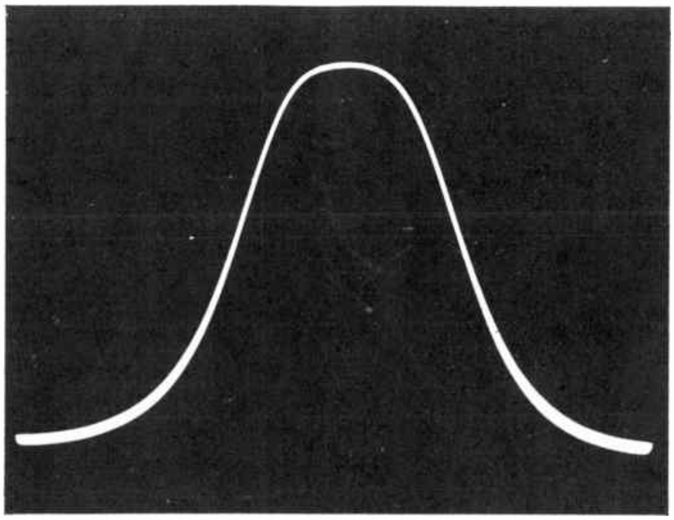

Fig. 14-A.

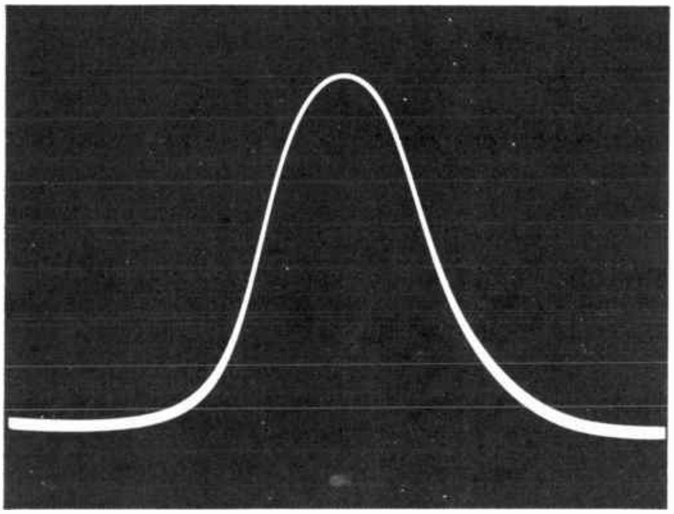

Fig. 14-B

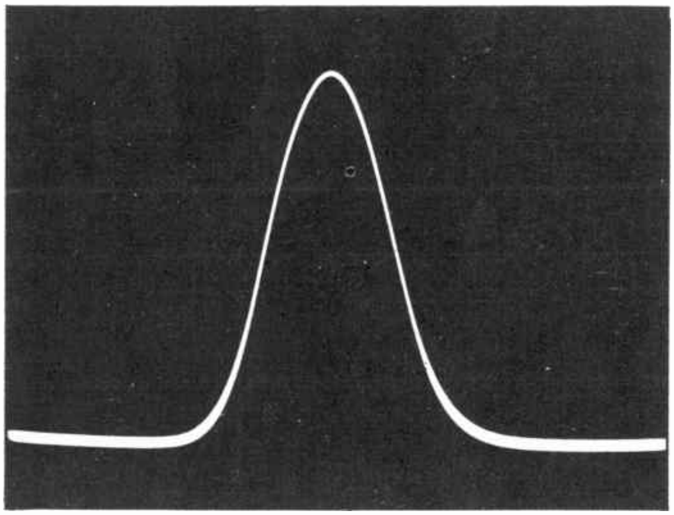

Fig. 14-C.

Fig. 14. Successive i-f responses as the signal generator connection is shifted from near the demodulator back to the mixer or converter.

The responses of Fig. 14 were taken during step-by-step alignment of the f-m i-f amplifier section in a combination set. The trace at A shows the output with the sweep generator connected to the grid of the second i-f amplifier following the converter. The response is quite broad because, between generator and oscilloscope there is only one i-f transformer in addition to the demodulator transformer.

The trace at B was taken with the sweep generator connection shifted to the grid of the first i-f amplifier. Oscilloscope vertical gain was adjusted to make all these traces of the same height, to allow comparisons of band width. With the additional i-f transformer between generator and scope the band width is narrower. With the sweep generator connection moved back to the signal grid of the converter the response is as at C. Band width is still narrower because still another i-f transformer has been included in the circuits which are active between generator and scope.

It is highly important to keep the output of either a sweep or a constant-frequency generator below the level at which limiting action occurs in a limiter tube or in a ratio detector circuit. Unless this is done, the responses will be flattened or double-peaked when they should be single peaked. These effects show quickly when using an oscilloscope, but they don't show on a VTVM unless you check for presence of two voltage peaks after making an adjustment. Generator output must be kept so low that slight increases or decreases of output cause proportional changes of trace height on a scope or of output voltage indicated by a VTVM.

When the oscilloscope is connected to the load circuit of a discriminator or to any point in a ratio detector circuit other than across the large storage capacitor, the capacitances of cable and scope must be isolated from the measured circuit. Otherwise the frequency response will be thrown so far off as to make alignment impossible within the range of transformer adjusters, or to make the alignment of such great error as to prevent satisfactory operation of the receiver on regular programs.

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(It is best to use a frequency compensating probe, provided this probe does not so reduce the vertical gain of the scope as to make traces too low for checking. Otherwise use at least 10,000 ohms, or as much as 50,000 ohms in series with the vertical lead. To make marker pins reasonably sharp, connect 0.001 mf or greater capacitance between ground and the scope side of the series resistance.)

F-M TUNER ALIGNMENT. It is a general rule that at least one service adjustment will be found at each capacitor or indicator that is varied by the tuning dial when selecting stations. Variable tuning elements are shown in Figs. 2 through 7 of this lesson. The oscillator always is variably tuned, and in the oscillator circuit always are one or more service or alignment adjustments. In addition to the oscillator, the antenna coupling is variably tuned in Figs. 2 and 3, the r-f amplifier is variably tuned in Figs. 5 and 7, while both antenna and r-f couplings are variably tuned in Figs. 4 and 6.

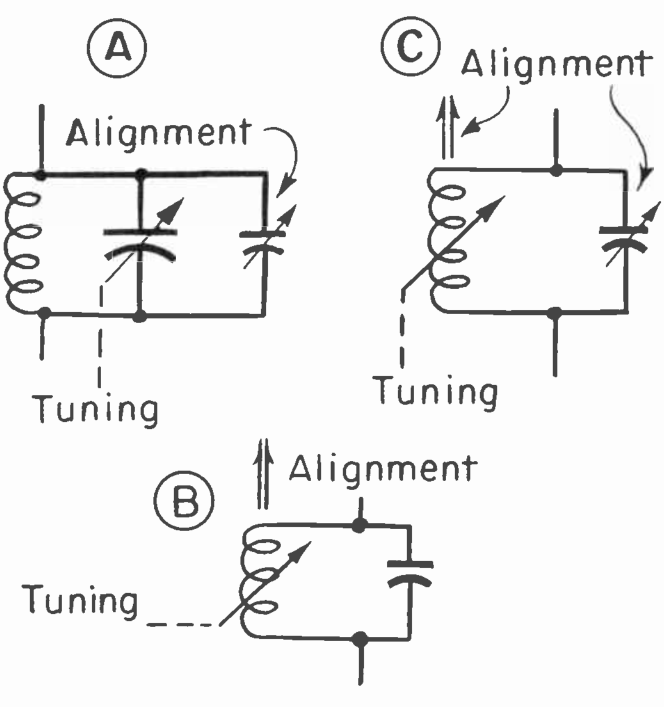

Fig. 15. Various combinations of tuning and alignment adjustments.

The variable tuning element may be a capacitor, as indicated by symbols at A of Fig. 15. In this case the alignment adjuster always is a trimmer capacitor. The variable tuning element may be an inductor, as indicated by a symbol at B of Fig. 15. In Fig. 1 of this lesson you can see variable inductors for f-m tuning in an AM-FM receiver. There are three inductors, one each for the antenna, r-f, and oscillator circuits. All three slugs are attached through threaded rods to an overhead bar which is raised or lowered by the tuning dial, thus moving the slugs within their coil forms to tune the circuits.

The position of each tuning slug in its coil form may be independently adjusted by turning its threaded rod in the supporting bar. These are the alignment adjustments for the three circuits. An equivalent arrangement is pictured by Fig. 16, where the slugs are raised and lowered together by their threaded rod attachments to the overhead plate, which is moved by pulleys and cord from the tuning dial. The slugs are adjusted independently for alignment by turning their threaded studs in the supporting plate.

In the symbol at B of Fig. 15 the fact that the inductor is adjusted for tuning is shown by an arrow, and the independent adjustment for alignment is indicated by the usual arrowhead. At C of this figure, tuning is by the variable inductor. There are two alignment adjustments, one by movement of the inductor slug and the other by an adjustable trimmer capacitor in parallel with the inductor.

For f-m tuner alignment it is necessary to have a constant-frequency generator capable of furnishing a range from somewhat below 88 mc to somewhat above 108 mc when the output indicator is to be a vacuum tube voltmeter. A sweep generator and marker generator used in connection with an oscilloscope must operate in this same frequency range.

If a constant-frequency r-f signal generator won't provide fundamental frequencies in the f-m carrier range, it may be possible to use harmonics of lower generator frequencies. For example, the mid-frequency of the f-m band (98 mc) is the second harmonic of 49 mc and the fourth harmonic of 24.5 mc. If adjusting the generator to one of these frequencies gives VTVM readings with the set tuned near the center of its range, the

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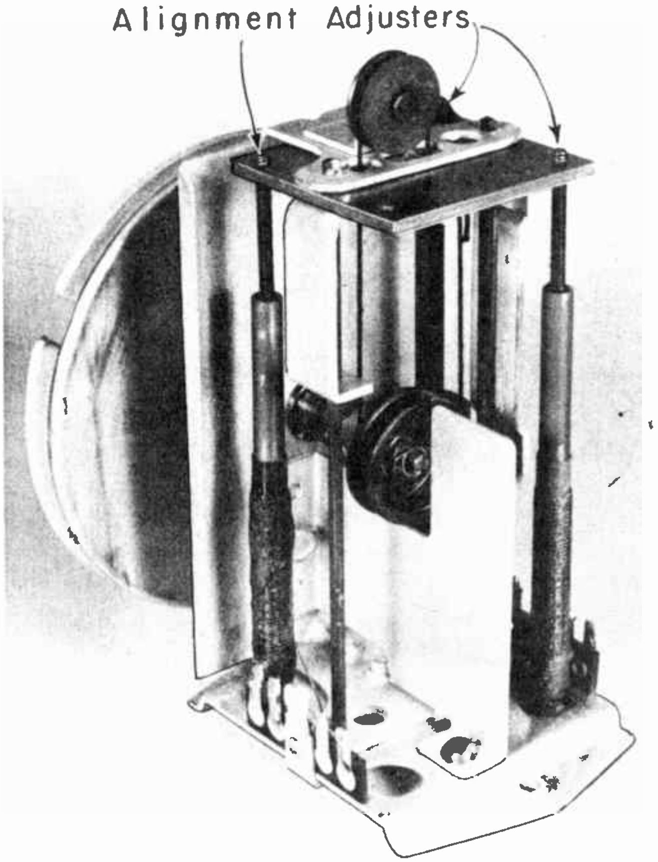

Fig. 16. An inductance tuner with screw-type alignment adjusters for each inductor.

harmonics are strong enough for service work. Percentage accuracy of harmonic frequencies is the same as that of fundamentals which produce the harmonics.

The output of the constant-frequency generator or sweep generator is connected to the f-m antenna terminals of the receiver, after disconnecting the antenna line from these terminals. The standard antenna input impedance of f-m broadcast receivers is 300 ohms. If there is no impedance matching network on the end of the generator output cable, connect one 120-ohm fixed resistor in series with each output lead and connect these resistors to the receiver antenna terminals.

Should one of the antenna terminals be plainly marked as connected to ground, you may connect the low side of the generator directly to the ground, and use a 270- or 300-ohm series resistor on the high-side lead to the other antenna terminal. The ungrounded terminal may be marked "A" or "F". Do not use series capacitors on the generator leads during tuner alignment.

The VTVM or oscilloscope used as output indicator is connected to a point of unbalanced d-c voltage on the f-m demodulator circuit. That is to say, the output indicator is connected in the same manner as for i-f amplifier alignment in the f-m receiver, or for alignment of takeoff, interstage couplings, and demodulator primary in a television sound system. If there is a limiter tube, the output indicator may be connected across the limiter grid resistor.

Observe the same precautions in isolating scope and cable capacitance as mentioned for i-f alignment. Also, be sure to keep the generator output below the level at which limiting occurs - unless your output indicator is on the limiter grid resistor, which makes output indications independent of limiting effects.

If the r-f oscillator has been disabled during i-f alignment, place it back in operation before working on the tuner. Continue using any avc overriding voltage which has been applied. Do not neglect placing the band selector in its f-m position.

The basic principles or methods of f-m tuner alignment may be explained in connection with Fig. 17. The diagram shows an r-f amplifier, a mixer, and an oscillator as separate triodes. There might be other types of tubes that may be combined in any of the ways described in earlier pages. The three tuning circuits contain fixed inductors, variable tuning capacitors, and adjustable trimmer capacitors. These circuits might otherwise be any of the types explained in connection with Fig. 15 without altering the principles of alignment.

Let's assume that the generator at the upper left Fig. 17 is furnishing a frequency of 98 mc, that the receiver dial is set at 98 mc, but that the three tuned circuits are in only approximately correct alignment. If you vary the oscillator trimmer C_o one way or the other the oscillator frequency will change. At some point of adjustment the oscillator frequency will become such as to beat with

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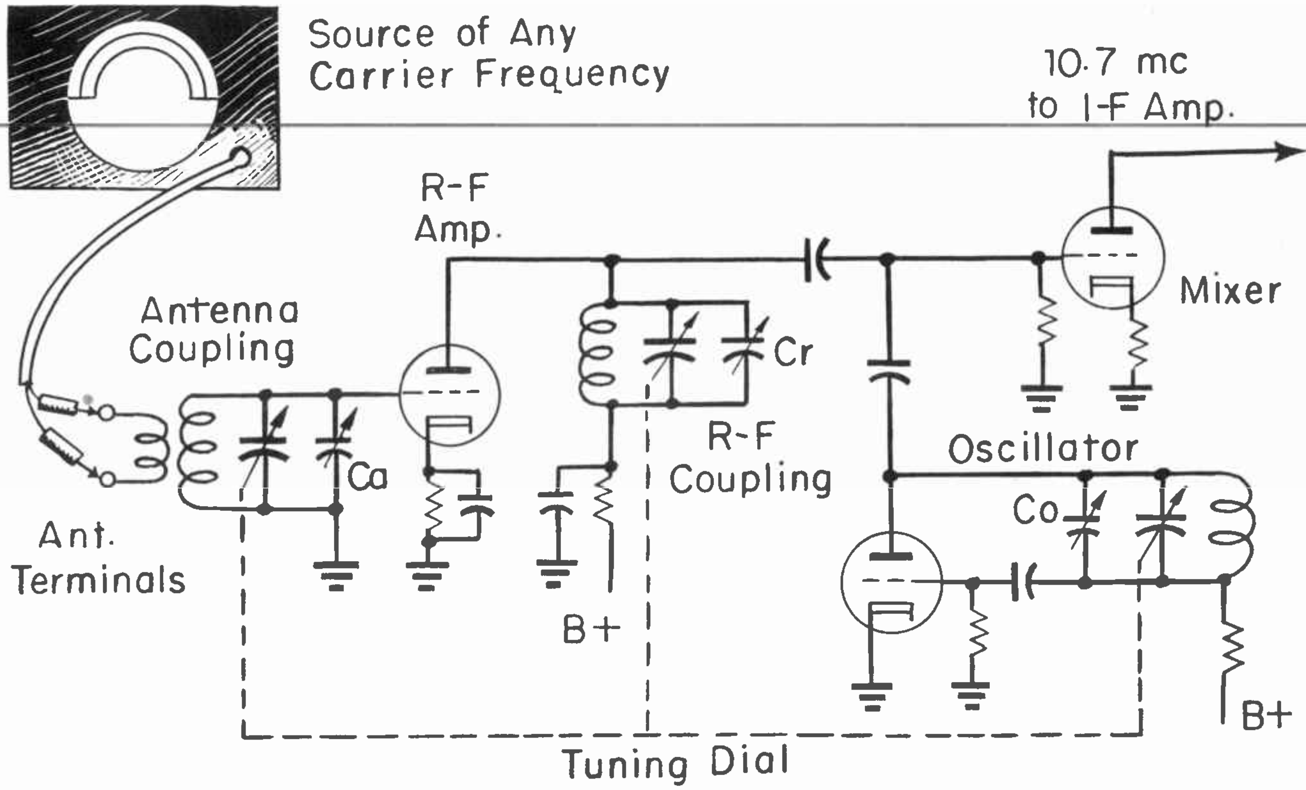

Fig. 17. Points of alignment adjustment in an f-m tuning system.

98 mc from the generator to produce a difference frequency of 10.7 mc.

Previously the i-f amplifier and demodulator will have been aligned for peak response at 10.7 mc. As you adjust the oscillator through the point giving this 10.7-mc intermediate frequency there will be peak voltage on a VTVM or a trace peaked at 10.7 mc on an oscilloscope connected as output indicator.

These peak indications will occur even with the antenna and r-f couplings far out of adjustment. There are two reasons. First, these circuits tune broadly and will pass enough of the 98-mc signal (or any other carrier frequency) to act on the mixer grid. Second, the signal voltage at the mixer grid is the sum of r-f and oscillator voltages, and very little r-f voltage need combine with the strong oscillator voltage to produce the 10.7-mc beat.

By adjusting or aligning the oscillator we have accomplished the following. The receiver tuning dial is set at the center frequency of a received f-m signal, simulated now by the generator. The oscillator is aligned for this dial frequency. The correct frequency of 10.7 mc is being fed to the i-f amplifier and demodulator.

Next, without changing the 98-mc frequency from the generator, and without altering the position of the tuning dial or pointer, we might adjust the antenna coupling trimmer Ca and the r-f coupling trimmer Cr for peak output indications. The results would be a practically perfect alignment for 98-mc, the middle of the f-m broadcast band, but the antenna and r-f couplings might not track with the oscillator at lower or higher frequencies in the f-m band.

To obtain better tracking, our method may be modified in this manner. The first step still will be precise adjustment of the oscillator trimmer for peak response with the signal generator and tuning dial at the same frequency. Then change the generator and tuning dial to a higher or lower frequency, at or close to either 88 mc or 108 mc. Next, adjust either the antenna or the r-f trimmer with one hand while "rocking the dial" back and forth through the selected frequency with your other hand. Find the combination giving

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the highest peak on either the VTVM or scope. The dial setting doubtless will be a little off the generator frequency, but not enough to interfere with tuning by the set operator.

If there are three alignment adjustments, as in Fig. 17, proceed now to tune the generator at or near the other end of the band, and change the tuning dial to this frequency. Adjust the third trimmer, not previously aligned, for peak indications while rocking the tuning dial. Again the dial probably will be a little off the generator frequency.

Should there be only two alignment adjustments in the tuner, commence by adjusting the oscillator at a frequency near either the top or bottom of the f-m band, near 108 or 88 mc. Then make the dial rocking adjustment of the second tuned circuit at a frequency near the other end of the band.

If the dial or pointer position after one of the rocking adjustments is so far from the generator frequency as to cause confusion in tuning for stations, it may be possible to make a correction by spreading or squeezing turns on the inductor for this adjustment. If indicated dial frequency is too high, spread the turns for less inductance. Then the dial will have to be set for more capacitance, at the desired lower frequency point. If dial frequency is too far below generator frequency, squeeze the turns for more inductance, while will require setting the tuning capacitor for less capacitance, or at a higher dial frequency.

Supposing now that we are to align a tuner having two adjusters for each circuit, with tuning by means of variable inductors. The parts and connections might be as in Fig. 18, which shows an r-f amplifier tube and a converter acting as mixer and oscillator. The circuits have been made different from those of Fig. 18 merely to bring out the fact that methods of alignment depend on the number and location of adjusters, not on the types of tubes and of tuning elements.

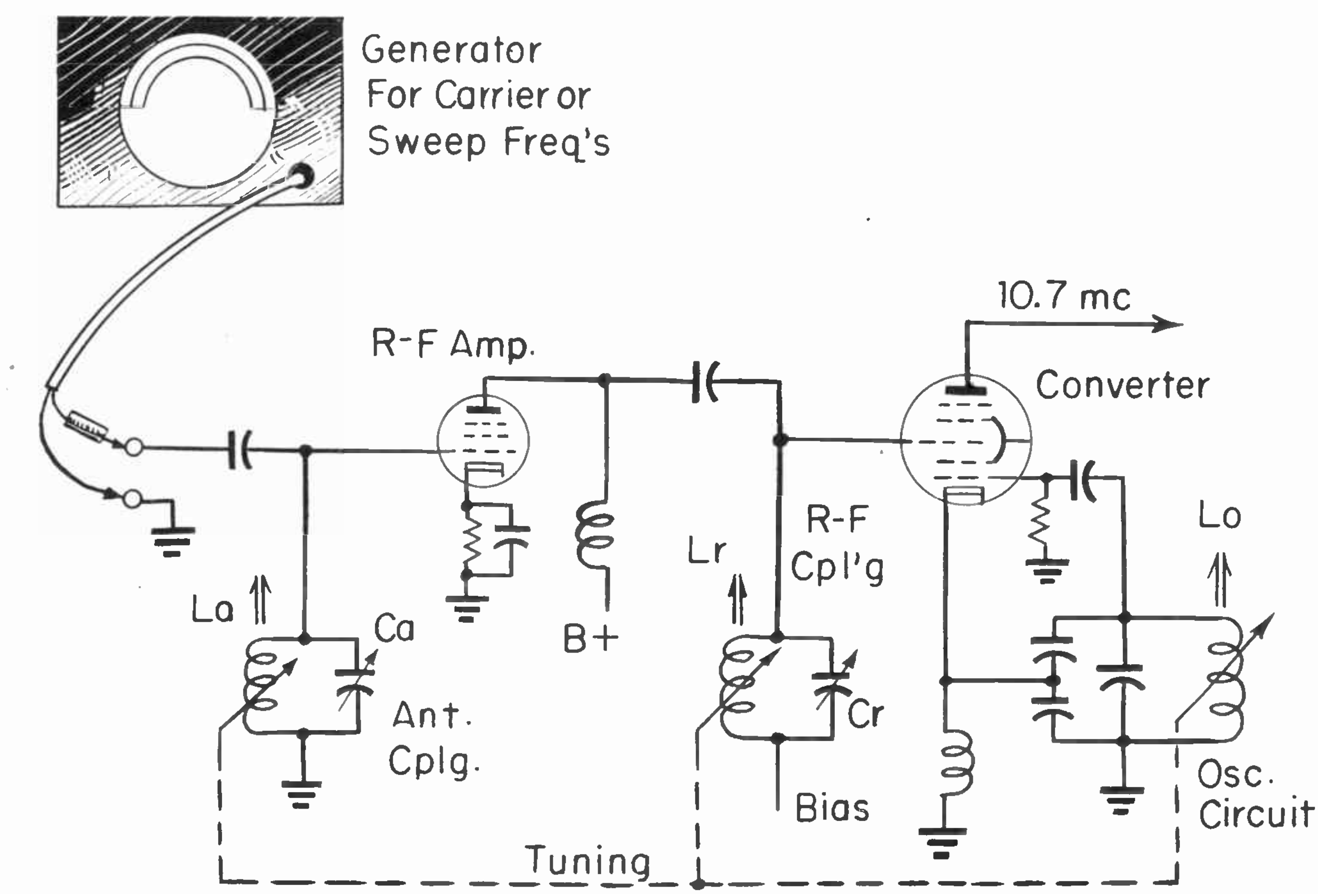

Fig. 18. Tuning by variable inductors. Alignment by adjustable inductors and capacitors.

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In the antenna and r-f tuning circuits there are inductor slug adjustments La and Lr, also trimmer capacitors Ca and Cr. The oscillator circuit is shown with only an inductor slug adjustment Lo, but in some cases the capacitor shunted across the entire inductor might be an adjustable trimmer. The second adjuster for any circuit is used to improve the tracking. After one of the adjusters is used for alignment at a frequency in one part of the band, say around 105 mc, the second adjuster is aligned at a frequency near the other end of the band, possibly at 90 mc.

An alignment process might be carried out in this manner, which is merely an example. 1. The oscillator is aligned with the generator and receiver dial at 88 mc, using the oscillator slug adjustment. 2. The other slug adjustments are aligned at the same frequency, or possibly at 90 mc, while rocking the tuning dial as explained earlier. 3. If the oscillator has a second adjuster, align it with the generator and receiver dial at 98 mc, without rocking the dial. 4. Align the second adjusters of the other circuits with the generator at 105 mc, rocking the tuning dial to obtain maximum peaks of output on the VTVM or scope.

The order of alignment and the order in which you employ frequencies at the top, middle, and bottom of the f-m carrier band may be varied widely. No matter how you do the work, the final result must be reasonable agreement between received center frequencies (or generator and marker frequencies) and tuning dial indications all across the dial. Also, no matter how you make the first adjustments in all circuits, never fail to repeat the entire procedure at least once. The second adjustments always affect tuning at dial and generator frequencies other than those employed while making these adjustments. This is the reason for repeating the entire alignment before considering that the job is complete.

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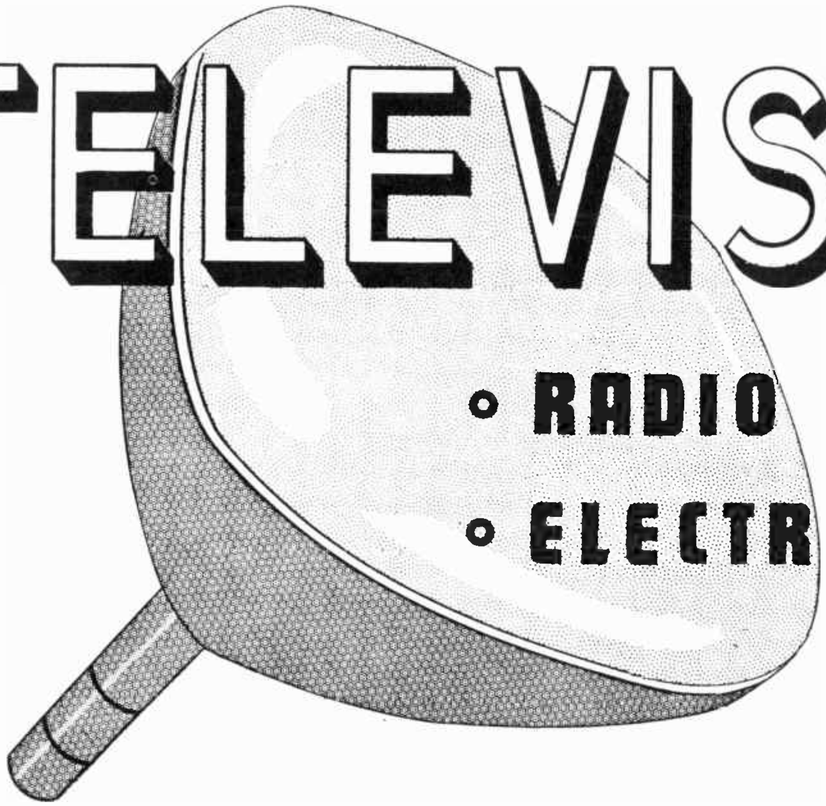

• RADIO
• ELECTRONICS

LESSON 63 — SPEAKERS AND AUDIO AMPLIFIERS

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Lesson 63

SPEAKERS AND AUDIO AMPLIFIERS

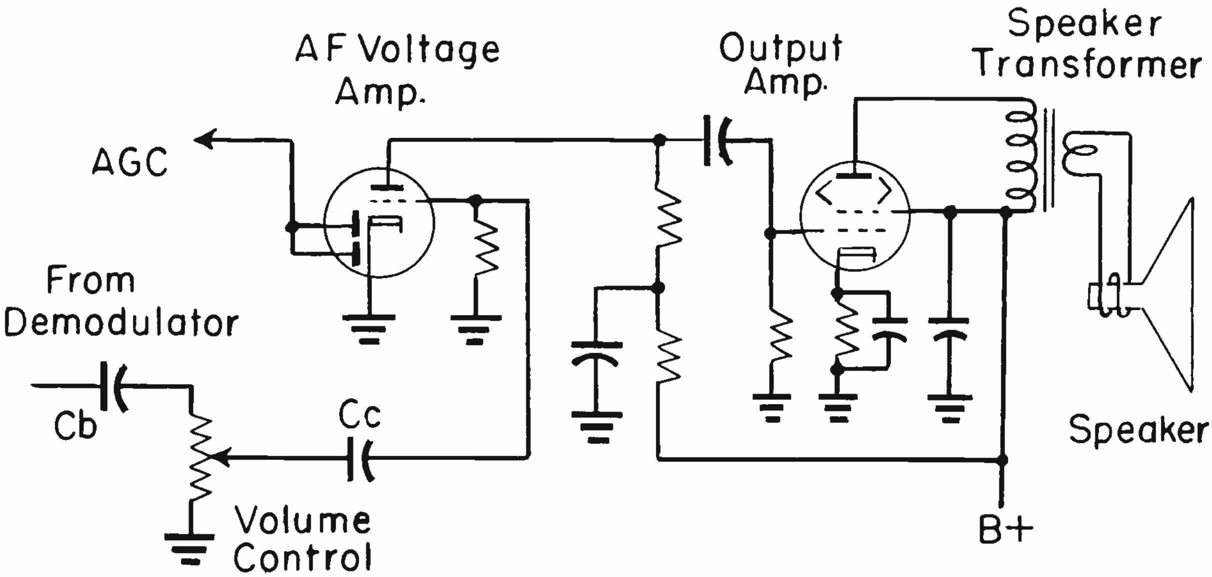

Fig. 1. An audio amplifier section such as used in many home receivers.

All receivers have speakers, and all have either diode sound detectors, f-m sound demodulators, or both. Between the demodulator or detector and the speaker is the audio amplifier section. In the majority of home receivers for a-m broadcast, for am-fm broadcast, or for television broadcast, the audio amplifier sections are of the same general type.

Circuits for a typical audio amplifier in a television receiver are shown by Fig. 1. Audio signal voltage from the demodulator passes through blocking capacitor Cb to the volume control. The slider of the volume control is connected through another capacitor Cc to the grid of the triode section in a duodiode-triode tube. This section of the tube acts as an audio voltage amplifier.

The diodes of the duodiode triode here are used in the automatic gain control circuit for i-f and r-f amplifiers in the television or video portion of the set. Using part of a tube in the audio system and other parts in other sections of the receiver illustrates a fact of importance. In any combination tube having a single cathode, grounding of the cathode allows using one part of the tube for any purpose requiring a grounded cathode, and other parts for other entirely unrelated purposes requiring a grounded cathode.

When the triode of a duodiode-triode is used for audio amplification the diode plates are not always used for the agc system. One or both might be used in an a-m diode detector circuit, or in an agc keying circuit, or for other purposes. Sometimes the diodes are not used at all, they are grounded. This is done because many duodiode triodes have triode characteristics better suited to audio voltage amplification than any readily available tubes having only triode sections.

The plate of the voltage amplifier triode of Fig. 1 is resistance coupled to the grid of a beam power tube used as audio output amplifier. The plate of this output amplifier is coupled through an iron-core transformer to the speaker.

When diodes of a combination tube are to be used in an f-m demodulator circuit there must be two separate cathodes. Separate cathodes are found in commonly used triple-diode triode tubes. Fig. 2 shows how such a tube may be used as ratio detector and

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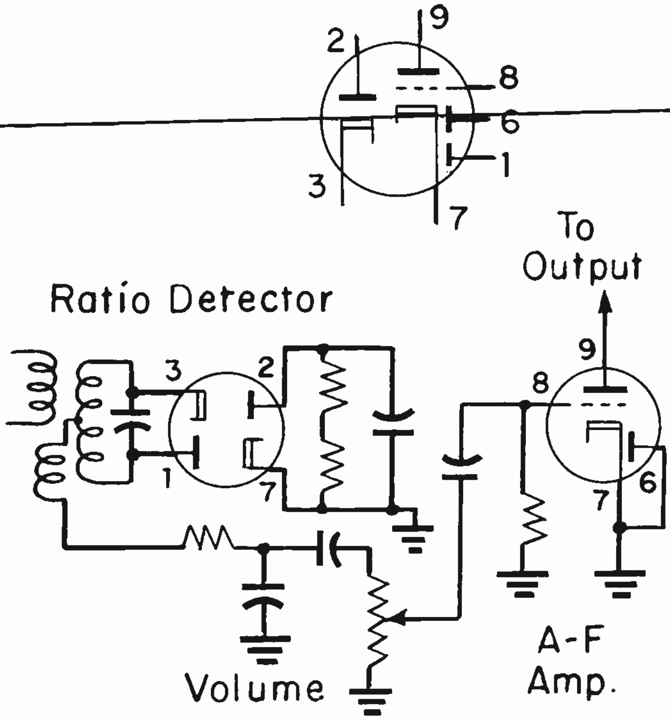

Fig. 2. F-m demodulators require separate cathodes.

audio voltage amplifier. A symbol for the complete triple-diode triode tube is shown above the circuit diagram, with base pin numbers. The connection diagram shows separated symbols for a twin-diode and a triode, with the same base pin numbers. Tube symbols often are separated on service diagrams, sometimes with possible confusion. For example, note that the cathode for pin 7 has to be shown twice in the diagram having separated symbols, although there is only one cathode on pin 7.

The audio amplifier is the simplest section of television and sound broadcast receivers in which we are particularly interested. Seldom are there any service adjustments in this section. Servicing consists of locating defective units, of locating shorts, grounds, opens, and abnormal resistances, and of replacing parts which cause trouble.

In some more costly sets designed for a-m and f-m broadcast reception, record playing, and possibly television as well, the audio amplifier and speaker system may be quite elaborate. Then there are various service adjustments, also manual controls for separate regulation of bass and treble response and for overall volume. There are selector switches for radio, phonograph, and sometimes for microphone inputs.

The difference between these more elaborate audio systems and those in television receivers and ordinary a-m and f-m sound receivers is largely in the range of audio frequencies reproduced uniformly and with negligible distortion. This matter of audio response deserves a little consideration.

<u>RANGES OF AUDIO FREQUENCIES.</u> Consider a flute, which is capable of producing fundamental audio frequencies in the approximate range of 260 to 2300 cycles. A violin will produce all these fundamentals and more, its range being from about 195 to 3100 cycles. Yet notes at or close to a given fundamental frequency from a flute and from a violin do not sound alike. It is chiefly differences in overtones or harmonic frequencies which make each instrument sound unlike any other.

A piano will produce fundamentals in the approximate range of 30 to 3500 cycles per second, and there will be harmonics extending to 10, 15, or 20 thousands of cycles. To perfectly reproduce the full range of piano frequencies an entire audio system from input through speaker would have to provide uniform and distortionless response from 30 to 20,000 cycles. Even a close approach to this ideal would constitute what is called a high-fidelity audio system.

Frequencies transmitted as modulation in standard broadcast and television sound usually can go no higher than 5000 cycles, so there would be no point in putting a high-fidelity audio system into such receivers. With f-m broadcast the sound modulation may extend to a maximum of 15,000 cycles. The principal reason why f-m broadcast receivers often have better audio systems than a-m broadcast and television sets is for faithful reproduction of this wider range of frequencies.

If we assume that our listeners are average in frequency range and sensitivity of hearing, and that receivers will be used where surrounding noise is at the level of an average home, uniform reproduction in a

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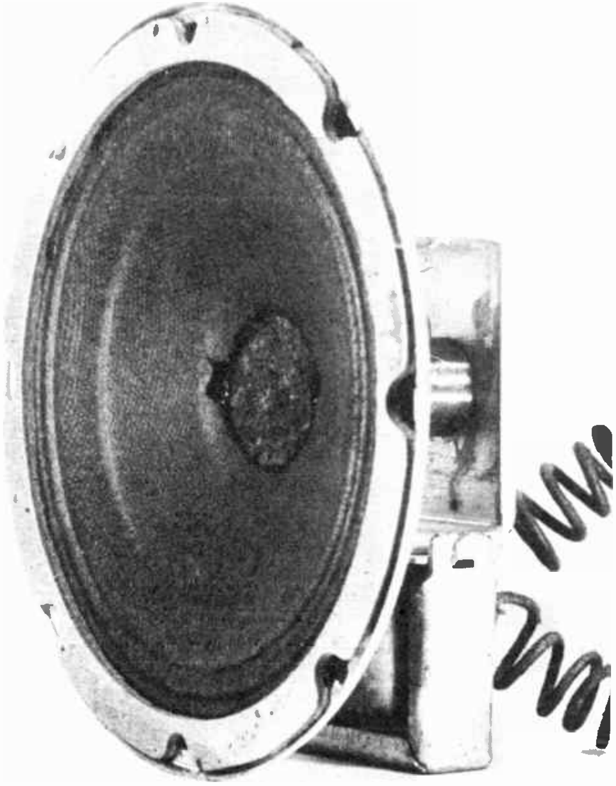

Fig. 3-A.

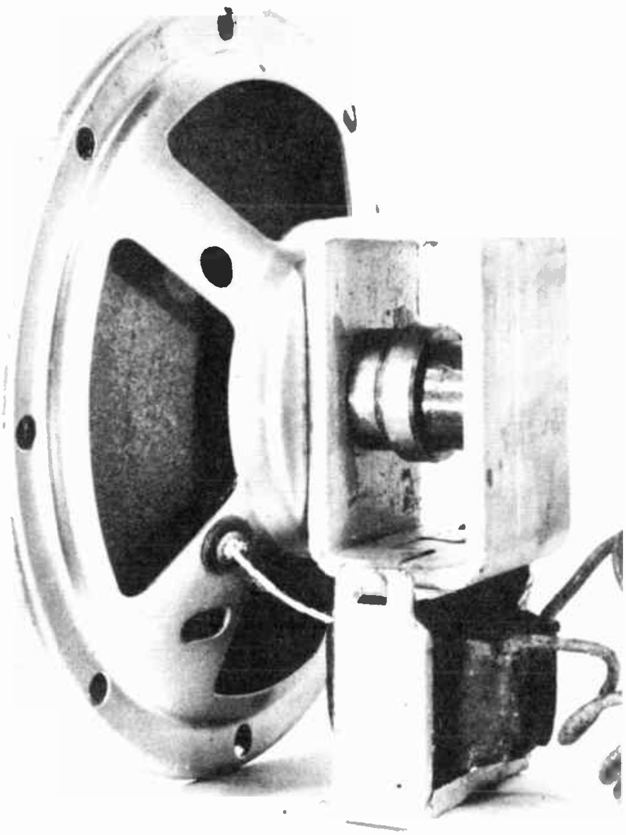

Fig. 3-B.

Fig. 3. Front and rear views of a small PM (permanent-magnet) speaker.

range from 70 or 80 cycles up to about 8000 cycles gives the effect of perfect reproduction, so far as frequency influences the judgment of listeners. Uniformity from about 100 to 5000 cycles sounds very good, except to the most critical listeners. All this applies to reproduction of music.

When it comes to reproduction of speech, uniformity in a band from about 250 to 2500 cycles allows the average listener to understand everything that is said. Although a few separate words might be confused, the meaning would be clear because the listener would get the context. Any frequency range giving acceptable reproduction of music will be entirely satisfactory for speech.

SPEAKERS. The object of audio amplifiers is to produce audible sounds from speakers. It will simplify our studies if we commence at the speaker end of the audio system, note the characteristics and performance of speakers, then learn how requirements may be met by amplifier tubes and circuits.

A speaker such as used in many television and radio receivers is pictured by Fig. 3, a front view at A and a rear view at B. The arrangement of parts in a speaker of this kind is shown by Fig. 4. A cone made of stiff paper or fibre is supported around its outer edge on the main frame or basket of the speaker. On the center of the cone is a small cylindrical extension which goes back into a circular magnetic gap. This gap is formed between the outside of a cylindrical pole piece on a strong permanent magnet and the inside of a round opening in the magnet pot.

Securely attached to the extension of the cone is a winding of a few turns of indulated wire, called the voice coil, You can see the voice coil in Fig. 5, on a cone which has been removed from a speaker frame. The cone extension and voice coil are held exactly centered in the magnetic gap by a spider of

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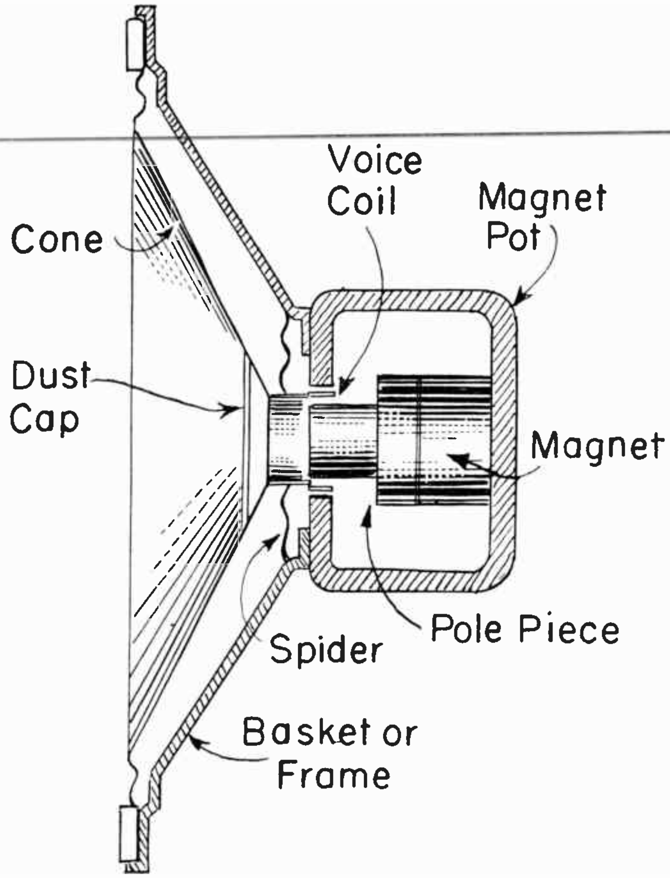

Fig. 4. Principal structural parts in a PM speaker.

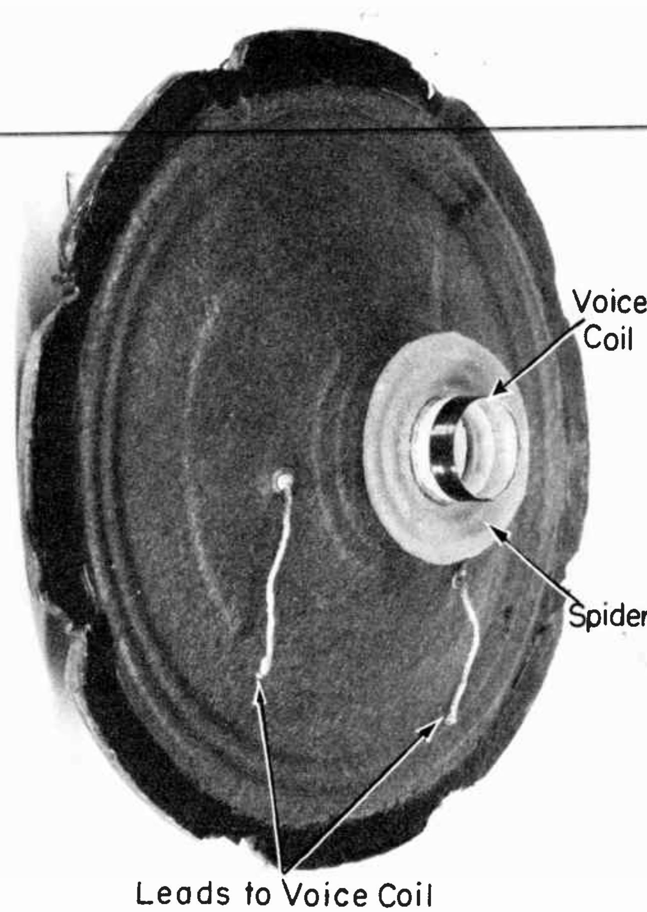

Fig. 5. The cone, the voice coil, and the spider of a speaker.

semi-flexible material extending from the cone to the speaker frame. The two ends of the voice coil winding are connected to flexible conductors attached to the cone. These conductors or leads go to terminals which, at B of Fig. 3, can be seen on the speaker frame.

The magnetic gap is very small in comparison with cone dimensions. When the cone is 4 inches in diameter the gap width may be about 1/25 inch, with thickness of voice coil and cone extension less than 1/50 inch where they fit into the gap. To keep the gap free from foreign matter the center of the cone is closed by a dust cap which shows at A of Fig. 3 and also in Fig. 4. The rear of the gap is protected by a metal sleeve around the magnet, as you can see in Fig. 6. This sleeve may also hold the magnet pole piece centered in the magnetic gap.

Magnetic lines of force from the permanent magnet pass from its forward end through the pole piece, across the gap, and return through the iron or steel of the pot to the rear end of the magnet. There is a strong magnetic field in the gap, and in this field is the voice coil. When currents at audio frequencies flow in the voice coil they produce their own magnetic fields which react with the field of the permanent magnet. When these currents and their resulting field are of one polarity the voice coil is forced forward, and when polarity reverses, the voice coil is forced backward.

The cone must move with the voice coil to which it is attached. Consequently, the cone vibrates at the audio frequencies of currents in the voice coil, and audible sound waves at these frequencies are set up in surrounding air.

At lowest audio frequencies the entire cone moves back and forth, and were the cone absolutely rigid this would hold true also at high frequencies. But the cone is not rigid,

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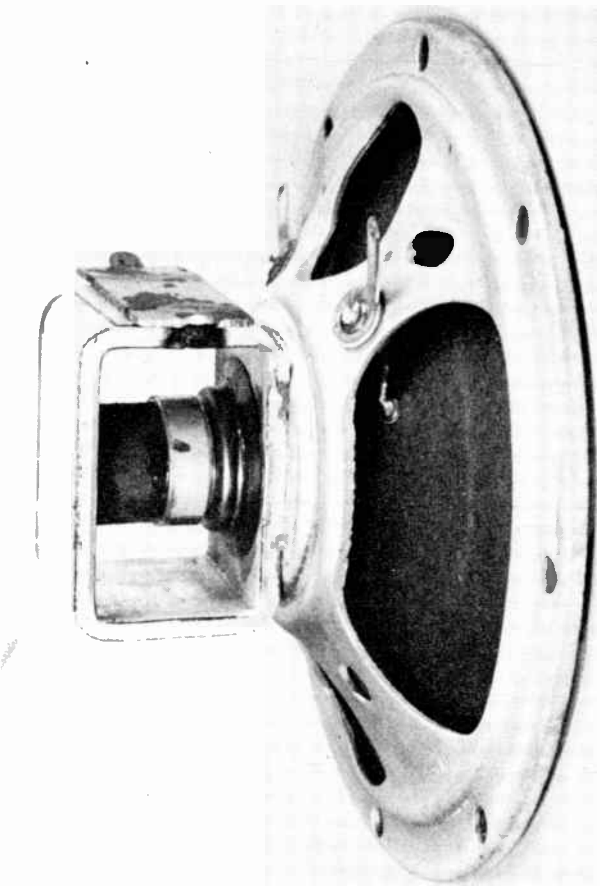

Fig. 6. The rear opening to the voice coil gap must be closed against foreign matter of all kinds.

and with increasing frequencies the vibrations extend to less distances from the center, with the outer edge of the cone remaining relatively motionless.

With other factors unchanged, the greater the cone diameter the better will be the response at low frequencies. Free vibration of the cone is limited by stiffness or lack of stiffness in the spider and at the outer edge of the cone where corrugations (Fig. 4) form what is called the cone rim hinge. Since back and forth travel of the cone is, theoretically, inversely as audio frequency, greater "compliance" or flexibility at spider and rim hinge helps low-frequency response.

The ability of a speaker to transform electric power input to the voice coil into sound waves in surrounding air is called sensitivity. Sensitivity depends largely on strength of the magnetic field in the gap, increasing with field strength. Field strength sometimes is specified as gap energy level, measured in millions of ergs. An erg is a unit of energy equivalent to a force of about two millionths of a pound acting through a distance of one centimeter, about 0.4 inch.

Another way of expressing magnetic strength in the gap is to give the weight in ounces of the permanent magnet, on the assumption that the magnetic force is proportional to magnet weight or size. The greater the gap field strength or the magnet weight, with other factors unchanged, the more sensitive is the speaker and the wider is its frequency response, especially when large powers are to be handled at low frequencies.

Speakers are rated as to maximum electrical powers in watts, at audio frequencies, which they will transform into sound waves in air without the speaker itself becoming so overloaded as to cause extreme distortion, or without the cone being forced to travel greater distances than normal to design of spider, rim hinge, field coil and gap dimensions. These maximum powers apply to middle frequencies. Much less power can be handled without distortion at the lower and higher frequencies.

It is a fairly safe rule to select a speaker having rated power capacity in watts somewhat greater than maximum "undistorted" output power of the tube or tubes connected to the primary of the speaker transformer. A speaker of too little power rating, when operated at high settings of the receiver volume control, will cause rattling and rasping noise, and the voice coil and cone extension may be torn from their fastenings.

Catalog specifications of speakers include five principal factors as follows:

1. Cone diameter. This is the diameter at the front or exposed end of the cone, inside the fastening to the frame, and is less than the outside or frame diameter. Diameters for receiver-type speakers range from $3\frac{1}{2}$ to 15 inches. In television sets the diameter usually is between 4 and 10 inches. Cones and speaker frames are not always round, they

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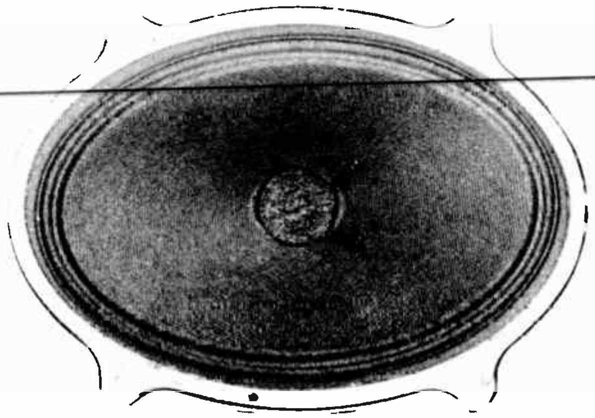

Fig. 7. A straight front view of an oval speaker.

may be oval as pictured in Fig. 7. Common dimensions for oval units are 4 by 6 inches, 5 by 7 inches, and 6 by 9 inches.

2. Power capacity, in watts. Powers for home receiver installations may be as little as 2 watts and as great as 20 watts. Power capacities and cone diameters are roughly proportional, with larger cones for greater powers and smaller cones for lesser powers.

3. Magnetic strength in the voice coil gap, or weight of the permanent magnet. Gap energy levels for speakers up to about 4-watt capacity may be from 1/4 to 1/2 million ergs, and for 16 to 20 watt capacity may be 6 million ergs or more. For a 4-watt capacity the weight of a permanent magnet may be from about 0.75 to 1.5 ounces, increasing with power capacity to something like 8 to 12 ounces for 20 watts.

4. Voice coil diameters increase with cone diameters and with power capacities. In a speaker with 4-inch cone the coil diameter may be as small as 1/2 inch, and in 15-inch speakers the diameter may be between 1-1/2 and 2-1/2 inches. Coil diameters ranging toward the small size may provide greater sensitivity and better high-frequency response, while large diameters tend to improve the low-frequency response.

5. Voice coil impedances, in ohms. This is a matter of which we shall speak further when discussing output tubes and speaker coupling transformers, because the effective plate resistance of the output tube or tubes must be matched to the impedance of the speaker voice coil by a suitable transformer.

FIELD COIL SPEAKERS. We have been talking about speakers in which the magnetic field for the voice coil gap is furnished by a permanent magnet. These are called permanent magnet types or "PM" speakers. There are other speakers in which the field for the voice coil gap as provided by an electromagnet. These are called field coil types, or wound field types, or by a trade name "electrodynamic" speakers.

A speaker with a wound field is shown by Fig. 8. Where the permanent magnet and its pole piece are used in PM speakers, we have here a coil of many turns of insulated wire around a central core of magnetic steel or iron. The forward end of this core extends into the opening of the pot to form a magnetic gap just as such a gap is formed by the pole piece of a permanent magnet.

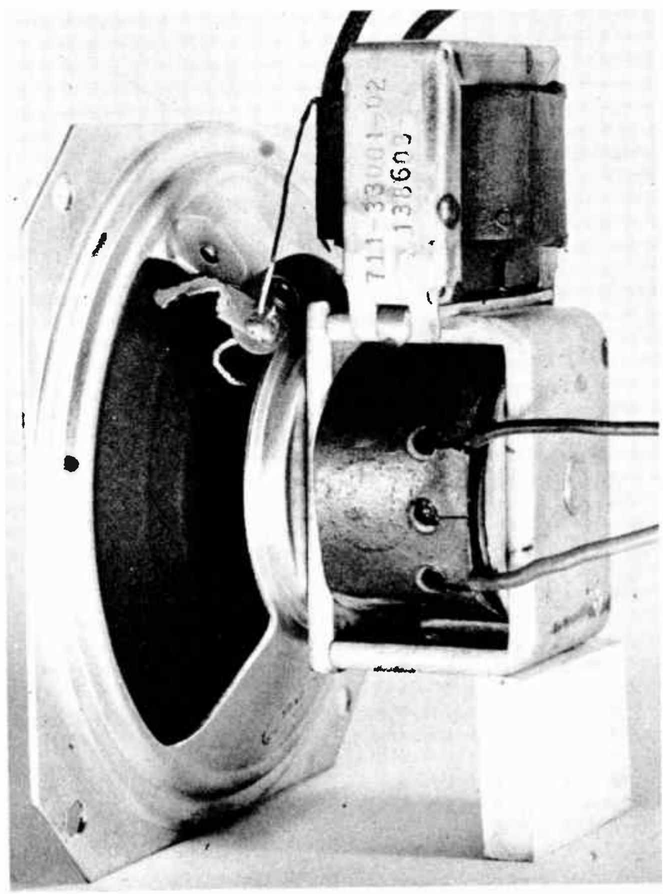

Fig. 8. This speaker has a field coil in place of a permanent magnet.

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On top of the magnet pot in Fig. 8 is mounted a transformer that couples the plate of the audio output tube to the voice coil of the speaker. Extending back from the field coil are the two leads for this coil.

The field winding of the speaker must be supplied with direct current, because magnetic lines in the voice coil gap must remain in one direction or one polarity, just as with a permanent magnet. The direct current is provided by using the speaker field winding as a filter choke in the low-voltage power supply of the receiver. This was mentioned when we studied low-voltage power supplies.

Catalog ratings for speaker field coils always include d-c resistance in ohms and sometimes also the watts of power used in the field coil when it is producing magnetic strength in the voice coil gap of a value such as otherwise would be furnished by a permanent magnet. Knowing the numbers of watts and ohms, it is possible to determine the d-c voltage drop across the field coil by using an alignment chart or this formula.

$$\text{Field coil volts drop} = \sqrt{\text{watts} \times \text{ohms}}.$$

Then, from computed voltage drop and ohms of resistance we may determine the field coil current, thus.

$$\text{Field current, ma} = \frac{1000 \times \text{volts drop}}{\text{ohms resistance}}$$

How much current actually will flow in the speaker field winding, and the allowable voltage drop, will depend on design of the low-voltage power supply and on d-c current furnished through the speaker field, as a choke, to receiver circuits. More current increases magnetic field strength and sensitivity of the speaker. Increase of sensitivity will be somewhat less, in percentage, than increase of current. Less than normal coil current will drop speaker sensitivity by a greater percentage than the decrease of current.

Common values of field coil resistance range from 400 to as much as 3000 ohms, but in some speakers for television sets may be less than 100 ohms. The number of field coil watts for normal magnetic strength and speaker sensitivity is about equal to rated watts of audio input power for the speaker.

When a speaker field winding is used as a power supply filter choke, current in the winding is not pure d-c but has a small a-c component or ripple. This is obvious, because the purpose of a filter choke is to reduce ripple, and were there no ripple there would be no need for the speaker field as a filter choke. The effect of ripple current is to cause corresponding variations of magnetic strength in the voice coil gap, and to produce in the sound output a hum at the ripple frequency.

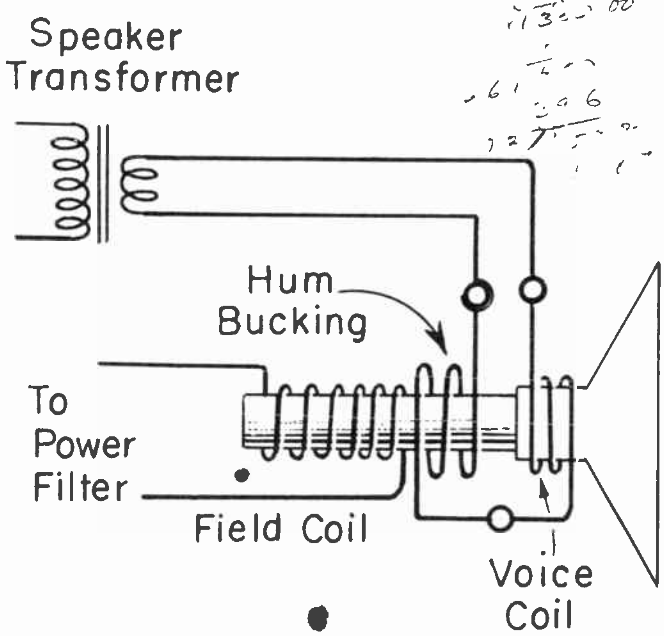

Fig. 9. Connections of a hum bucking winding in a speaker with wound field.

Hum due to power supply ripple may be lessened by means of a hum bucking winding on the speaker field. Connections are as shown by Fig. 9. The hum bucking winding consists of a few turns around the outside of the field coil, and connected in series with the voice coil. The bucking turns are so connected that hum voltage induced in them is of opposite polarity to hum voltage produced in the voice coil.

<u>CABINETS AND BAFFLES.</u> When the cone of a speaker moves forward, sound waves in air are caused to move away from the front of the cone and toward the back of the cone. Backward movement of the cone

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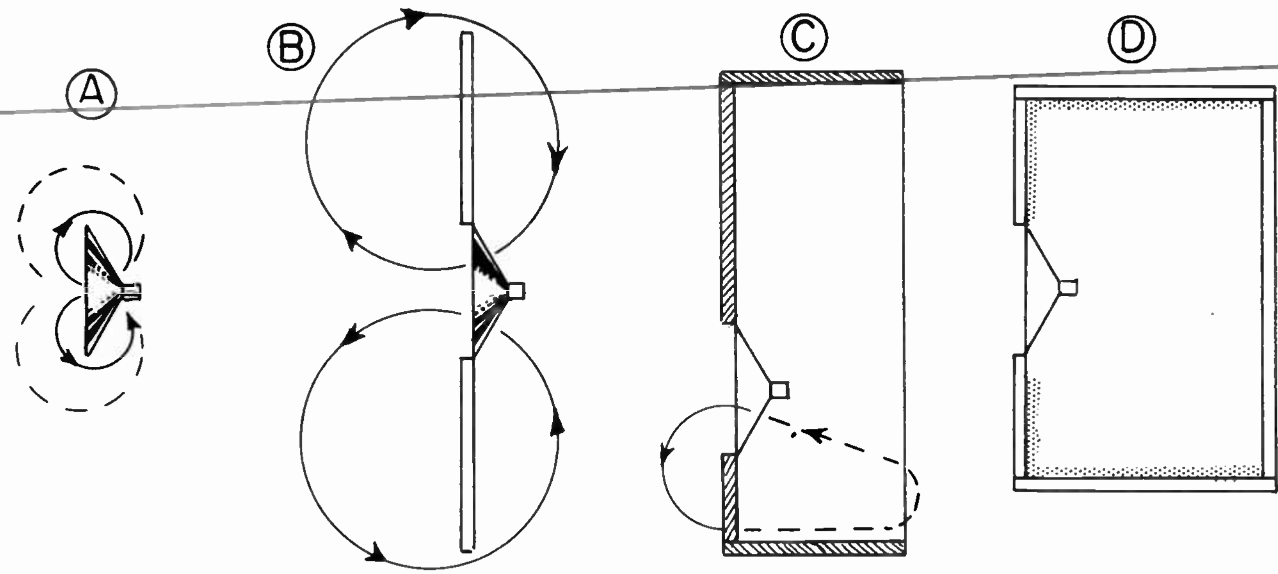

Fig. 10. Speakers require baffles for effective reproduction of low frequencies.

causes sound waves in opposite directions at opposite sides. Were the speaker used in open air, as represented at A of Fig. 10, sound waves could travel around the edges of the cone and cancel their forces. At low frequencies, where sound wavelengths in air may be 10 to 15 feet long, there would be almost complete cancellation and these sounds would not be radiated in any appreciable strength. High frequencies, of proportionately short wavelengths, would not be cancelled but would be radiated.

Were the speaker at the center of a large, flat "baffle", as at B, sound waves would have to travel much farther between front and back of the cone. Then the longer waves or lower frequencies would suffer less cancellation of forces and would be more effectively radiated. With the speaker in an open-back cabinet, such as a radio console represented at C, sound waves would have to travel around the outside and into the back of the cabinet in order to cancel, and effectiveness of low-frequency radiation would increase with this distance.

A completely closed cabinet of ample cubic-foot volume, lined with sound absorbent or deadening material, as at D, will absorb all wave energy of back radiation. Low-frequency radiation or response then will depend almost entirely on cone diameter, rigidity, and other factors mentioned earlier. Still better cabinet or baffle designs include the bass reflex enclosure which causes the back wave to radiate from a separate opening, in phase with the front wave from the cone. Various "folded horn" designs have similar effects.

Most radio cabinets, even when large, allow front and back radiations to combine in irregular manners, with additions and partial cancellations at various frequencies. Ordinary cabinets usually are resonant at certain frequencies; they cause strong build-up of these frequencies in the manner of an organ pipe. Such effects usually occur at frequencies below 200 cycles. The presence of radio and television chasses in the sound spaces prevents uniform frequency response.

AUDIO POWERS AND DECIBELS. When talking about stages preceding the output tube in an audio amplifier system we are interested in voltage gains. But with reference to overall gain, from grid input at the first tube to voice coil in the speaker, we should consider power, not only voltage. This is true because power is needed to vibrate the speaker cone and surrounding air. There must be such a combination of voltage and current as will produce necessary driving power.

Voltage measurements with reference to overall gain are misleading. In the case of a certain audio amplifier, represented by Fig. 11, an r-m-s signal of 0.03 volt at the

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grid of the first tube caused 0.92 r-m-s signal volt across the speaker voice coil. This is an overall voltage gain of somewhat less than 31 times. But audio power into the voice coil was found to be 1,343 times as great as into the grid circuit. It was 1.8 watts at the voice coil and only 0.00134 watt at the grid input.

The difference between gains of voltage and of power results chiefly from differences of impedances. In the amplifier tested, voice coil impedance was only 3.75 ohms, while grid input impedance was about 565 ohms. Power is inversely proportional to impedance or resistance, so would be about 150 times greater in the voice coil than at the grid were the voltages equal.

Power also is proportional to the square of the current. In the small impedance of the voice coil it takes only moderate signal voltage to cause large current and large power. The small signal voltage in the relatively high impedance of the grid circuit causes only small signal current, and only a little power is used.

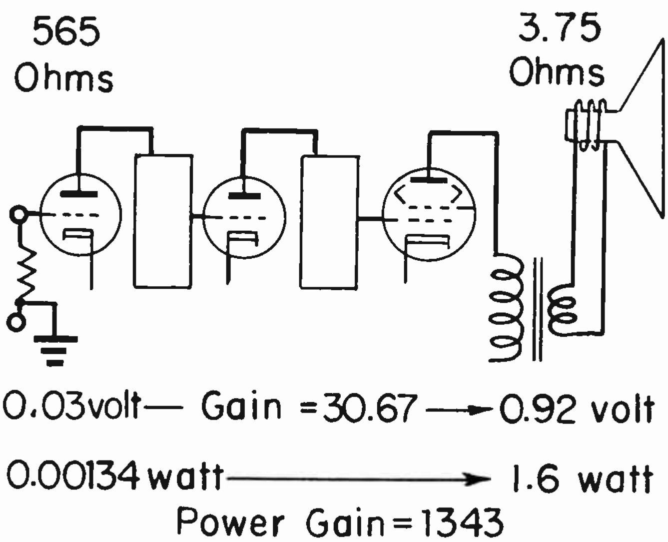

Fig. 11. Voltage gain and power gain in an audio amplifier system.

Power gains in amplifier systems may be stated as the number of times power is increased between input and output, or as the ratio of output power to input power. In the amplifier of Fig. 11 this ratio is 1,343-to-1, since output power is 1,343 times greater than input power. This power ratio would or should hold good when power input is increased or decreased within reasonable limits.

Were input power adjusted to 1/1000 or 0.001 watt, a power gain of 1,343 times would bring output power to 1.343 watt. The increase from 0.001 to 1.343 would be 1.342 watts. Were input power adjusted to 0.004 watt, the power gain of 1,343 would bring output power to 5.372 watts. The increase from 0.004 to 5.372 would be 5.368 watts. Now we have the same amplifier giving power increases of 1.342 watts and of 5.368 watts. To describe the amplifier as capable of either of these power increases, or of any other increase measured in watts, would mean very little - for the increase in number of watts depends on changes of input power.

However, were we to say that the amplifier has power gain of 1,343 times or that its ratio of gain is 1,343 would have very definite meaning. This ratio might be applied to any operating conditions or any input power within the power handling ability of the amplifier and speaker.

The amplifier whose performance has been cited has fairly high gain, about as high as would be found in large combination receivers. Small amplifiers of the general style shown by Fig. 1 of this lesson are likely to have power gains or power ratios on the order of 150. Large amplifiers built as separate units for use with radio tuners and record players often have maximum overall gains of 1 million to as much as 40 million times.

Audio power gains and losses seldom are expressed in ratios or in numbers of times one power is greater than another. They are expressed in decibels, a word usually abbreviated to db. Relations between decibels and power ratios are shown by Fig. 12. At the center of the graph is a vertical line for a power ratio of 1 or 1-to-1. This, of course, means that input and output powers are equal, there is neither gain nor loss, or we may say there is zero gain and zero loss. Accordingly, we mark the center horizontal line for zero db, our starting point.

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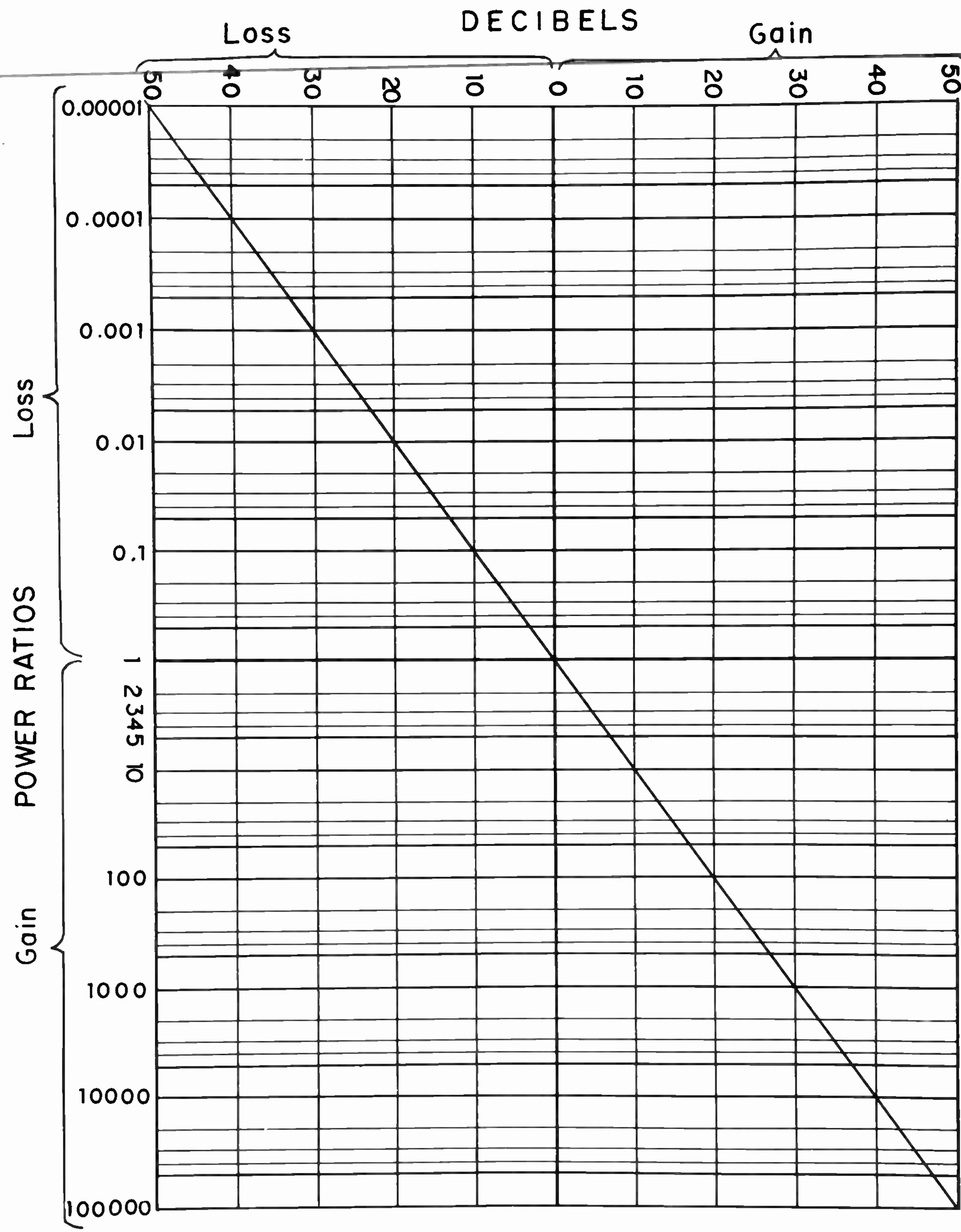

Fig. 12. Relations between decibels and power ratios of gain and loss.

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Every time the gain changes in the ratio of 10-to-1 the fact is indicated as a change of 10 db. Consequently, we show the power ratio change from 1 to 10 as a change of 10 db. Increasing the power ratio to 100 from 10 again is in the ratio of 10-to-1, and we add 10 more db to make a total of 20. A power ratio increase to 1,000 from 100, still an increase of 10-to-1, adds another 10 db for a total of 30. We may continue thus indefinitely. So long as output power is greater than input power we have db of gain.

In circuits containing no tubes there are losses of power, output power is only a fraction of input power. Such fractions, changing in inverse ratios of 10 or in ratios of 1/10-to-1, are shown on the loss side of the power ratio scale in Fig. 12. A reduction to 1/10 or 0.1 of the original power is a loss of 10 db. Every time the power ratio is cut to 1/10 we add another 10 db of loss, and continue so for any degree of reduction in power ratio.

Horizontal scale lines for numbers of decibels and vertical lines for corresponding power ratios meet on the diagonal line. The power ratio scale is logarithmic, with heavy lines at multiples and inverse fractional ratios of 10 and with lighter lines for principal intermediate values. The decibel scale is uniform or linear, allowing intermediate values to be estimated easily.

Decibels, as we have been using them up to this point, are not units of power. They show only ratios of powers, how much greater or less one power is than another power. You would have to know the value of one power in watts or fractions of a watt in order to determine the number of watts for the other power. When decibels are to have definite values in watts it is common practice in radio to give to the number 1 on the power ratio scale of Fig. 12 a value of 1 milliwatt (1/1000 watt or 0,001 watt) of power used or dissipated in a resistance or impedance of 600 ohms.

The power value assigned to the ratio of 1 to 1-to-1 and thus to zero db is called the reference level. When 1 milliwatt is our reference level you can see from Fig. 12 that a gain of 10 db will bring the power up to 10 milliwatts, a gain of 20 db will mean power of 100 milliwatts, a gain of 30 db means 1,000 milliwatts, and so on, with all these powers used or dissipated in 600 ohms. Losses in decibels will bring the power down to fractions of a milliwatt shown on the graph. Other reference levels may be used. For instance, a reference of 6 milliwatts in 500 ohms or of 6 milliwatts in 600 ohms is found in telephone practice.

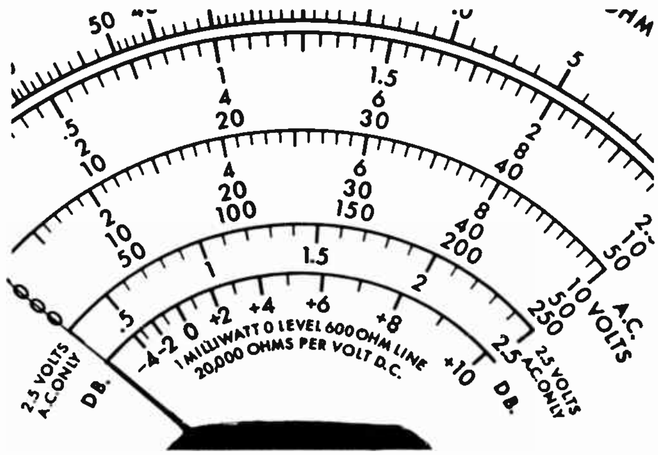

Fig. 13-A

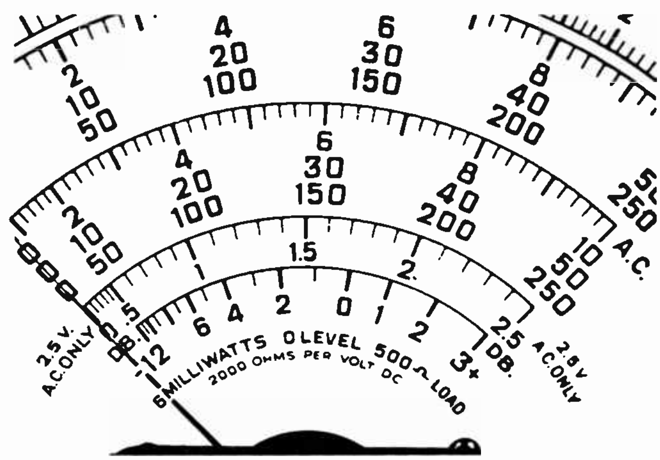

Fig. 13-B.

Fig. 13. Decibel scales as used on dials of VOM's and VTVM's.

DECIBEL METERS. On the dial of your vacuum tube voltmeter or volt-ohm-milliammeter there probably is a scale marked "Decibels" or "DB". This scale may be used for db measurements, with the function selector set for a-c volts. Any a-c voltmeter might be calibrated and used for db measurements. A db scale on the dial of a VOM is

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shown at A of Fig. 13. The reference level for which this meter is calibrated is marked on the dial as "1 Milliwatt O Level 600 Ohm Line", which is the usual reference level for radio. The meter at B is calibrated, as marked on its dial, for a reference level of "6 Milliwatts O Level 500-ohm Load".

The difference between the two decibel scales for the two reference levels is in the number of volts on the a-c volts scales corresponding to zero on the db scales. The zero db voltage is determined as follows.

$$\text{Zero level volts} = \sqrt{\text{ohms} \times \text{watts}}$$

Using this formula with 600 ohms and 0.001 watt (1 milliwatt) gives approximately 0.775 volt. Note that when the pointer of the meter at A of Fig. 13 is at 0 db it is also at 0.775 volt on the a-c volts scale immediately above the db scale. If we use 500 ohms and 0.006 watt (6 milliwatts) in the formula it gives approximately 1.732 volts. On the dial of the meter at B you can see that the pointer will be at this value of 1.732 a-c volts when it is at 0 on the db scale.

When a meter used for db measurements is connected across any impedance or resistance other than that for which the instrument is calibrated, indications must be corrected by adding or subtracting certain numbers of decibels on all readings.

Fig. 14 shows db additions and subtractions for actual "loads" between 30 and 8,000 ohms when meter calibration is for a 500-ohm load. As an example, assume that the meter at A of Fig. 13 is connected across an actual resistance or impedance of 200 ohms, and reads +8 db. The chart shows that 4 db should be added to any reading when the connected load is 200 ohms instead of 500 ohms, so we add 4 db to the reading of +8 db and thus obtain a corrected value of +12 db. Were this meter to read -2 db when connected across 200 ohms, adding 4 db to -2 db would give a corrected value of +2 db.

Meters ordinarily have db graduations on only one of the dial scales, and are calibrated for direct db readings only when the range switch is at the position for this one scale. For example, with both meters of Fig. 13, db graduations would hold good only with the range switch at the 2.5-volt a-c position, because the adjacent a-c volts scales read 2.5 volts at full scale. With some other meter the db scale might be based on a 5-volt a-c scale, and db readings would be correct only with the range switch in its position for 5 a-c volts.

When a meter is used on a volts range greater than that corresponding to the db scale it is necessary to make corrections by adding certain numbers of db to readings on the db scale. First, divide the full-scale volts of the range actually used by full-scale a-c volts for the db range. Find this multiple along the bottom of Fig. 15, follow upward to the diagonal line, then across to the db scale at the left. Add the number of db there shown to the reading on the db scale of the meter.

Here are some illustrative examples applying to the meter at A of Fig. 13. The a-c volts scale corresponding to the db scale reads 2.5 volts at full scale. Other a-c volts scales have full-scale readings of 10, 50, and 250 volts. These other scales are multiples of the 2.5-volt scale respectively by 4 times, 20 times, and 100 times. Find the multiples along the bottom of the chart and determine corresponding db additions from the left-hand vertical scale of the chart, thus.

Full-scale Volts	Multiples Of Db Volts Scale	Decibels Added To Readings
2.5 (db scale)	1	0
10	4	12
50	20	26
250	100	40

If you use a VTVM or VOM for decibel measurements it is convenient to determine from Fig. 15 the numbers of db to be added at each position of the range switch, then mark these additions at the range switch positions. Some meters have such db additions already marked on their range switches.

FREQUENCY RESPONSE OF SPEAKERS. Decibels are used not only for electrical powers and power ratios but also in measuring relative pressures or intensities of sound waves in air. Fig. 16 illustrates the

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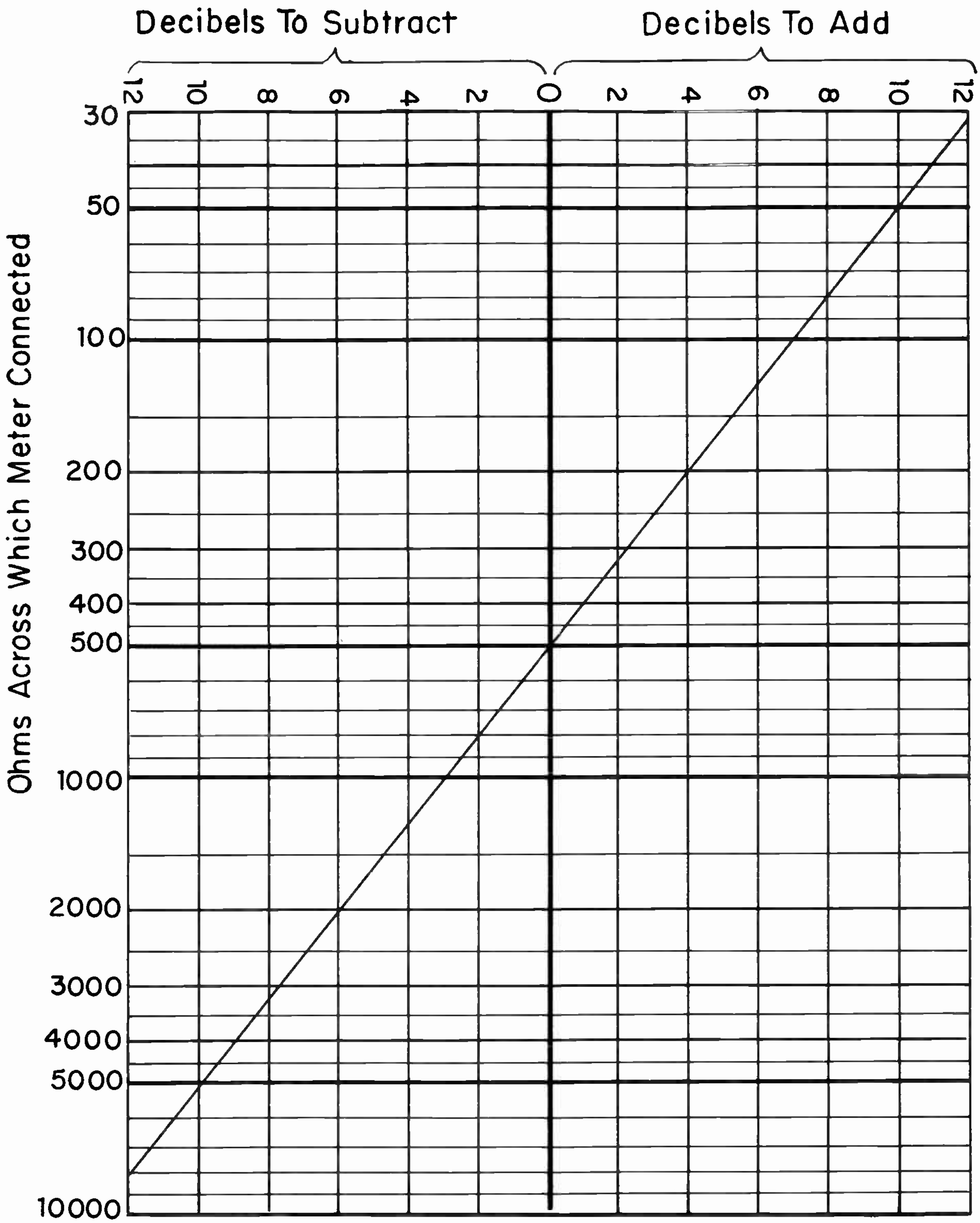

Fig. 14. Numbers of decibels added or subtracted on meter readings when the instrument is across impedance other than that for which calibrated.

general manner in which sound wave pressure from a typical radio or television speaker will vary when the speaker is fed with the same electrical signal power at all measured frequencies. The decibel scale shows ratios of outputs at lower and higher frequencies to output at a zero level of 400 or 1,000 cycles. Response curves for particular speakers usually have minor peaks and valleys all the way across, but follow an average path much as illustrated.

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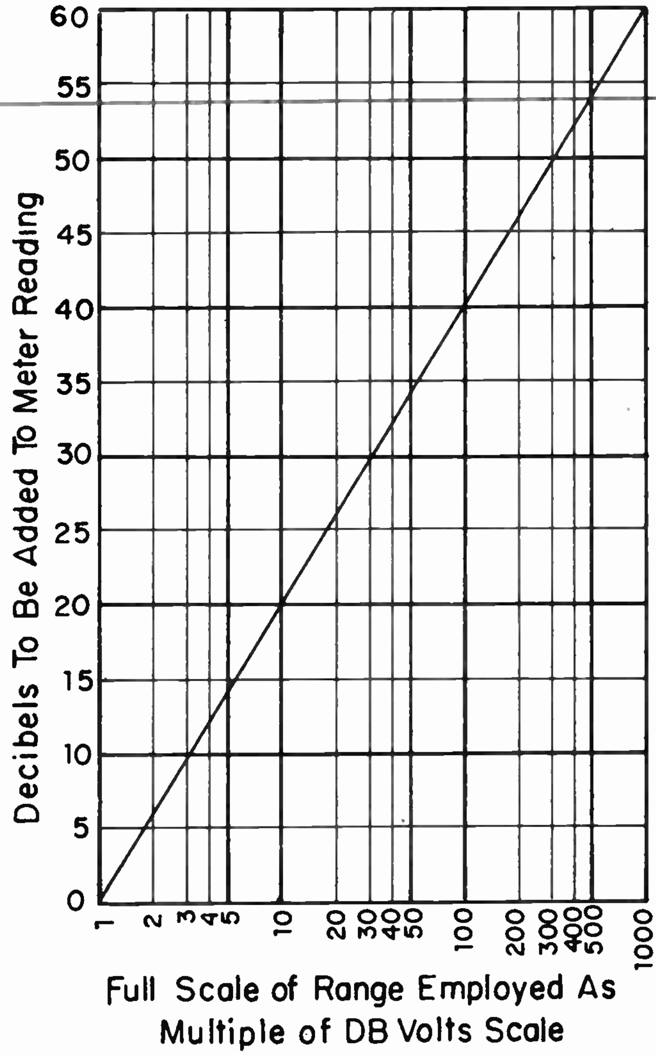

Fig. 15. Decibels added to meter readings when the instrument is used on a range other than the a-c volts range for the decibel scale.

Usually there is a small rise of response near 100 cycles, with rapid drop at lower frequencies. Response is fairly uniform through the middle frequencies, commonly rises somewhere around 2,000 cycles, remains high to about 5,000 cycles, then drops at still higher frequencies. Speaker responses are measured with the help of microphones, amplifiers, and pressure-calibrated indicators, under controlled conditions. A response shows the ability of the speaker to produce air wave pressures when conditions are those of the original measurements, but it does not necessarily indicate how the speaker will sound in ordinary rooms.

In rooms there are reflections of sound waves from walls, floor, ceiling, and all objects in the rooms. All these surfaces also absorb sound energy in varying degrees at different frequencies. The location of a speaker affects its performance. Low frequencies sound louder with the speaker in a corner and near either the ceiling or floor, and less loud when the speaker is near the center of a flat wall. Higher frequencies sound louder when listeners are nearly in line with the speaker axis than when far to one side. Low frequencies sound louder in a large room than in a small one.

IMPEDANCE MATCHING. In the output end of the audio amplifier of Fig. 17 we have a 6V6 beam power tube with 250 volts on the plate and screen, and with 12.5 volts grid bias. Manufacturers' ratings for this tube show that, with these operating voltages, resistance or impedance in the plate load should be 5,000 ohms for satisfactory performance.

Audio power from the tube plate must be transferred to the speaker voice coil, whose impedance in much of the a-f range is only 3 to 4 ohms. To get maximum audio power into the voice coil this coil must be connected to a power source whose impedance is no greater than that of the coil itself.

To provide the tube plate circuit with required high impedance for a load, and at the same time furnish the audio power from a low impedance to the voice coil, we use an impedance matching transformer. This transformer has many more turns in the primary or plate winding than in the secondary or voice coil winding. In the plate winding there will be high impedance, small signal current, and high signal voltage. In the voice coil winding there will be low impedance, large signal current, and small signal voltage.

Power always is proportional to current times voltage, to the product of current and voltage. The product of large current and small voltage in the transformer secondary is practically equal to the product of small current and high voltage in the primary. Therefore, we have the same audio power in both windings, and get all of the plate circuit power over into the voice coil circuit.

In parts catalogs you will find listings of many varieties of impedance matching trans-

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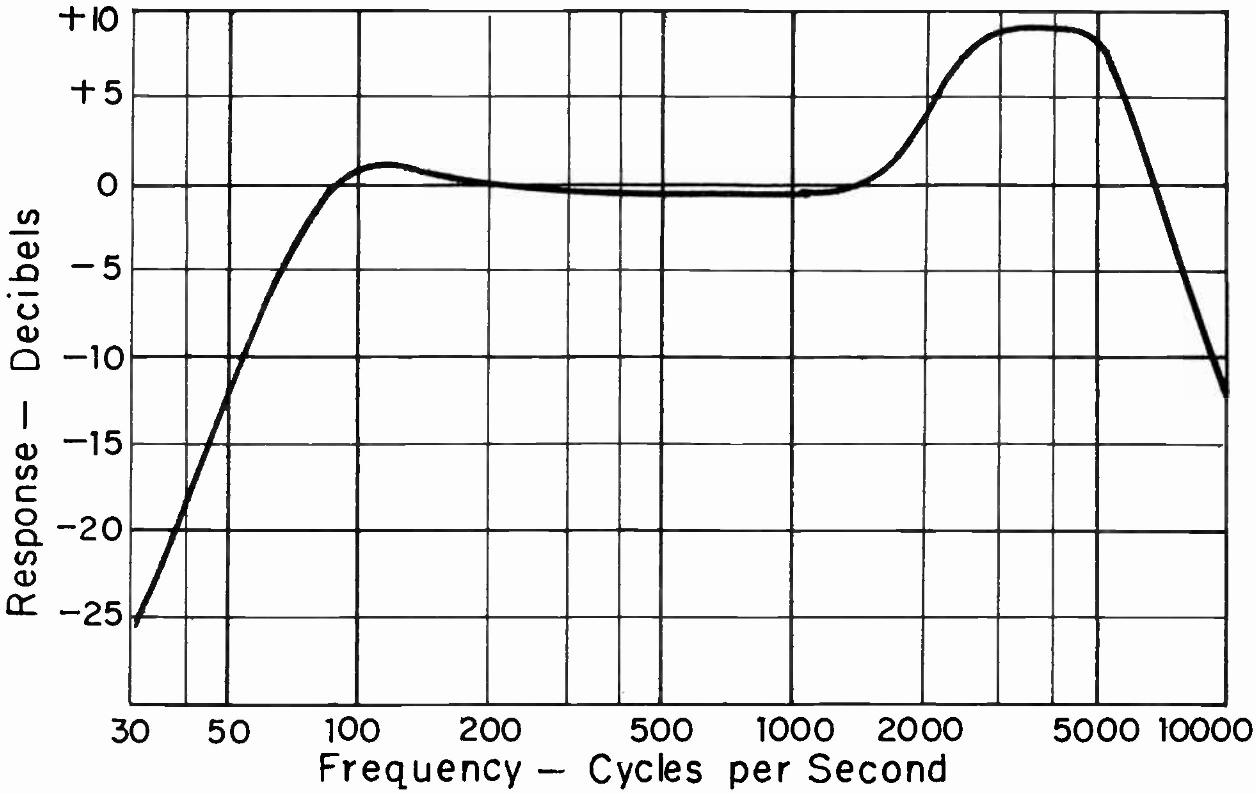

Fig. 16. Sound output power of a speaker, measured as air waves, varies in this general manner at various frequencies.

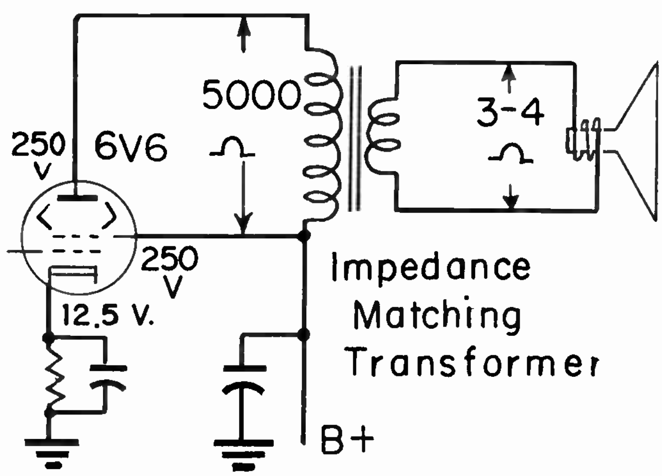

Fig. 17. Impedances to be matched in a typical audio output stage.

formers. Often they are called output transformers or speaker coupling transformers. Various combinations of primary and secondary impedances suit these transformers to all kinds of audio output tubes and all kinds of speaker voice coils. For speakers rated at no more than 3 to 4 watts of audio power the speaker coupling transformers are of small size and often are mounted on the speaker frame or magnet cup, as you can see in Fig. 8 and at B in Fig. 3.

Primary impedances of speaker transformers may be of such values, in ohms, as 1,500, 2,000, 3,000, 4,500, 7,500, 10,000 and 15,000. Secondary impedance may be 4, 8, or 16, ohms.

It is not always possible to obtain a transformer with exactly the primary impedance recommended for certain output tubes, nor with secondary impedance which is an exact match for the speaker voice coil. Then select a transformer having greater rather than less primary impedance than desired. There is little loss of audio power with primary impedance 10 per cent low, but it should be no lower. There is little chance of added distortion with primary impedance up to 25 per cent high, but it is not desirable to go any higher.

On the secondary side of the matching transformer it is better that impedance be lower than that of the voice coil, rather than higher. There is better power transfer from the lower primary impedance to a higher voice coil impedance than were the relations

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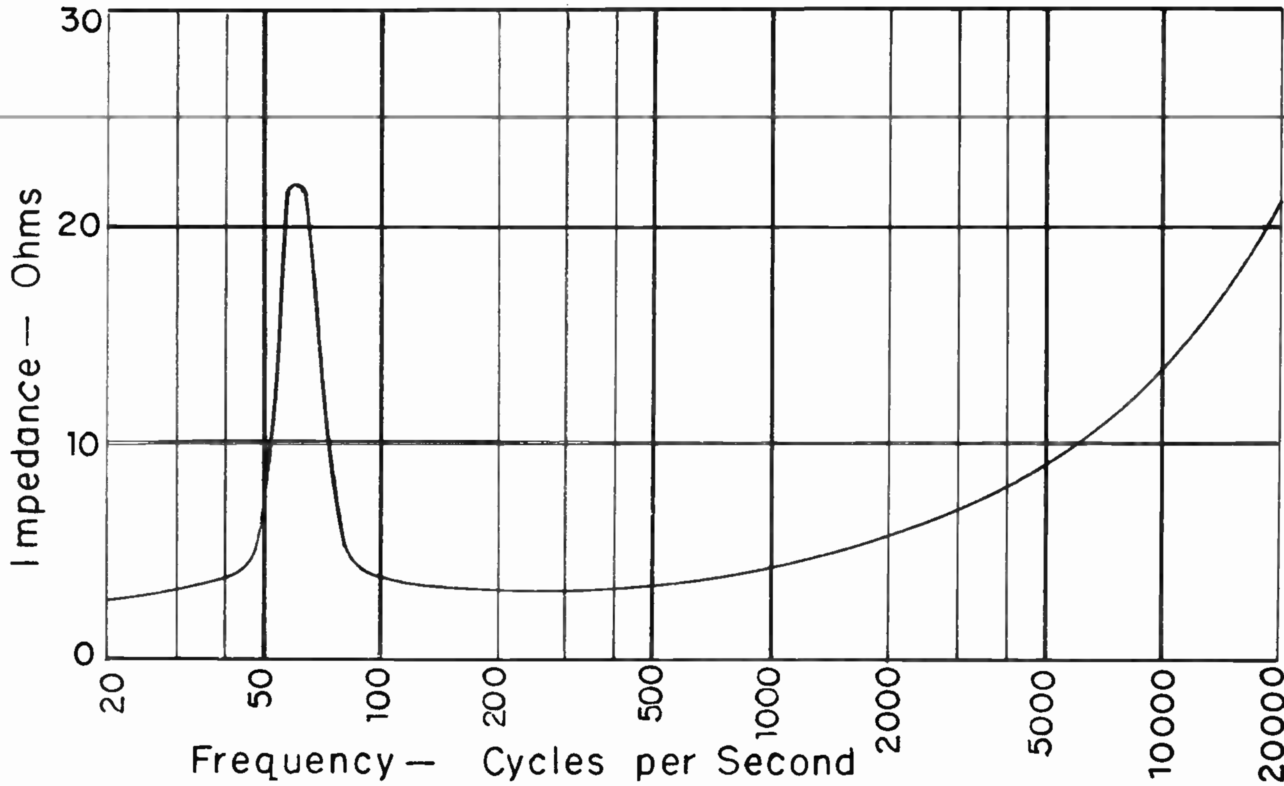

Fig. 18. How impedance of a certain voice coil varies with frequency.

reversed. When voice coil impedance is somewhat higher than transformer secondary impedance, the impedance "reflected" back into the transformer primary is increased. This causes higher effective primary impedance, and better transfer of audio power from output tube to transformer. When voice coil impedance is LESS greater than transformer secondary impedance, reflected primary impedance is lowered and there is poorer transfer of audio power from tube to transformer.

Impedances of voice coils vary with frequency about as shown by Fig. 18, which illustrates measured impedance of a speaker with 9-inch cone taken from a television console. Impedance is minimum at very low audio frequencies. There is a resonant peak near 60 cycles for this particular speaker. This peak preferably and usually is closer to 100 cycles, but it always exists. Then follows a decrease of impedance to a low which usually occurs around 400 cycles per second. The impedance at the bottom of this drop which follows the resonant peak, or the impedance at 400 cycles, is the rated impedance of the voice coil. At higher frequencies the voice coil impedance rises quite steadily, a condition which favors high-frequency response.

Speakers most commonly used have rated voice coil impedances of 3.2 ohms or of 3 to 4 ohms. This rated impedance is found with cones as large as 12-inch diameter and with audio power ratings as great as 15 watts. Larger and more powerful speakers often have voice coil impedances of 6 to 8 ohms, or even of 16 ohms.

What are called universal output transformers have tapped secondaries and sometimes tapped primaries as well. As a general rule the secondary taps allow for impedances of 4, 8, or 16 ohms. There may be also a secondary tap for 500 ohms for use when the transformer is connected through fairly long conductors to a distant speaker. In this case an additional "line to voice coil" transformer is used at the speaker, to match the 500-ohm impedance to the voice coil impedance. On these universal output transformers there may be primary taps for plate load impedances such as 3,500 ohms, 7,000 ohms, 10,000 ohms, or other values.

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AUDIO OUTPUT TUBES

TYPE NUMBERS	KIND	ELEMENT VOLTAGES Plate	Screen	Grid	RESISTANCE, OHMS Plate	Load	Harmonic Distortion	OUTPUT Watts
6V6 7C5	Beam	180	180	- 8.5	50,000	5,500	8%	2.0
		250	250	-12.5	50,000	5,000	8%	4.5
		315	225	-13.0	80,000	8,500	12%	5.5
25L6 50A5 50L6	Beam	110	110	- 7.5	13,000	2,000	10%	2.1
		200	110	- 8.0	30,000	3,000	10%	4.3
35L6 35A5	Beam	110	110	- 7.5	14,000	2,500	10%	1.5
		200	110	- 8.0	40,000	4,500	10%	3.3
6K6 7B5	Pentode	100	100	- 7.0	104,000	12,000	11%	0.35
		250	250	-18.0	90,000	7,600	11%	3.4
		315	250	-21.0	110,000	9,000	15%	4.5
6B4	Triode	250		-45.0	800	2,500	5%	3.2

Note: The 6AQ5 operates like the 6V6 at the two lower combinations of element voltages, except for slightly greater plate resistance.

AUDIO OUTPUT TUBES. Nearly all audio output tubes in television and radio receivers are beam power types. Only occasionally will you find power pentodes, and hardly ever power triodes. Compared with triodes, beam power tubes deliver greater audio signal power for a given input signal voltage at the grid. Power pentodes also possess this advantage over triodes, but tend to have greater audio distortion than beam power tubes.

Triodes have less inherent distortion than either power pentodes or beam power tubes. However, part of the extra output power available from a beam tube, as compared with a triode, may be used for degenerative feedback and other means for improving audio quality. Then the end result, even from the standpoint of distortion, is in favor of the beam tube when only a limited number of amplifying stages are used.

Several important features of audio output tubes are best illustrated by examining typical operating characteristics of a few representative types, as given in the accompanying table. For each tube are listed two or more combinations of voltages on plate, screen, and grid. For each combination are given resulting plate resistance, recommended plate load resistance or impedance, total harmonic distortion, and audio output power in watts.

The limit of grid input signal voltage which does not make the grid positive may be taken as equal to listed grid bias voltages. These maximum input signals are required to produce listed power outputs. For outputs which are comparable, you will notice that signal input to a triode must be greater than to a power pentode, and input to a power pentode must be greater than to a beam tube.

Note how widely the plate resistances vary with different combinations of element voltages for the same tube. Note also that recommended load resistances increase, in a general way, with plate resistances. Consequently, since changing element voltages will alter plate resistance, changes of element voltages also will alter the load resistance required for most desirable performance. You cannot raise or lower the element voltages while retaining permissible distortion limits and desirable output powers without making compensating changes in load circuits.

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The table shows that there are no direct or uniform relations between plate resistances and recommended plate load resistances. Therefore, it always is advisable to consult manufacturers' ratings and operating characteristics for each type of tube when selecting speaker coupling transformers for correct matching of impedances.

Beam and pentode power tubes are operated with load resistances of only about 8 to 15 per cent of tube plate resistances. As a result, much more of the total B-power energy (d-c power supply energy) is used in the tube than in the plate load. This constitutes what is called high plate power efficiency. Plate loads for triodes must be at least double the plate resistance in order to avoid severe distortion. Then more B-power is dissipated in the load than in the tube. This is low plate power efficiency.

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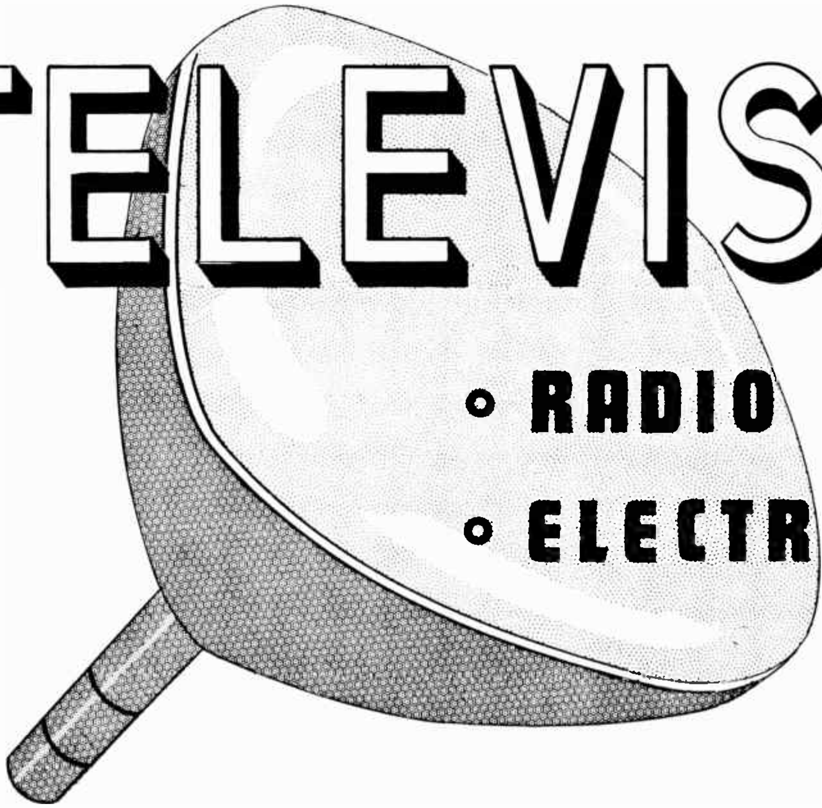
TELEVISION



• RADIO
• ELECTRONICS

LESSON 64 — AUDIO AMPLIFIER, CIRCUITS AND CONTROLS

Coyne School

practical home training

Chicago, Illinois

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Lesson 64

AUDIO AMPLIFIER, CIRCUITS AND CONTROLS

We have examined the behavior of audio amplifiers employing a single output tube. Such amplifiers are used in nearly all small standard broadcast sets, in most receivers designed only for television, and in many combination AM-FM sets. But in many of the larger standard broadcast receivers, also in many combination a-m, f-m, and television receivers, you will find two audio output tubes of the same type. The two audio tubes may be connected in parallel or in push-pull.

Fig. 1. An audio amplifier with two twin-triodes and two beam power tubes in push-pull. Controls are for volume, bass gain, treble gain, and impedance matching. A separate power supply is used.

Paralleled power tubes seldom are used, because the same two tubes in push-pull provide many advantages. Nevertheless, we should understand that with paralleled power tubes both plates, both screens, both grids, and both cathodes are connected together as in Fig. 2. Results, compared with those for a single power tube are:

The same grid signal voltage gives double the power output.

The same d-c voltages cause doubling of plate current and of screen current.

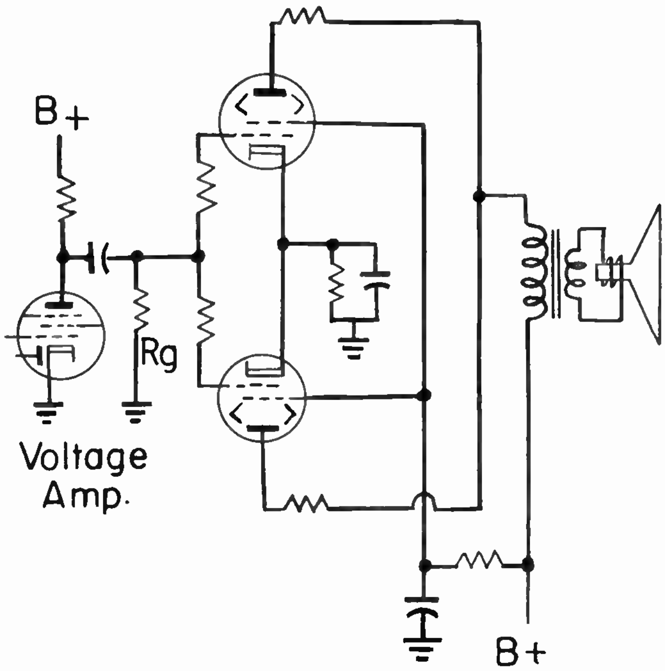

Fig. 2. Audio output tubes connected in parallel. Small resistors on grids and plates help balance voltages and currents.

Effective plate resistance is halved, and required load resistance or impedance is halved.

Since element currents are doubled, cathode bias resistance for given bias voltage is only half the resistance needed on a single output tube.

PUSH-PULL AMPLIFIERS. The simplest circuit for push-pull operation, and the one most clearly illustrating principles involved, is shown by Fig. 3. Later we shall look at circuits not so simple, but more commonly used.

The plate of the voltage amplifier which precedes the push-pull stage is coupled to the grids of the push-pull tubes through a transformer having a center-tapped secondary. When induced signal voltage at one end of this secondary is going positive, it is going negative at the other end. This is true in the secondary of any transformer, whether

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or not there is a center tap. As a result of oppositely changing grid voltages, plate signal voltage at push-pull tube A decreases or goes negative while plate voltage at tube B goes positive, and when plate signal voltage at A is going positive, it is going negative at B.

The plates of the push-pull tubes are coupled to the speaker through a transformer having a center-tapped primary. The tap goes to B+, and the outer ends of the primary to the push-pull plates. Opposite changes of signal voltages at the push-pull plates are applied to the ends of the transformer primary. We must conclude that, so far as changes of signal voltage are concerned, they act in the same directions across both halves of the primary. This is indicated by pairs of arrows on the diagram. The accompanying changes of primary signal current induce signal voltage and current in the secondary, which is connected to the speaker voice coil.

Input grid signal from a preceding amplifier to the push-pull stage must be double that to a single output tube when push-pull output power is to be double that from a single similar tube. This is because signal voltage induced in the entire secondary of the input transformer is divided between grids of the two push-pull tubes.

Although signal voltages and currents add their effects in the push-pull output transformer, this is not true of d-c plate current in the transformer primary. Plate current from tube A of Fig. 3 flows downward through the upper half of the primary to the center tap and to B+, while plate current from tube B flows upward through the lower half of the primary and to B+. If the two d-c plate currents are equal, as they should be, their magnetizing effects cancel in the primary winding. Variations of the opposite plate currents then cannot vary magnetization of the transformer core, and can cause no induced emf's and currents in the secondary.

Cancelling of d-c currents in the primary means that hum due to ripple voltage from the B-power supply will not appear at

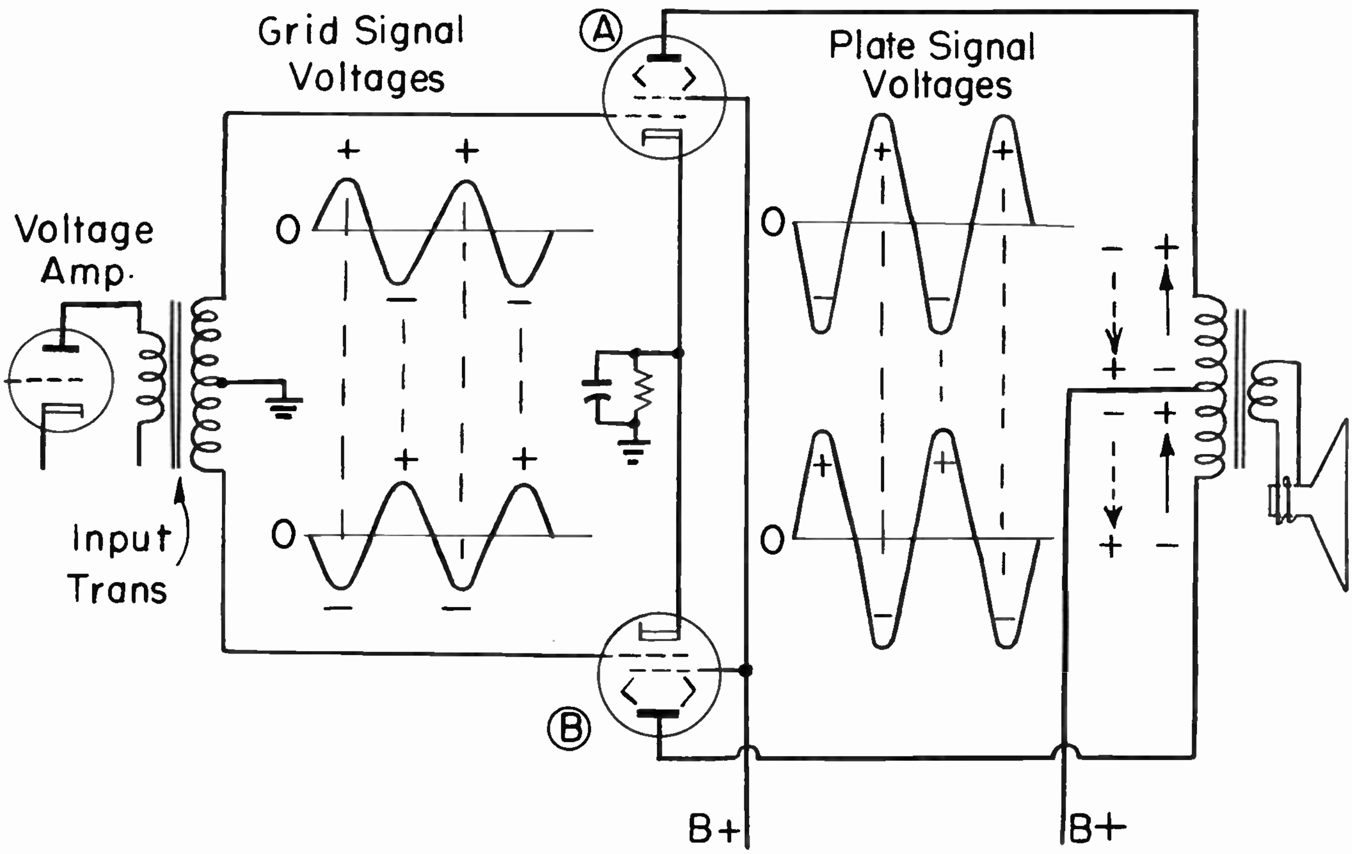

Fig. 3. Two output tubes connected in push-pull, showing how signal voltages divide and recombine.

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the speaker. Consequently, plate current for the push-pull tubes may be taken from the power supply filter at a point closer to the power rectifier, where there is greater ripple voltage. Neither will the speaker produce low-frequency noises which might be due to sudden changes of power line voltage.

These advantages of push-pull operation are fully realized only when d-c currents to the push-pull tubes are equal or balanced. Ripple voltage and any other variations of supply voltage which affect amplifiers preceding the push-pull stage will be fed to the push-pull grids. These voltage variations will not be cancelled, any more than regular audio signals from these preceding stages would be cancelled. Hum at power line frequency caused by heater-cathode leakage in amplifiers will not be cancelled. This is 60-cycle hum, as distinguished from 120-cycle ripple hum from a full-wave power rectifier system.

When using a single audio output tube, audio signal voltage greater than negative grid bias will cause plate current cutoff on negative signal peaks and possible saturation on positive peaks. In the single tube plate circuit the result is production of harmonic frequencies not present in the grid signal.

But because signal plate current increases in one push-pull tube while decreasing in the other tube, second, fourth, and other even harmonics are cancelled in push-pull operation. Greatest harmonic distortion is caused by the second harmonic of fundamental frequencies fed to the grids. Cancellation of this and other even harmonics brings total harmonic distortion with push-pull operation down to half or less of such distortion in a single similar tube.

Harmonic cancellation allows push-pull amplifiers to be operated with grid biases so negative as to cause plate current cutoff, with corresponding reduction of average d-c plate current and less accompanying heating of circuit elements and tubes. Signals greater than the bias voltage can be amplified without excessive distortion, thus increasing output

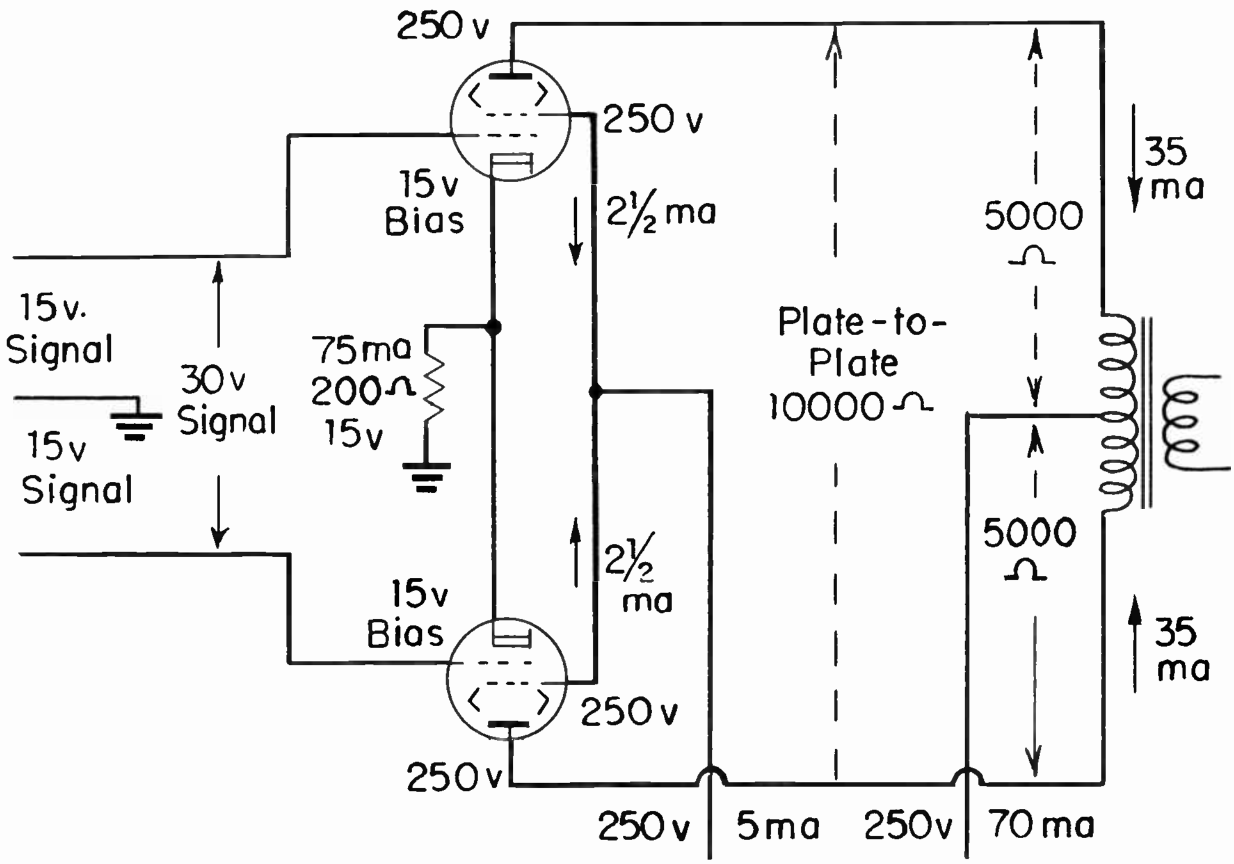

Fig. 4. Typical voltages, currents, and impedances in a push-pull stage.

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signal power from two push-pull tubes to more than double that from a single similar tube.

Fig. 4 shows relations between voltages, currents, and impedances in a typical push-pull stage, and illustrates many facts applying to all push-pull stages. Grid-to-grid signal strength is 30 volts, with 15 volts from grid to ground on each push-pull tube. Either tube alone would require plate load impedance of 5,000 ohms. The two tubes in push-pull require plate-to-plate load impedance of twice this, or 10,000 ohms. Recommended plate-to-plate load impedance or resistance is not always twice that for a single similar tube, but is approximately so. Catalog ratings for push-pull output transformers list plate-to-plate primary impedances. Secondary impedances must match the speaker voice coil, just as with single tube operation.

With any given d-c voltages from B-supply lines, total element currents for two push-pull tubes are double the currents for a single similar tube. In Fig. 4 we note the following.

Plate supply volts	250
Plate volts, each tube, less drop in primary	250
D-c plate current, each tube	35 ma
Total d-c plate current from B-supply	70 ma
Screen supply volts	250
Screen volts, each tube	250
D-c screen current, each tube	$2\frac{1}{2}$ ma
Total d-c screen current from B-supply	5 ma
Cathode bias resistor, volts drop	15
Cathode volts, each tube (the grid bias)	15
Cathode current, plate plus screen, each tube	$37\frac{1}{2}$ ma
Total cathode current through bias resistor	75 ma

When d-c average currents and changes of signal currents are equal or balanced in the two push-pull tubes it is not necessary to have a bypass capacitor across a cathode bias resistor. With exact balancing and cancellation in the output transformer primary, there are no voltage variations across the bias resistor and no bypassing is needed. Otherwise a bypass of 10 or more mf may be used.

Since cathode currents from both push-pull tubes flow in the one bias resistor, for a total of double the current from one tube, bias resistance may be about half that used with a single similar tube.

<u>PUSH-PULL INVERTERS.</u> We have seen that it is necessary for signal voltages at the grids of the two push-pull tubes to be of equal strengths or amplitudes and to be of opposite polarity of 180° out of phase. These equal and opposite grid signal voltages ordinarily are obtained by means of a tube operated as a phase inverter rather than by use of a center-tapped input transformer. Of the wide variety of inverter circuits used in radio and television, a few of the more popular will be briefly explained.

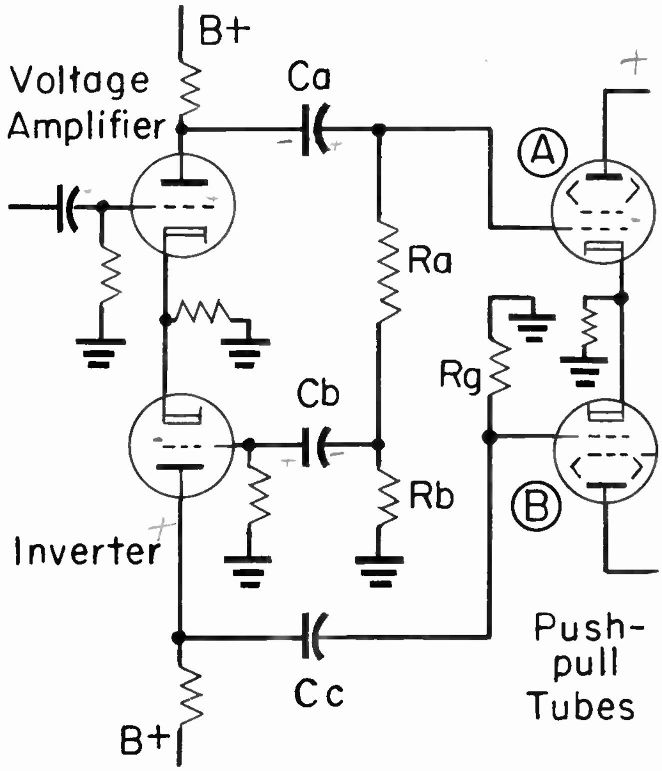

Fig. 5. Voltage-divider type of phase inverter in a push-pull amplifier.

Fig. 5 shows the elementary circuit for a voltage-divider inverter, which probably is more generally used than any other kind. To the grid of the voltage amplifier comes the

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audio signal from a detector or demodulator. Amplified signal voltage from the plate of this voltage amplifier goes through blocking capacitor Ca to the grid of push-pull tube A. This voltage appears also across resistors Ra and Rb in series.

Resistance at Rb is much smaller than at Ra, so only a small fraction of total signal voltage from the voltage amplifier appears across Rb. This fraction of signal voltage is applied through capacitor Cb to the grid of the inverter tube. The relatively small grid voltage is amplified by the inverter, and applied through blocking capacitor Cc to the grid of push-pull tube B.

Our objects are to make signal voltage at the grid of push-pull tube B equal in amplitude and opposite in phase to signal voltage at the grid of push-pull tube A. The first object is accomplished by suitable proportioning of resistances at Ra and Rb. To illustrate, we shall assume that voltage gains are equal in the voltage amplifier and inverter. These tubes, shown separated in the diagram, often are sections of a twin triode. Assume further, merely for this example, that voltage gain is 20 times.

Now, if we apply to the inverter grid a signal only 1/20 as strong as that at the grid of push-pull tube A, and if this inverter grid signal is amplified 20 times in the tube, the signal delivered from the inverter plate to the grid of push-pull tube B will be exactly equal in strength to the signal at the grid of push-pull tube A.

It is necessary only to make resistance at Rb 1/20 that of Ra and Rb combined. Then, since signal voltage across both resistors is the same as at the grid of tube A, voltage across Rb will be the required 1/20 of the total. Division of resistance between Rb and Ra is inversely proportional to voltage gain of the inverter. Total resistance, Ra plus Rb, for push-pull tube A is made equal or approximately equal to grid return resistance at Rg for push-pull tube B.

Fig. 6 shows circuit connections for what is called a self-balancing inverter. As before, the audio signal from the voltage amplifier is applied through capacitor Ca to the

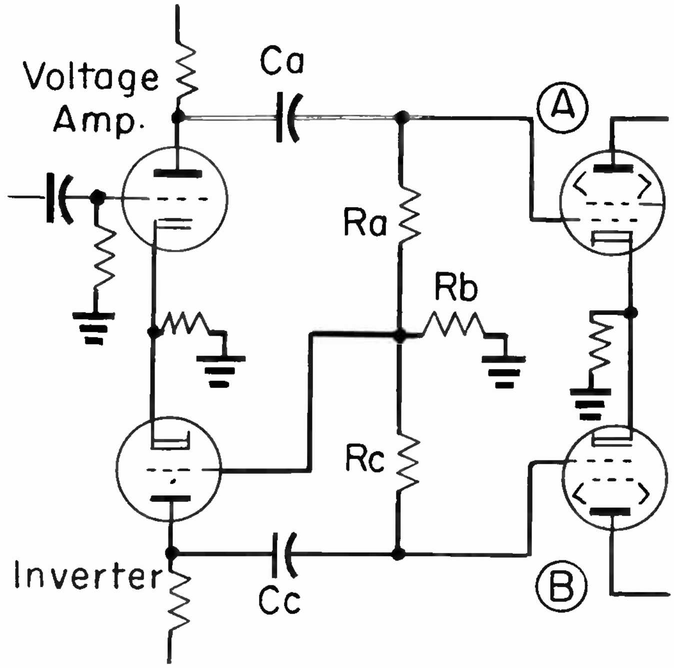

Fig. 6. Circuit for a self-balancing type of phase inverter.

grid of push-pull tube A. An audio signal of opposite polarity, from the inverter plate, is applied through Cc to the grid of push-pull tube B.

Audio signal voltage at the grid of tube A is across resistors Ra and Rb in series. The opposite-phase audio voltage at the grid of tube B is across resistors Rc and Rb in series. We have Rb carrying both audio signal voltages, which are opposite in polarity or phase. Voltage actually appearing across Rb can be only the difference between opposite-phase voltages in Ra and Rc. This difference voltage is applied to the inverter grid, because Rb is between the inverter grid and its cathode, through ground.

When this self-balancing inverter system operates, inverter grid signal voltage from resistor Rb rises just enough to make plate output voltage from the inverter, appearing in Rc, almost balance the signal voltage from Ra. This leaves only enough difference voltage to actuate the inverter grid. Resistors Ra, Rb, and Rc often are of equal values, or Rb may be as little as half the value of Ra or Rc. Slight unbalance of push-pull grid voltages may be corrected by adjustments of bias and plate voltage on inverter and voltage amplifier. In other designs the unbalance is

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prevented by making resistance at Rc somewhat greater than at Ra. Resistances usually are of values between 220K and 500K ohms.

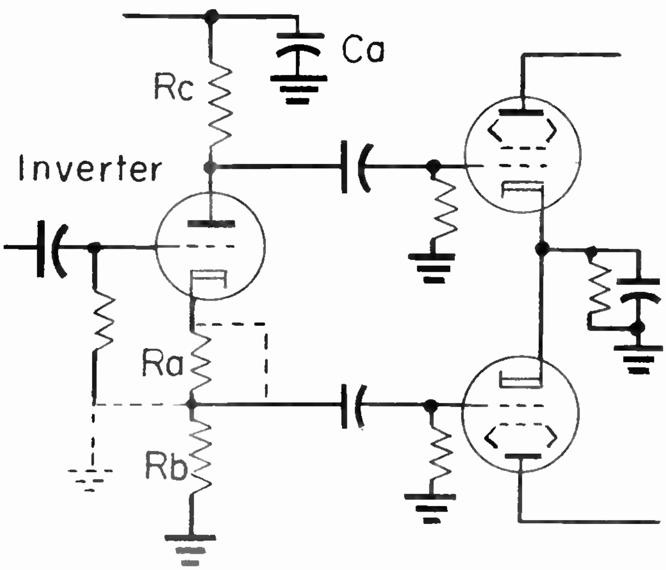

Fig. 7. A cathode-follower type of phase inverter in a push-pull amplifier.

Fig. 7 shows connections for a cathode-follower inverter. Equal signal voltages of opposite phase for the push-pull grids are provided from a single tube whose total plate circuit resistance is in two equal or approximately equal parts. The inverter plate circuit for alternating signal voltages and currents extends from the tube cathode through resistors Ra and Rb to ground, from ground through a large capacitance of very low reactance at Ca, thence through resistor Rc to the tube plate. Resistance at Rc and the sum of resistances at Ra and Rb commonly is between 20K and 50K ohms, at each plate. Resistances from plate and from cathode to ground are equal.

The sum of resistances at Ra and Rb is equal or practically equal to resistance at Rc. Therefore, in the signal circuit external to the tube, signal plate current is accompanied by equal signal voltages across Rc and across Ra plus Rb. Neglecting the small drop in capacitor Ca, signal voltage from ground across Rc to the inverter plate is equal to signal voltage from ground across Ra and Rb to the inverter cathode. Signal voltage from the inverter plate is applied to the grid of one push-pull tube, and equal signal voltage from the inverter cathode is applied to the grid of the other push-pull tube.

Signal polarity at the inverter cathode is the same as at its grid, but polarity at the plate is opposite to that at the grid, as is true with any triode. Consequently, we have the equal-strength signals 180° out of phase at the grids of the two push-pull tubes.

In the cathode follower inverter tube there is no gain, but rather a slight loss. In the other inverter systems the full gain of the voltage amplifier acts on one push-pull plate and equal gain of the inverter acts on the other push-pull plate. However, the cathode follower inverter needs only one tube or one section of a twin tube. By using a second tube or the other section of a twin tube as a voltage amplifier ahead of the inverter, we have the same total gain as in other inverters, with the same tubes or twin tubes.

Fig. 8 illustrates a method of checking balance or lack of it in a push-pull inverter and amplifier system. Apply any audio voltage to the grid of a voltage amplifier which feeds an inverter, or to the grid of a cathode-follower inverter. Most r-f signal generators have separate output for the audio voltage used for internal modulation, whose frequency usually is around 400 cycles. At C use a series capacitor of 0.01 mf or larger capacitance.

Connect the vertical input of an oscilloscope across the cathode bias resistor for the push-pull tubes. Set the internal sweep rate to show several cycles of audio voltage being supplied by the signal generator. Advance the vertical gain as may be necessary. If both push-pull tubes are amplifying equally the trace will be as at 1. Unbalance will cause a trace such as at 2 or 3, depending on which tube does most of the amplifying.

Unbalance usually is due to incorrect proportioning of inverter resistances or to defective resistors. It may be due to differences between characteristics of the two push-pull tubes or, of course, to faulty resistors, capacitors, or wire connections anywhere in the push-pull circuit.

CLASSIFICATION OF POWER TUBE OPERATION. When you look at operating characteristics of power tubes in manufact-

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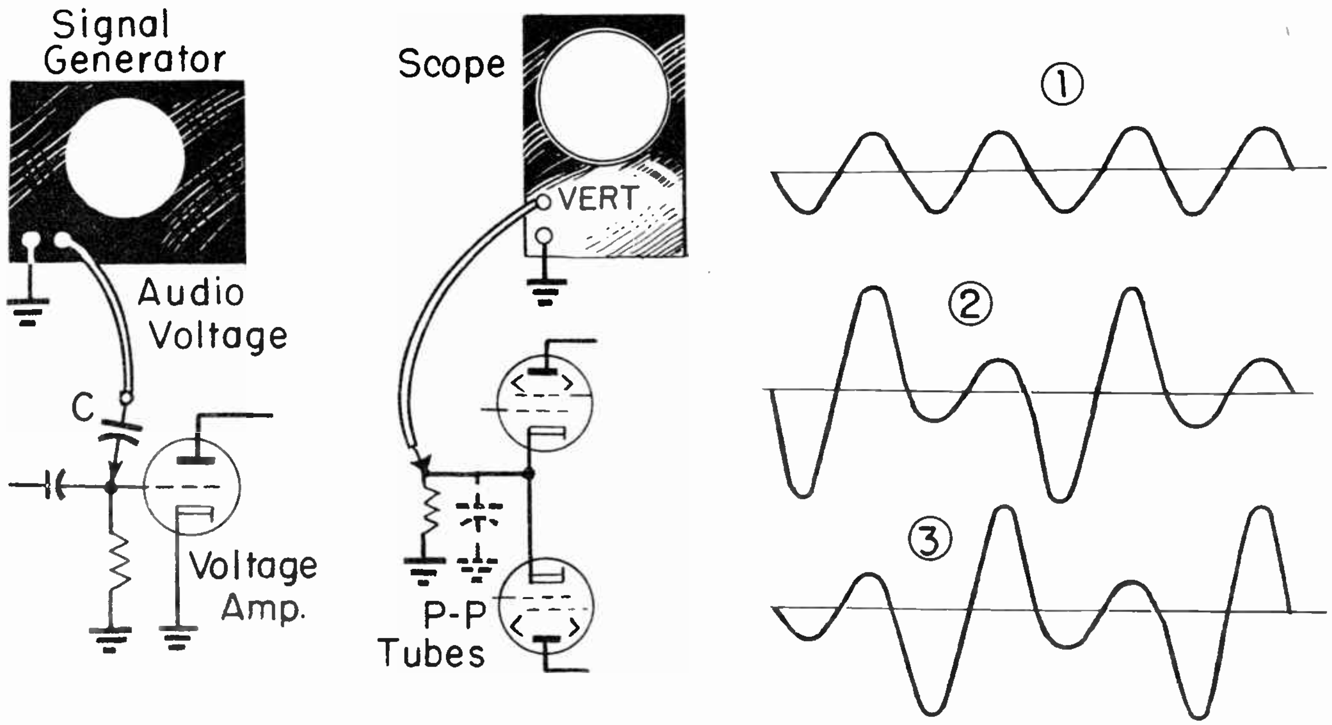

Fig. 8. Using oscilloscope and audio signal for checking balance in a push-pull amplifier.

urers' listings there will be notes such as "Class A1", "Class AB1", "Class AB2", and others of this nature. The letters A, B, and C of these classifications tell whether or not there is cutoff of plate current during part of each signal cycle. The numerals 1 and 2 tell whether or not there is flow of grid current. Such classification is necessary because, with push-pull power tubes, we may have plate current cutoff, we may have flow of grid current, or both, and still have cancellation of many distortion effects.

Meanings of letter classification are as follows.

Class A. Negative bias is equal to maximum signal amplitude. The signal never drives the grid so far negative as to cause plate current cutoff.

Class B. Bias is so negative as to nearly or completely cut off the plate current when there is no signal. Then all or nearly all of the negative signal alternations keep the plate current cut off, and plate current flows chiefly during positive signal alternations.

Class AB. Intermediate between classes A and B. Negative bias is such that signals of maximum amplitude cause plate current cutoff only during the more negative portions of signal voltage alternations.

Class C. Bias is more negative than for plate current with no signal. Only the more positive portions of signal voltage alternations cause flow of plate current.

Numerals which follow the letters in classifications have these meanings.

1. The grid never becomes positive, and there never is grid current.

2. The grid becomes positive on positive peaks of signal voltage, and there is grid current during these peaks.

Differences between class A or A1 operation and class B operation are illustrated by Fig. 9, and differences between AB1 and AB2 operation are shown by Fig. 10. Single output amplifier tubes in receivers always are operated class A1. Push-pull output tubes may be operated A1 or AB1, sometimes as AB2, and rarely as class B. Principal features of these four operating methods are compared in the accompanying table.

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AUDIO POWER TUBE OPERATION

	CLASS A1	CLASSES AB1, AB2	CLASS B
TUBE CIRCUITS	Always for single power tubes. Often for push-pull tubes.	Only with push-pull.	Only push-pull. Only with transformer input to push-pull stage, because of grid current.
INPUT SIGNAL	Amplitude limited to value of negative bias. Less than would cause plate current cutoff or grid current flow.	May be greater than for A1 without excessive distortion. AB2 handles stronger signals than AB1.	When correctly designed and operated, stronger signals than the other classes without excessive distortion.
OUTPUT POWER	Capable of less output power than the other classes because of limit on input signal.	AB1 capable of about $1\frac{1}{2}$ to $2\frac{1}{2}$ times maximum of A1, when input signal sufficiently strong. AB2 capable of more output than AB1.	Capable of more power output than AB classes, when sufficient input signal applied.
DISTORTION	Less inherent distortion than AB and B, because operates only on straight portion of Eg-Ip curve.	Little if any more than A1. Less than for a single power tube. Is about same for AB1 and AB2.	When correctly designed and operated, about same distortion as AB classes.
GRID BIAS	With no signal, brings average d-c plate current to center of straight portion of Eg-Ip curve. Bias resistor may need no bypass.	20% to 33% more negative than for A1. Requires bypass on bias resistor because sum of plate currents not constant.	Brings plate current with no signal to cutoff or nearly cutoff. Requires bypass on bias resistor.
PLATE CURRENT	No cutoff, flows during entire cycle of signal. Average d-c current same with and without signal.	Flows during more than half, but less than entire signal cycle. Increases when signal applied. Less average d-c current than A1.	Flows during about half of signal cycles. Zero or near zero when no signal. Increases when signal applied. Less average current than for AB classes.
GRID CURRENT	None at any time, the grid always is negative.	None when signal peak less than bias (AB1). Flows when peaks exceed bias (AB2). On weak signals operates A1 or AB1, on strong signals AB2.	Flows during all or nearly all of positive alternations of signal.
EFFICIENCY	Power efficiency poor.	Better than A1.	Better than AB classes.
POWER SUPPLY	May have rather poor voltage regulation.	Good regulation for AB1, very good for AB2.	Very good voltage regulation required.

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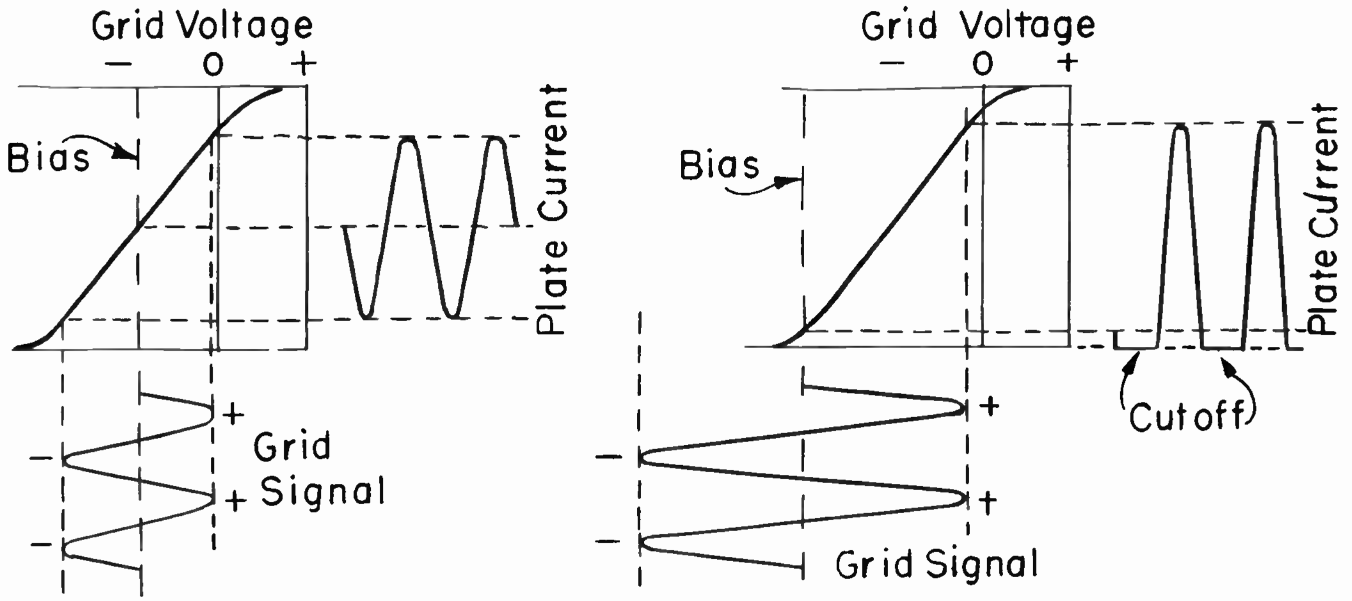

Fig. 9. Class A or A1 operation (left) and class B operation (right).

COMPENSATED VOLUME CONTROL. With the simple volume control of Fig. 11, music sounds completely natural only when the control is advanced to a point allowing high output power or high intensity from the speaker. As you turn down the volume, the lower frequencies or bass notes seem to disappear, and at minimum volume there is also considerable loss at treble or high frequencies. Almost everyone has noticed that music does not sound so well at low volume as at high.

The fault is not in the volume control nor, to any great extent in actual loss of power at low and high frequencies in speaker output, the fault is in our ears. At high volume or high intensity of sound the response or sensitivity of the average ear is fairly uniform throughout the range of audio frequencies, following the upper curve of Fig. 11. Music from an audio amplifier and speaker of good quality then sounds almost as though you were listening to the original production.

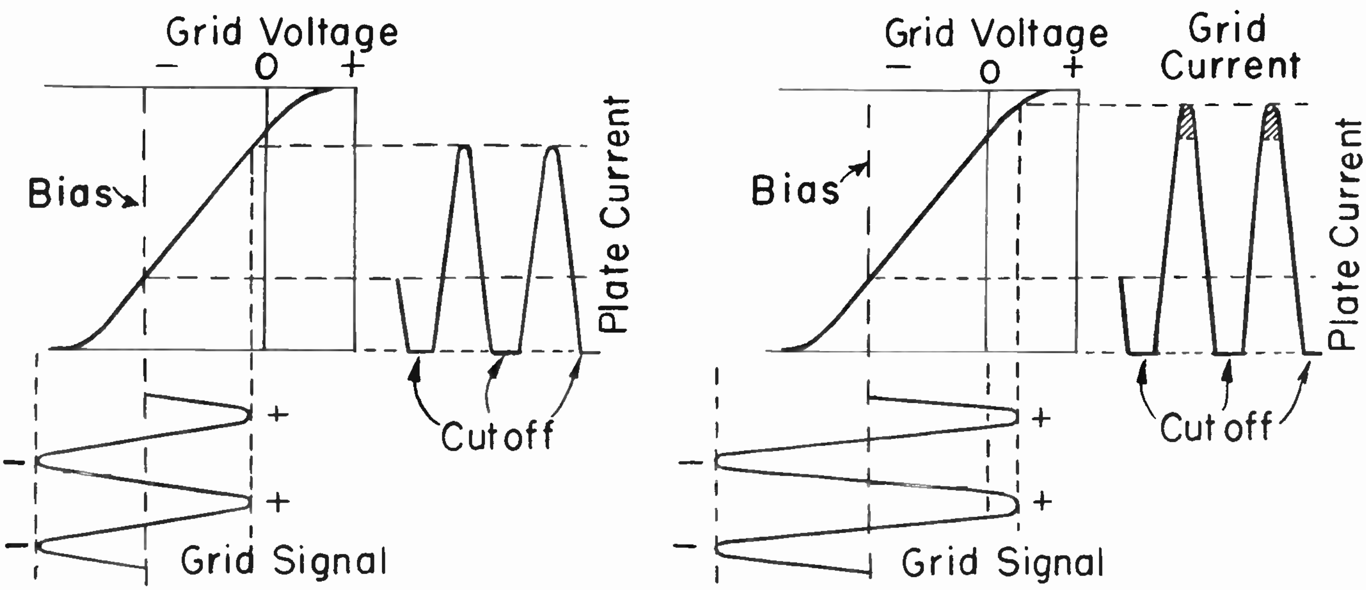

Fig. 10. Class AB1 operation (left) and class AB2 operation (right).

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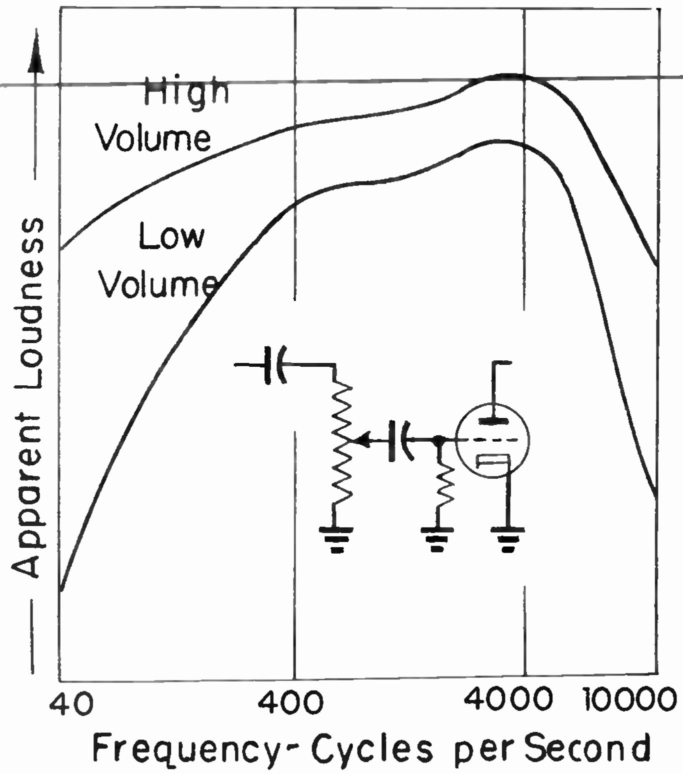

Fig. 11. Our hearing sensitivity is more uniform for all frequencies when sound intensity is high than when intensity is low.

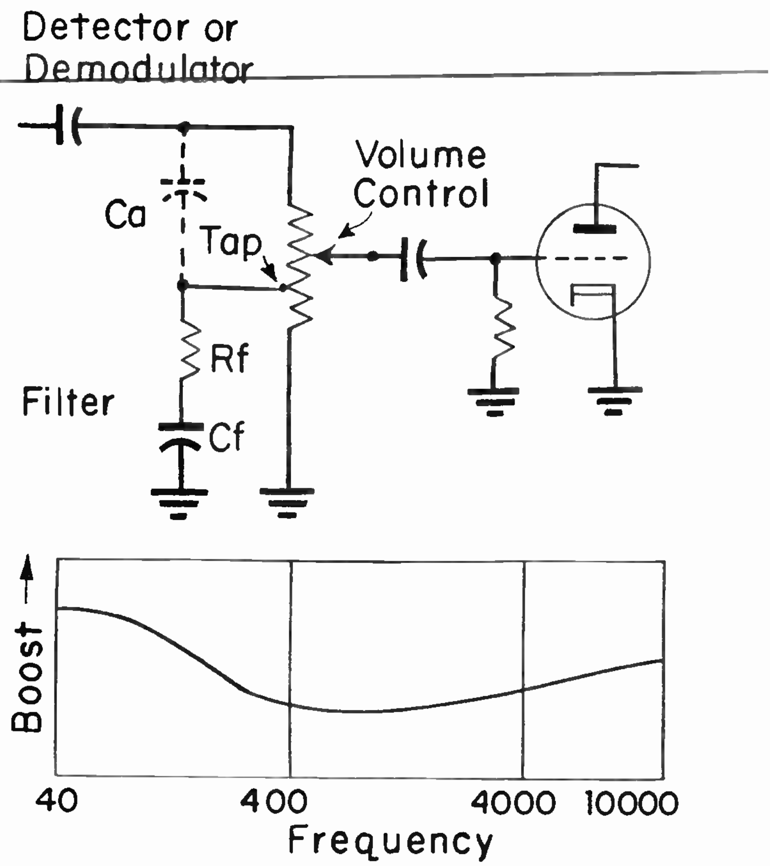

Fig. 12. A compensated volume control boosts signal voltage and power at low and high frequencies.

When the volume control is retarded, and sound intensity from the speaker is uniformly reduced at all frequencies, your ear sensitivity remains high at middle frequencies, but becomes relatively poor at both low and high frequencies. This is illustrated by the lower curve of Fig. 11.

The apparent loss of low notes and of highest notes may be overcome to some extent by use of the compensated volume control circuit of Fig. 12. The resistance element of the volume control potentiometer is tapped at a point somewhere between half the total resistance and about one-fifth of the total, measured from the grounded end. Total resistances are on the same order as in other volume controls, usually between 250K ohms and 2 megohms.

Between the tap of the volume control and ground is a tone filter consisting of resistor Rf and capacitor Cf in series. Resistance may be between 15K and 100K ohms, with capacitance of 0.05 mf to as little as 0.002 mf. Larger filter resistances and smaller capacitances are used together, but exact values depend on what the designer wished to accomplish in boosting output at low and high frequencies to compensate for falling off in ear response. Additional capacitance of a few hundred mmf at most may be used at Ca.

There is maximum frequency compensation with the volume control slider at the tap position, and least compensation with the slider at the position for maximum volume. Compensation is most effective at various levels of speaker output when signal strength from detector or demodulator to volume control remains nearly constant during reception from different stations. Inasmuch as uniform strength depends on avc action, and the usual avc systems allow variations as great as five to one, the compensated volume control can make only partial correction for ear response.

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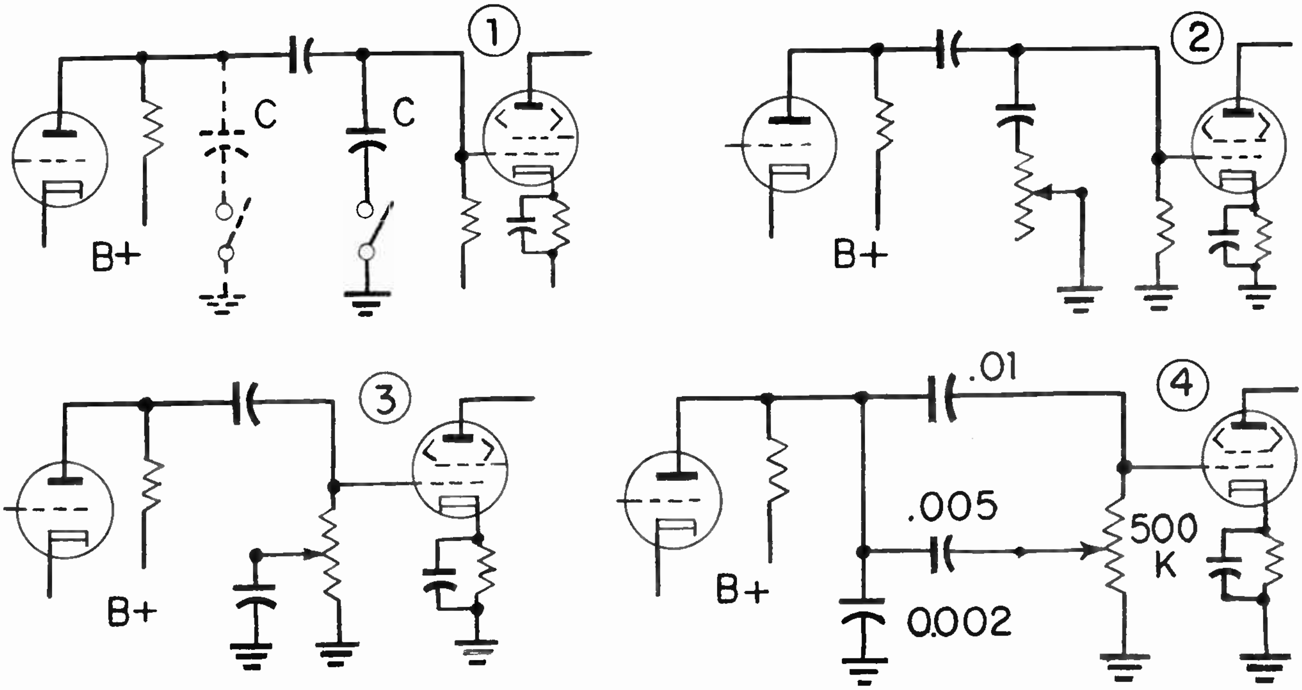

Fig. 13. Simple tone control control circuits used in receivers.

TONE CONTROLS. The purpose of a variable tone control is to compensate for non-uniform frequency response of amplifiers and speakers, or to provide such distribution of gain at various frequencies as appeals to the musical taste of a listener. Desired results may be accomplished by either boosting or attenuating the bass, by boosting or attenuating the treble, or by some combination of bass or treble boost or attenuation.

The words bass and treble have no very definite meanings. Bass refers, in a general way, to the lowest portion of the musical scale, usually to frequencies below 400 cycles. Treble refers to the high end of the musical scale, usually to frequencies in excess of 2,000 cycles per second. In between are the middle frequencies. It is gain at middle frequencies which is used as a reference level when speaking of changes at the bass or treble ends of the scale.

Boosting the bass means to increase the gain at low frequencies. Much the same effect on listeners results from decreasing the gain at middle and high frequencies. Boosting the treble means to increase the gain at high frequencies. Equivalent effects result from reduction of gain at middle and low frequencies.

Tone control and tone correction are big subjects, so full of theory and technicalities that four or five lessons might be used for their study. This would be desirable were you specializing in high-fidelity audio equipment and in applications such as public address. But tone controls for television sound are of simple types when used at all, and in most a-m and f-m broadcast sets are not highly intricate.

Parts and connections for receiver tone control circuits are between the volume control or grid input of the audio voltage amplifier and the grids of the audio output amplifier or amplifiers. These controls make use of fixed capacitors and usually of fixed or variable resistors in circuits such as those of Figs. 13 and 14.

Control action depends on the fact that reactance of a capacitor, or its opposition to signal currents, becomes less as frequency rises. Reactance is inversely proportional to frequency. For instance, capacitance of 0.01 mf has reactance of 160,000 ohms at 100 cycles, but of only 1,600 ohms at 10,000 cycles per second. Reactance of capacitors usually is combined with series or parallel resistances which modify the impedance of tone control circuits.

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At 1 of Fig. 13 a tone control capacitor C is shunted across the plate load of the first amplifier, on either the plate side or grid side of the coupling and blocking capacitor. Closing the tone switch bypasses high frequencies to ground, and thus emphasizes low frequencies. Other diagrams in this figure show how the effect of a load-shunting capacitor may be altered by variable tone control resistors.

High-frequency attenuation depends not only on values of control capacitance and variable resistance, but also on plate resistance of the preceding tube and on the grid resistor for the output tube. Diagram 4 shows a somewhat more elaborate arrangement for varying the effects of shunting capacitances which attenuate high frequencies in emphasizing the lows.

Fig. 14 shows methods of combining tone control circuits with two types of volume controls. The variable tone control potentiometers in circuits of this general type have values between 500K ohms and 3 megohms. Capacitors in series with the tone control potentiometers usually are between 0.002 and 0.05 mf.

DEGENERATION. If a small part of the output signal energy from an amplifier is fed back to the input in such polarity or phase relation as to oppose input signals we have degeneration. The action is called also by names such as inverse feedback, negative feedback, and degenerative feedback.

The chief reason for using degeneration in audio amplifiers or any other amplifiers is to make frequency response more uniform. As an example, with an audio amplifier whose frequency response is initially as shown by the full-line curve of Fig. 15, a rather strong degenerative feedback could change the response to that of the broken-line curve.

Degeneration causes little reduction where gain is small to begin with, which is at lowest and highest frequencies in Fig. 15. There is relatively great reduction where gain is high to begin with, as at the middle frequencies. In addition to smoothing an entire response, degeneration reduces peaks and valleys such as result from harmonics, from variations of impedance in voice coils and transformers, from power line voltage surges, and from resonances or R-C time constants which tend to cause oscillations.

One method of securing degenerative feedback is illustrated by Fig. 16. Input signal from detector or demodulator to the audio voltage amplifier is represented at 1. Plate

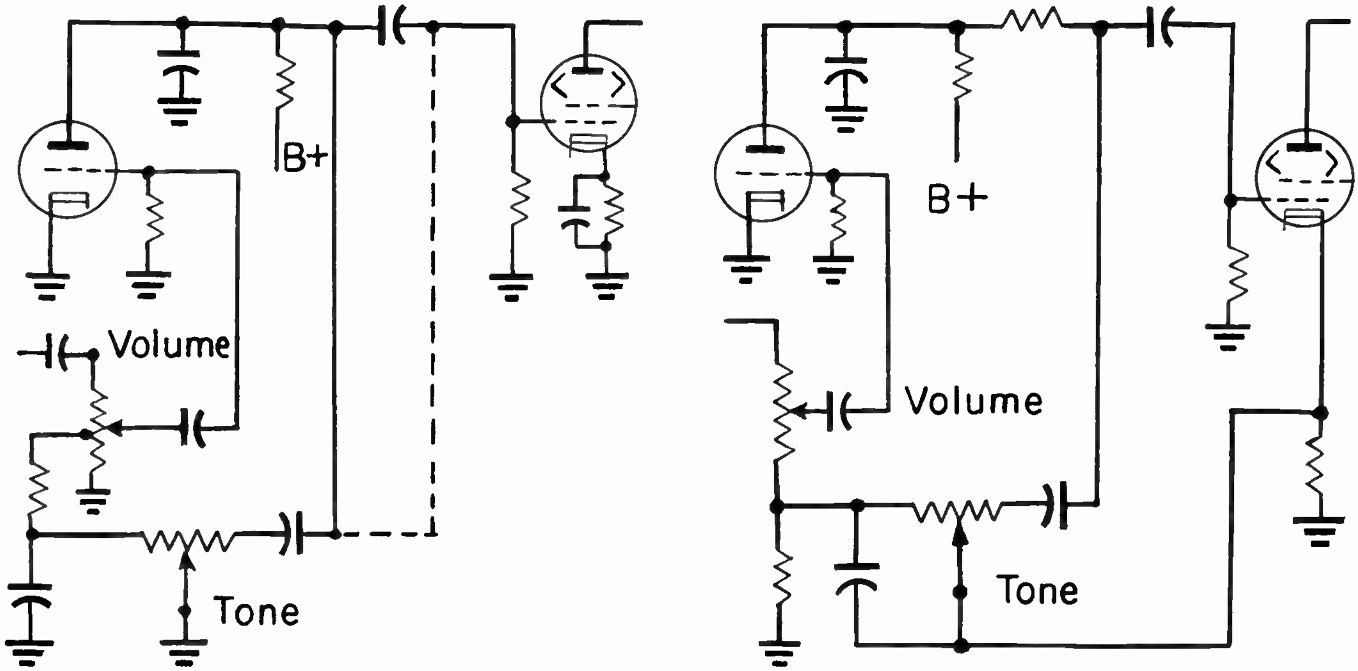

Fig. 14. Tone control circuits combined with volume control circuits.

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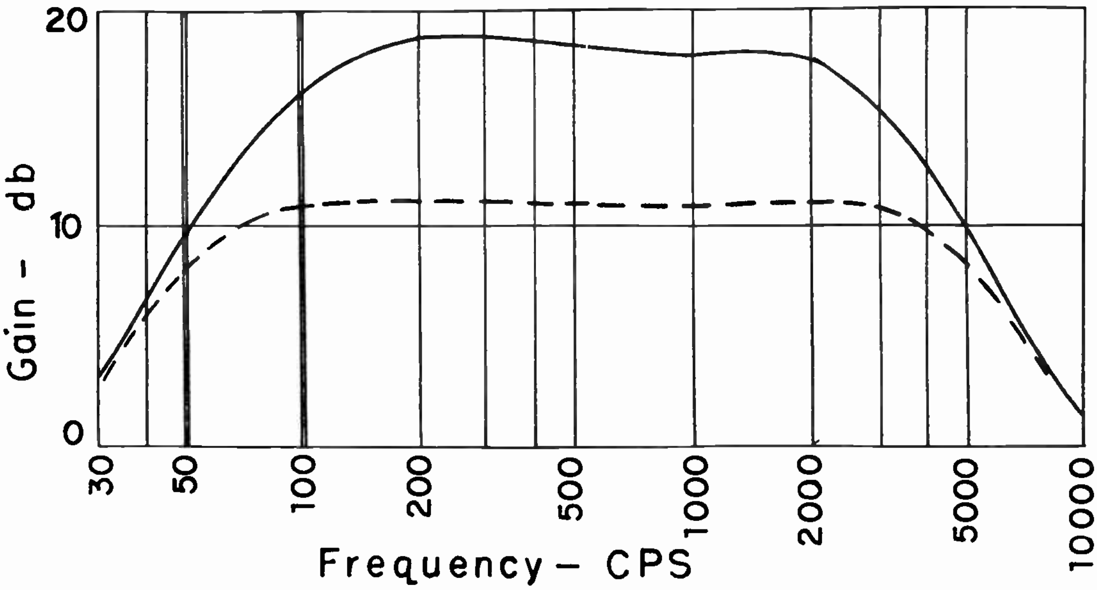

Fig. 15. Degeneration makes gain more uniform at all audio frequencies.

signal voltage is of opposite phase or inverted in polarity, as at 2. A small portion of this plate signal voltage, represented at 3, is applied to the grid through capacitor C and resistor R.

As a general rule that sole purpose of capacitor C is to block positive d-c plate voltage away from the grid. Capacitance may be about 0.05 mf, giving reactance which is small compared to resistance at R, which may be from 50K ohms up to several megohms. Strength of feedback voltage is determined chiefly by resistance at R. Since feedback voltage is opposite in phase to input signal voltage, the feedback weakens grid signal voltage, as at 4. Signal voltage output from the plate is, of course, reduced proportionately to reduction of signal voltage at the grid.

An equivalent feedback circuit is shown by Fig. 17. Feedback signal voltage from the plate of the second tube is taken through re-

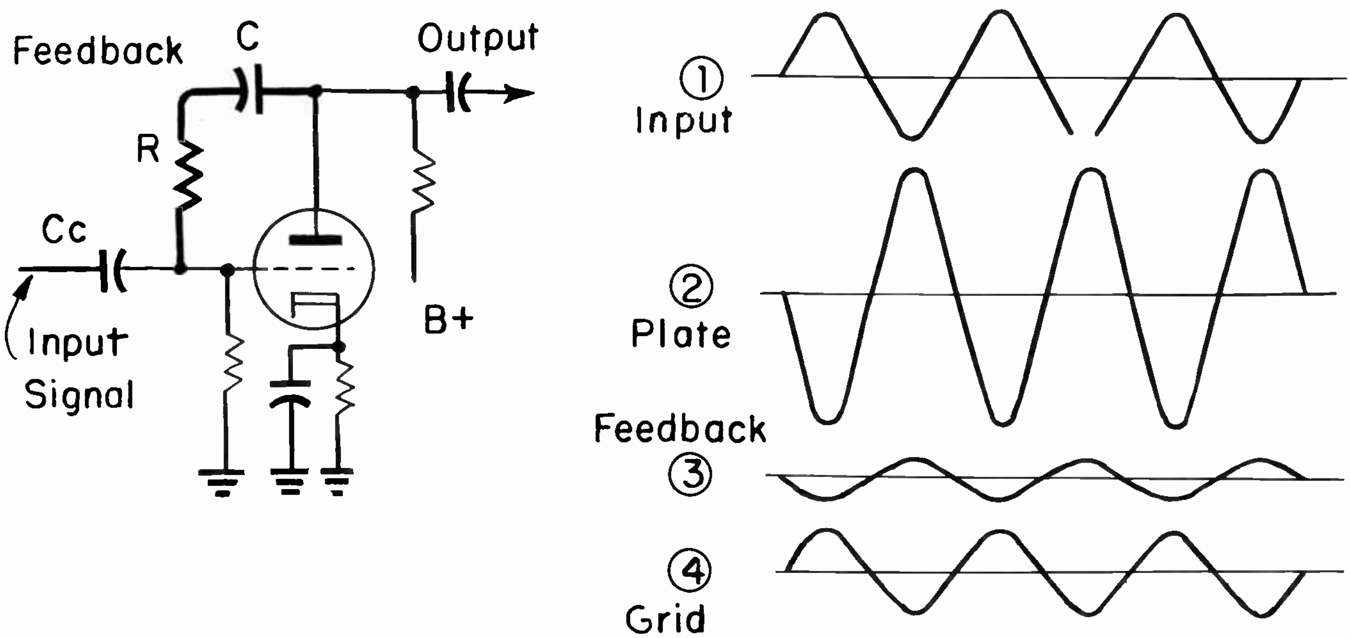

Fig. 16. Connections of a simple feedback circuit, and the manner in which all degenerative feedbacks operate.

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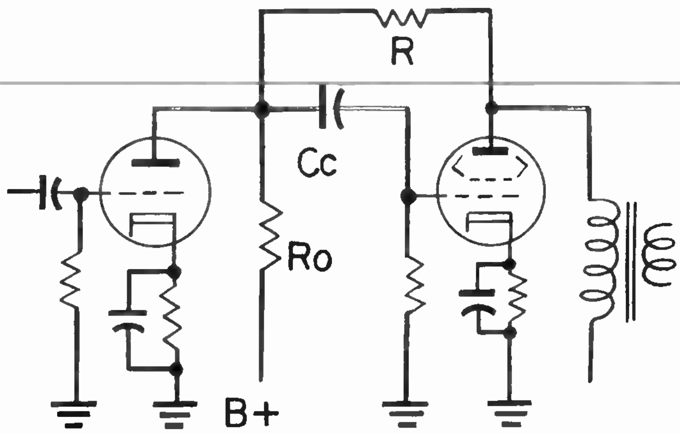

Fig. 17. Voltage feedback from plate of one tube to plate of a preceding tube.

sistor R to the plate load of the first tube rather than to the grid of the second tube. Feedback voltage combines in plate load resistor Ro with plate signal voltage from the first tube. The feedback is of opposite phase to plate signal voltage in Ro, and there is degeneration. The combined signal voltage goes through capacitor Cc to the grid of the second tube, at whose plate is originating the feedback voltage.

As at A of Fig. 18, degenerative feedback voltage from the output of a two-stage amplifier often is applied at the cathode of the first tube. Signal polarities which exist simultaneously at various points are shown with small circles on the diagram. During any instant in which signal polarity is positive at the grid of the first amplifier it is positive also at the cathode of this tube. Then feedback to the cathode must be of negative polarity in order to be degenerative.

At the instant considered, signal voltage polarity is inverted and negative at the plate of the first amplifier and at the grid of the output amplifier. Another inversion in the output amplifier makes its plate signal voltage positive. In the secondary of the speaker coupling transformer, positive alternating voltage at one end is accompanied by negative alternating voltage at the other end, as in every transformer winding.

Our feedback line, containing voltage-dropping resistor R, is connected to the end

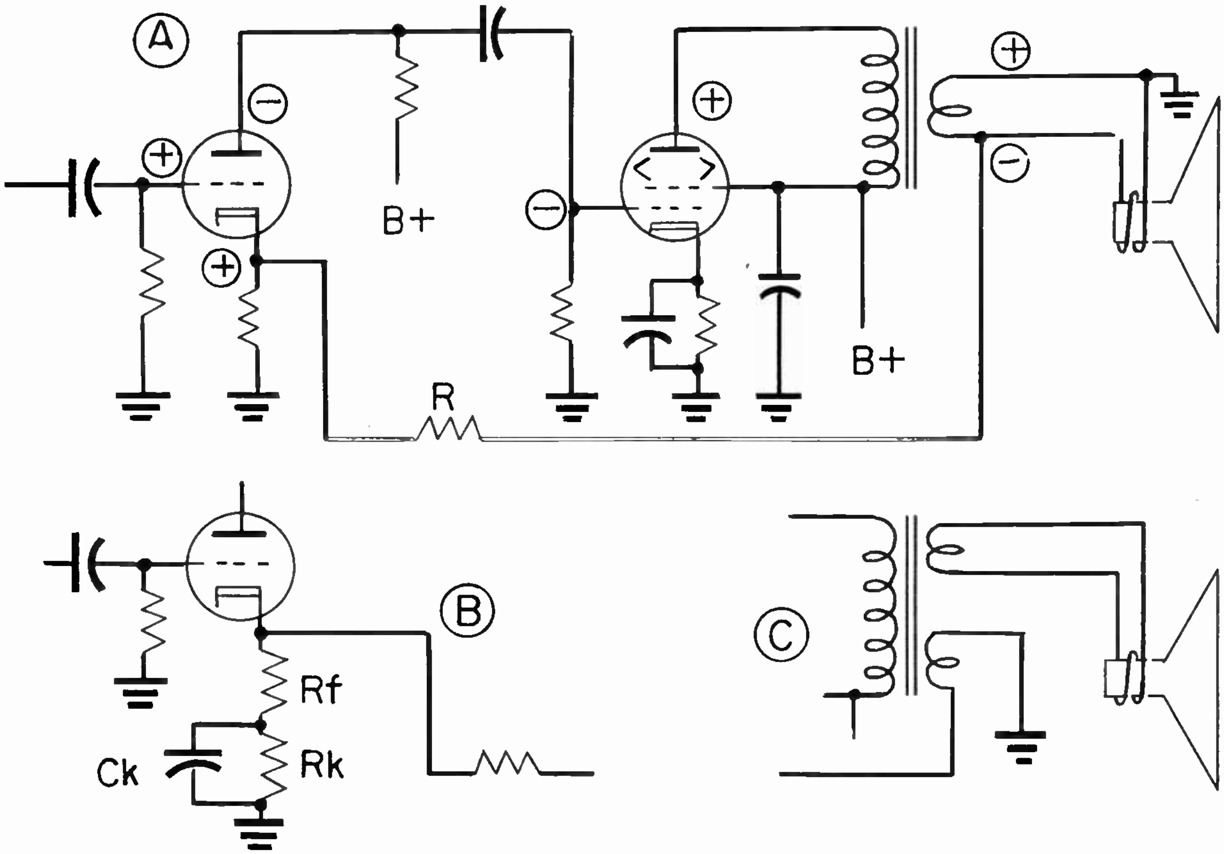

Fig. 18. Degenerative feedbacks from output transformers to cathodes of voltage amplifier tubes.

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of the transformer secondary which provides the required negative feedback voltage during instants in which grid and cathode of the first amplifier are positive. Resistance at R may be as great as several hundred thousand ohms.

No computations are necessary in determining which end of a secondary winding or of any other source of signal voltage should be used for feedback. Connection to a point giving degeneration weakens output voltage and power from the entire amplifier system, but reproduction sounds good. A wrong connection causes in-phase feedback and regeneration which changes to oscillation. Oscillation makes the amplifier motorboat, with putt-putt noises, or else there are squeals and howls, or amplification ceases due to power consumed in high-frequency oscillations.

If applying feedback voltage across an entire cathode bias resistor, as at A of Fig. 18, causes excessive feedback, or if grid biasing required cathode resistance not suited for feedback, we may use the scheme at B. Feedback current and voltage act in resistor Rf, but are bypassed around Rk by capacitance of 10, 20, or more mf at Ck. Resistors Rf and Rk in series provide voltage drop suitable for biasing.

As at C of Fig. 18, speaker coupling transformers may have a third, or "tertiary", or feedback winding used solely to provide suitable feedback voltage and current. When feedback is obtained from any transformer winding in which there is only signal voltage and current, with no d-c voltage or current, no blocking capacitor is needed in the feedback line. This is the case with transformer feedbacks of Fig. 18.

Principles of polarity or phase selection which have been illustrated apply also to degenerative feedbacks in push-pull amplifiers. Fig. 19 shows polarity relations in a system having a voltage-divider phase inverter. Simultaneous signal voltage polarities are shown within small circles. If feedback to the cathode of the voltage amplifier is to be degenerative, feedback polarity must be negative when the input signal is making the grid and cathode of this tube positive.

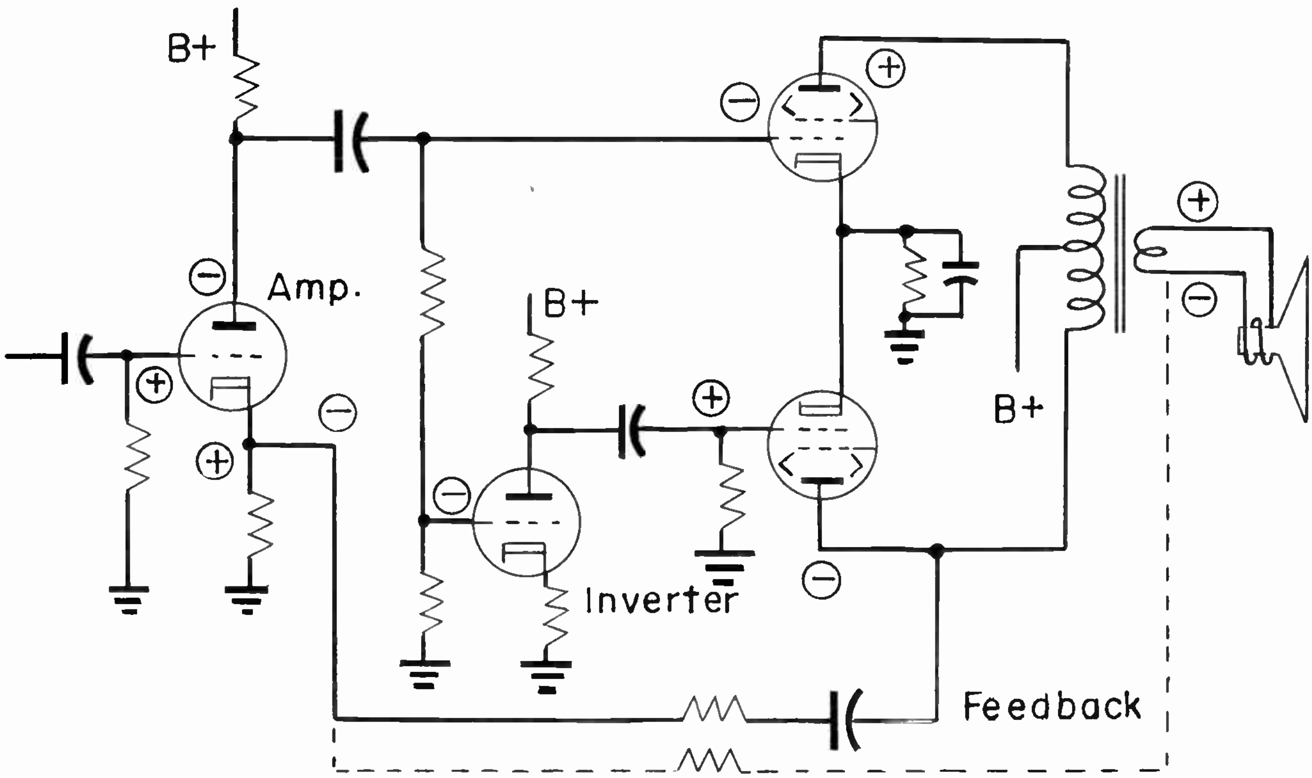

Fig. 19. Feedback connections in push-pull amplifier having inverter of the voltage-divider type.

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Negative feedback polarity may be obtained from the plate or any plate connection on the push-pull amplifier which is fed from the inverter. Such feedback could be obtained also from one side or the other of the secondary in the speaker transformer. When the feedback is applied to the voltage amplifier tube, degeneration will affect both push-pull tubes, because both get their grid signals originally from the voltage amplifier. Were feedback applied to the inverter there would be degeneration for only one of the push-pull tubes.

There is degenerative feedback from plate to grid of any amplifier tube having a cathode-bias resistor. The reason is illustrated by Fig. 20 at A. Here the path of signal currents in the plate circuit is marked by arrows. When grid signal voltage goes positive there is increase of plate signal current. Increase of plate signal current in cathode resistor Rk increases the voltage drop across this resistor, making the lower or grounded end increasingly negative. To this end of the cathode resistor is connected the grid, through ground. Consequently, the grid is made more negative by increase of plate current in the cathode resistor. This opposes the positive swing of signal voltage at the grid, and there is degeneration.

If, as in diagram B, the cathode resistor is bypassed with large capacitance of small reactance, most of the alternating signal current will flow in the bypass and relatively little in the resistance. Alternations of plate current, the audio signal, cause little change of voltage drop in the cathode resistor, and there is little degeneration. The strength of degenerative feedback depends on the ratio of resistance at Rk to reactance at Ck for any frequency considered. The greater the capacitance and smaller its reactance the less will be the feedback effect. Less capacitance increases the feedback. No capacitance or no bypass gives maximum feedback.

Since reactance of any capacitor increases with drop of frequency, more of the total plate current will be forced to flow in the cathode resistor and less will remain in the bypass capacitor as frequency decreases. At the lower frequencies there will be more feedback plate current in the resistor, more degeneration, and consequent weakening of output. Low-frequency degeneration usually is not wanted, the lows are weak enough to begin with. Such degeneration may be reduced by using a cathode bypass capacitance so large that its reactance at the lowest important frequency is only a small fraction of resistance in the cathode resistor.

In all diagrams of Fig. 20 there is a bypass capacitor Cd for the voltage-dropping resistor in the plate circuit. If, as at C, this bypass goes from the bottom of load resistor Ro directly to the tube cathode instead of to ground, most of the plate signal current may flow in Cd and stay out of resistor Rk. How much of the total plate signal flows in Cd depends on its capacitance and on its reactance compared to impedances opposing signal currents in other connected circuits. More capacitance and less reactance at Cd lessens

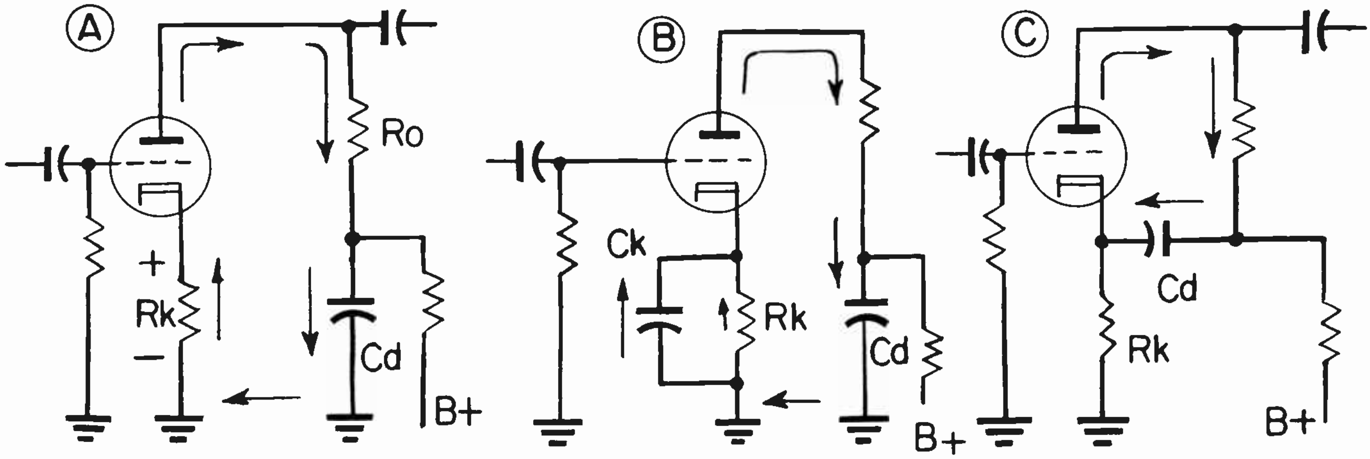

Fig. 20. Degenerative feedback occurs in amplifiers having cathode bias.

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degeneration. In addition to the bypass at Cd there may be also a bypass capacitor across Rk, to ground, to further reduce degeneration.

Feedback due to variations of current, as of plate current in Fig. 20, may be called "current feedback". Feedback due to variations of signal voltage, from wherever taken, may be called "voltage feedback". Figs. 16 through 19 illustrate voltage feedbacks. Both voltage feedback and current feedback may be used together in the same amplifier system.

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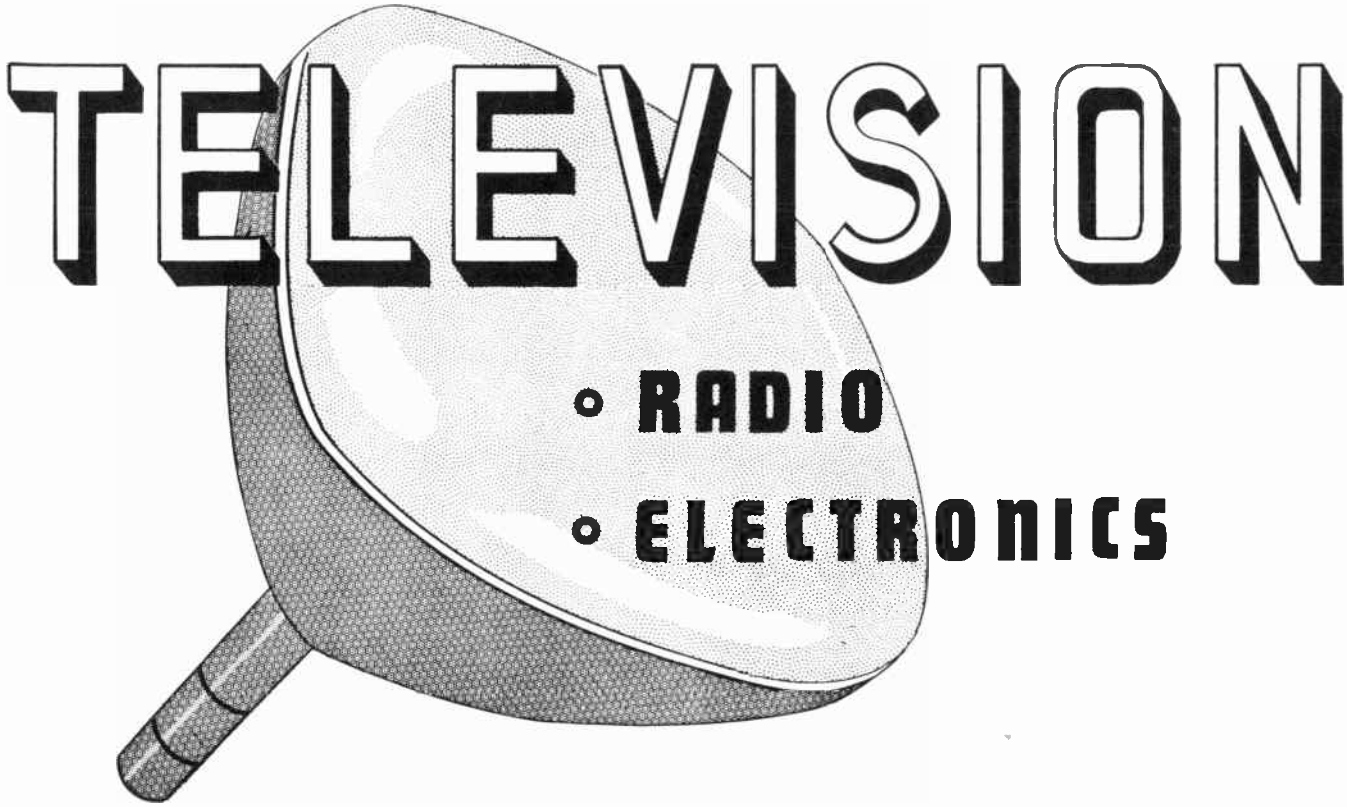

LESSON 65 — THE SYNC SECTION

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Lesson 65

THE SYNC SECTION

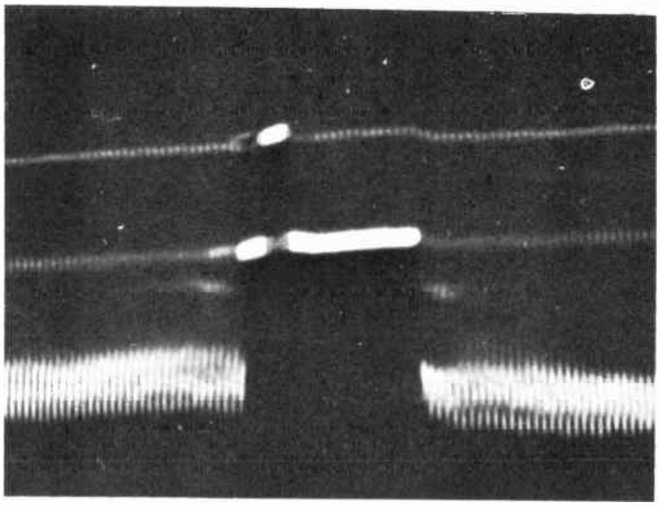

Fig. 1-A

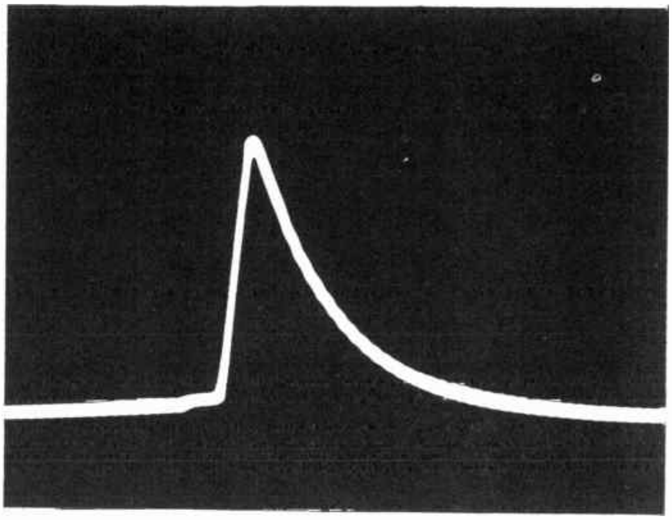

Fig. 1-B

Fig. 1. Vertical sync pulses are changed to voltage peaks suitable for triggering vertical oscillators.

In the composite television signal at A of Fig. 1 are picture signals and three kinds of sync pulses - horizontal sync, vertical sync, and equalizing pulses. This particular trace was made with the oscilloscope timed to show most clearly one of the vertical sync pulses which occur during vertical blanking intervals, between picture fields. These pulses synchronize the vertical sweep oscillator that acts to deflect the picture tube beam vertically. The pulses cannot be applied directly to the oscillator, but first must be changed to the waveform shown at B. This change is a job for the sync section of the television receiver.

By stepping up the rate at which the oscilloscope views the composite television signal we may see individual horizontal sync pulses, as at A of Fig. 2. These pulses time

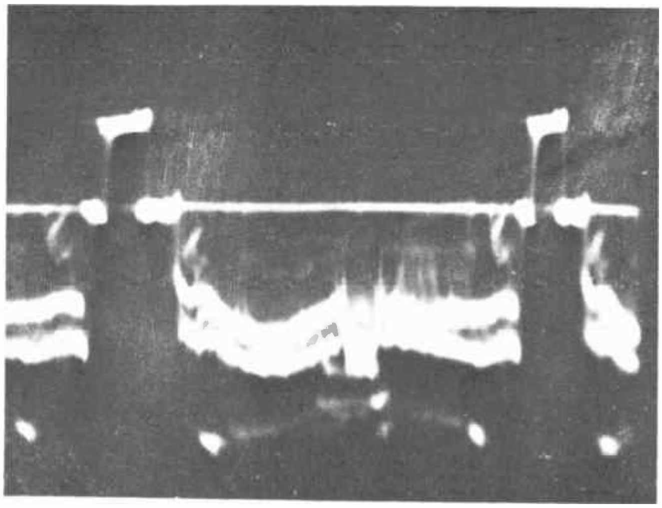

Fig. 2-A

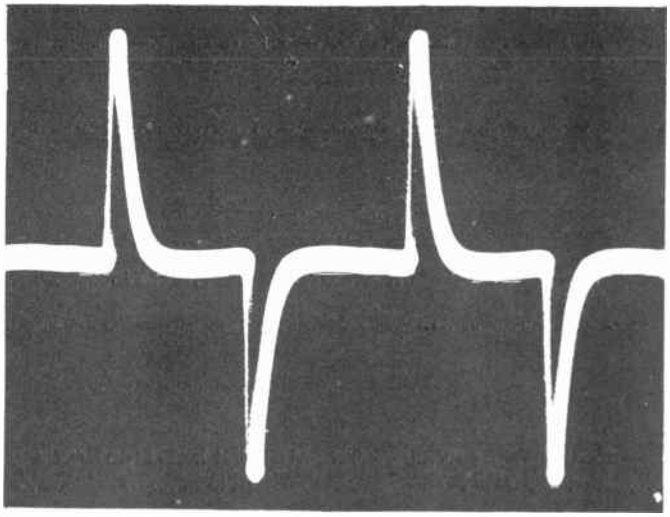

Fig. 2-B

Fig. 2. Horizontal sync pulses can control sharp pips of positive and negative voltage.

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the horizontal sweep oscillator, which then controls horizontal sweeps of the picture tube beam. The signal pulses themselves are not suitable for application to the oscillator, they must be changed into sharp "pips" of voltage, as at B. This is another job for the sync section.

The waveforms which act directly on the sweep oscillators, and which are said to "trigger" the oscillators, must be free from any effects due to picture signal variations which are part of the original composite signal. Therefore, still another job for the sync section is to remove picture signal variations and leave only sync pulses.

The remaining sync pulses may be of unequal or non-uniform strengths, which might cause erratic timing of the sweep oscillators. To insure uniform timing all the pulses are trimmed down to the same strength. This limiting of pulse strength for the sake of uniformity may make the pulses too weak for the work to be done. This calls for voltage amplification in the sync section.

Many sweep oscillators require positive-going voltages for triggering, but other kinds require negative voltages. Also, for certain types of horizontal sweep controls there must be simultaneous positive and negative pulse voltages. To meet these requirements the sync section must provide inversions of pulse or signal polarity when necessary.

Somewhere during travel of the composite signal, either in space or in wired circuits, it may acquire voltage pulses not part of the original radiation. These added pulses, which may result from any of dozens of kinds of electrical disturbances, would cause noise from a sound receiver. For want of a better name these added voltages are called noise pulses when they appear in the video signal. Noise pulses can trigger the sweep oscillators, causing the regular sync pulses to lose control and allowing pictures to jump sideways or to roll vertically. In many sync sections there is suppression or removal of noise pulses before they get to the sweep oscillators.

Now we may make a summary of functions performed in sync sections, thus.

1. Separate sync pulses from picture signals, and get rid of picture signal variations. Tubes operated for this purpose are called sync separators, or sometimes clippers or strippers.

2. Amplify the strength of all the sync pulses when necessary. Tubes which accomplish this are called sync amplifiers.

3. Limit the strength of sync pulses to a uniform value. Tubes which do this are called sync limiters. The name clipper sometimes is applied to these tubes.

4. Invert pulse polarity as may be required for triggering of sweep oscillators. Tubes performing this operation are called inverters.

5. Produce a waveform, B of Fig. 1, suitable for triggering or timing the vertical sweep oscillator. This is done at the output of the sync section, in a circuit called the integrating filter.

6. Produce voltage pips, B of Fig. 2, suitable for triggering a horizontal sweep oscillator. The circuit doing this is called a differentiating filter.

7. Suppress or remove noise pulse voltages before they can act on the sweep oscillators. There is great variety in noise suppression circuits, and in how they are connected to the sync section. The tube or tubes used for noise suppression may be called by any names which appeal to the designer of the system.

A single tube or single section of a twin tube may perform only one of the functions listed. There are other cases in which one tube or one section may both separate and amplify, or may both limit and invert, or may combine other jobs. Twin triodes handling two or more functions are common in sync sections. Pentodes often are used as amplifiers and as limiters.

The signal furnished to the input of the sync section is the composite video signal shown at A of Figs. 1 and 2. This is the same signal furnished to the picture tube. The picture tube makes use of picture varia-

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tions and discards the sync pulses. The sync section makes use of the sync pulses and discards the picture signals.

The several operations performed in the sync section may be carried out in various orders. For example, at A of Fig. 3, the first step is amplification, then comes separation, next limiting, and finally inversion before the pulses pass to the vertical and horizontal (integrating and differentiating) filters. At B the order is separate, limit, and amplify. There is no additional inverter stage because we assume that grid-to-plate inversions in the other stages cause the pulses to be of correct polarity for a sweep oscillator. Many other orders are possible.

The composite signal for the sync section may be taken from any of various points in the video amplifier between video detector output and input to the grid-cathode circuit of the picture tube. Typical sync takeoffs are shown by Fig. 4. The signal at A, from the video detector load, is relatively weak and would require more amplification in the sync sections that would signals taken from farther along in the video amplifier.

The signal at B has been strengthened in a first video amplifier tube, while the one at C has been made still stronger by a second video amplifier. Note that there is inversion of signal polarity between the detector output (A) and output of the first amplifier (B) also between this point and output of the second amplifier (C).

Excessive loading of video detector or amplifier circuits is prevented by an isolating resistor R which you will find in most sync takeoff connections. D-c voltages in video detector or amplifier circuits are blocked from the sync section by capacitor C.

When sync takeoff is from beyond the contrast control, as at C of Fig. 4, strength of the composite signal fed to the sync section varies with setting of the contrast control. Retarding the contrast control weakens

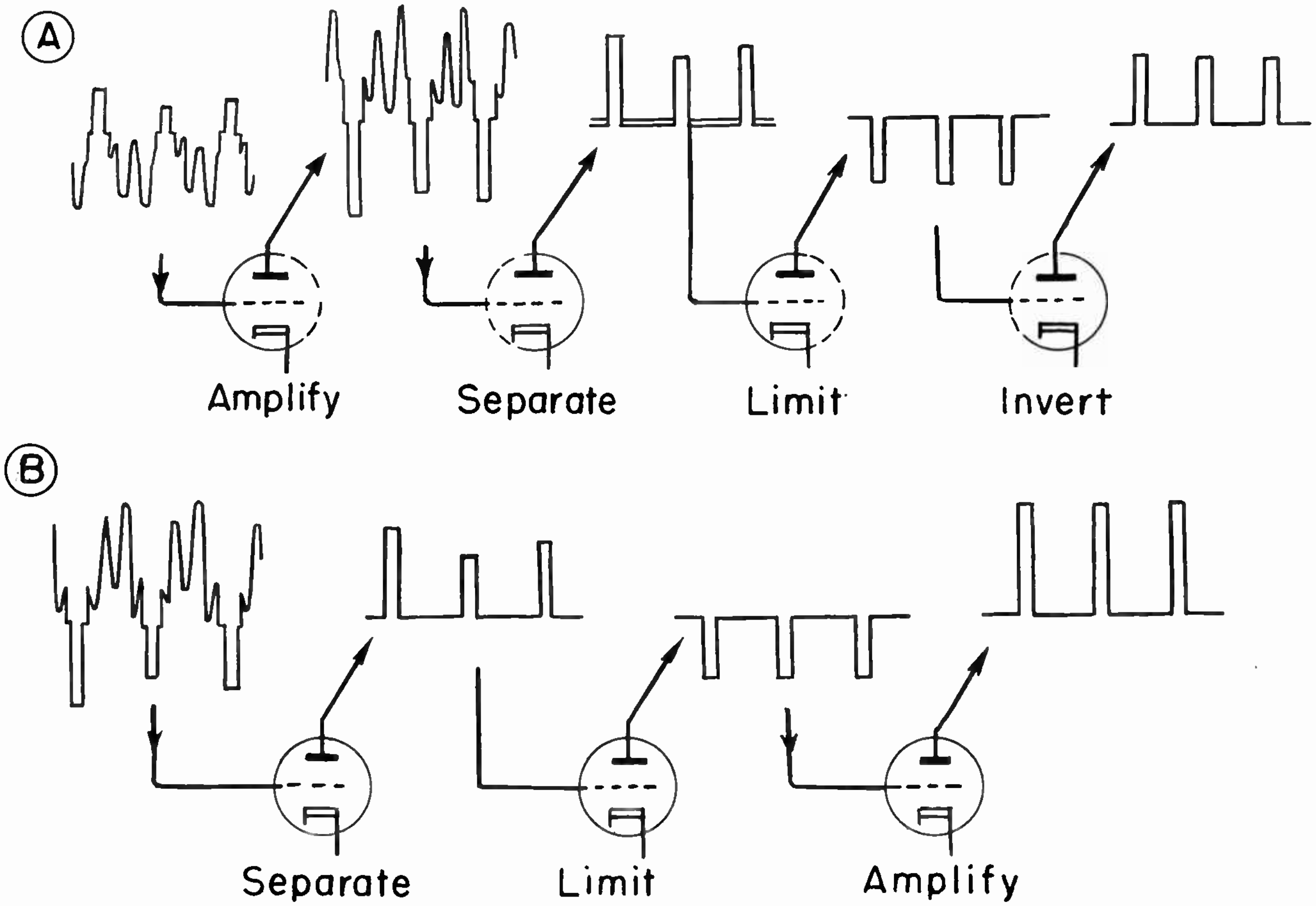

Fig. 3. Operations performed in sync sections may be carried out in various orders.

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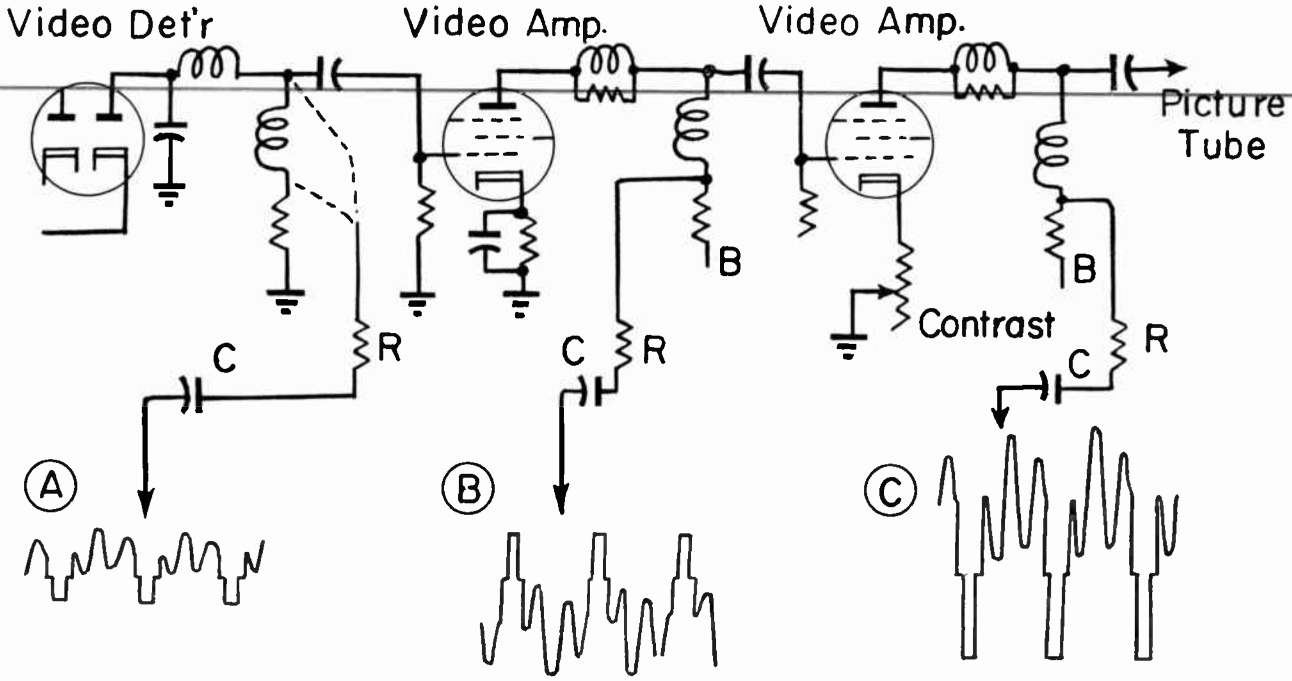

Fig. 4. Composite signals to be used for synchronization may be taken from various points in the video amplifier.

the signal and lessens ability of sync pulses to hold the sweep oscillators in synchronization. Such adjustment of contrast may make necessary a readjustment of horizontal or vertical hold controls. However, with the hold controls in correct adjustment, a contrast control setting for acceptable pictures should provide good vertical and horizontal synchronization.

SYNC SEPARATION. Sync pulses must be positive in the composite signal applied to the grid of a tube used as sync separator. Then picture signals can be removed by plate current cutoff as illustrated by Fig. 5.

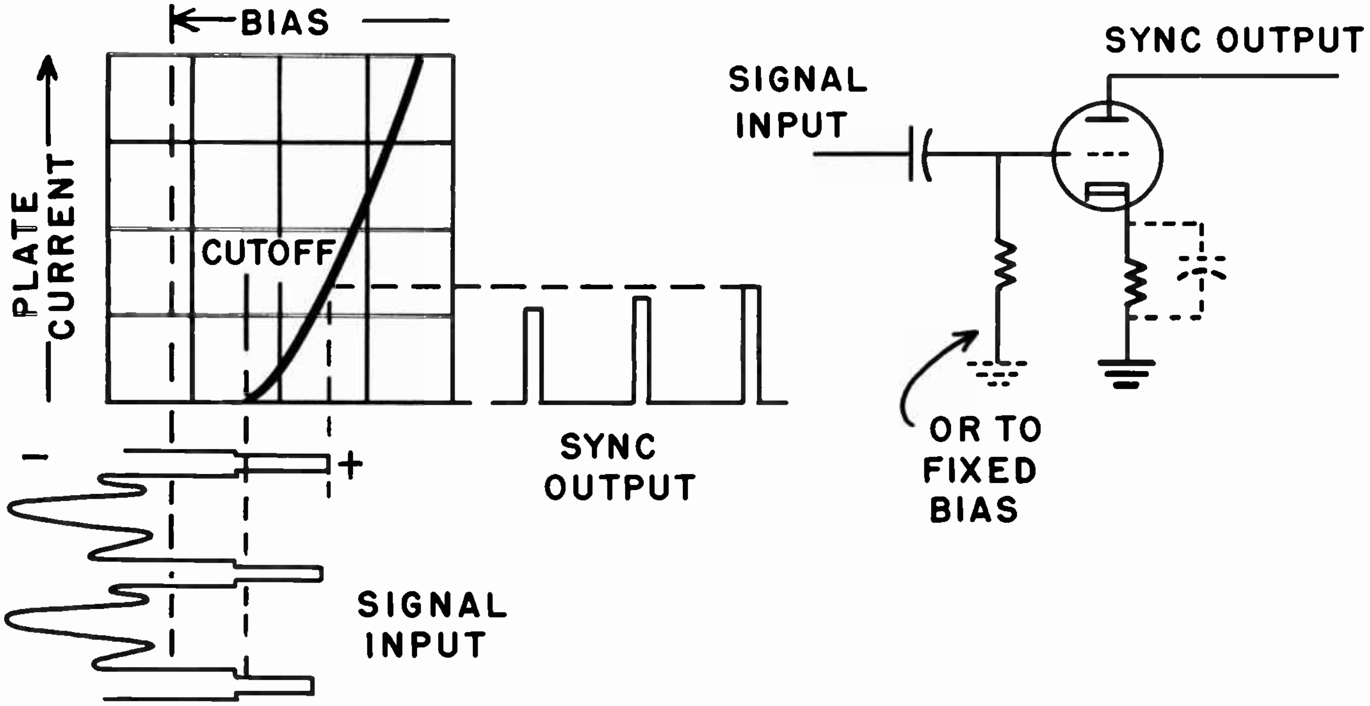

Fig. 5. A sync separator tube is biased to cut off picture signals while passing sync pulses.

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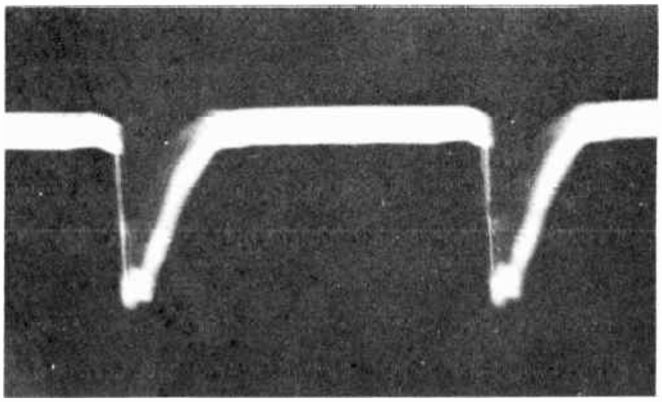

Fig. 6-A

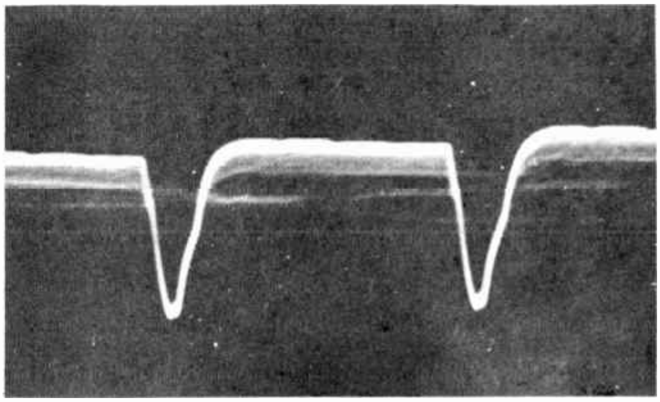

Fig. 6-B

Fig. 6. When separation is incomplete, portions of picture signals remain with the sync pulses.

Separator tubes are operated with grid-leak bias. High resistance in the grid leak holds the negative bias voltage almost equal to positive voltage or amplitude at tips of sync pulses in the applied signal. This bias automatically becomes more negative on strong signals and less negative on weaker signals. In the sharp cutoff pentodes and medium-mu triodes used as separators this biasing causes plate current cutoff to remain somewhat on the positive side of the black level. Then only the positive sync pulses cause conduction of plate current, and only pulse voltages appear in the output of the separator.

If bias is insufficiently negative, cutoff will be on the picture side of the black level and there will be incomplete separation. This is shown by the traces of Fig. 6, taken at the plates of sync separators. Insufficient bias may result from too little grid coupling capacitance or from too little grid leak resistance. Low voltages on plates and screens of separators helps make cutoff action effective even when pulse strength is so weak as to cause only a moderate negative grid bias.

Separators sometimes are operated with fixed bias in addition to grid-leak bias. This brings the cutoff point farther above the black level. Then only the more positive portions or only the tips of sync pulses cause conduction. Complete removal of picture signals is insured. If bias is so negative as to leave only the tips of original pulses in the separator output, additional amplification will be needed in the sync section.

When there is only grid lead bias and when plate and screen voltages are moderately high, there will be some amplification of sync pulse voltages in the separator stage. That is, pulse voltage or amplitude at the separator plate load may be greater than that of sync pulses on the input composite signal.

Sync pluses which are positive at the takeoff, as at B of Fig. 4, allow takeoff connection to the separator grid, with action as just described. If pulses are negative at the takeoff, as at A or C of Fig. 4, this connection must lead first to the grid of a tube used as amplifier, inverter, or limiter. This tube will invert the signal and make sync pulses positive at its plate. Then the plate may be coupled to the grid of a separator tube, in which the positive sync pulses will act as shown by Fig. 5.

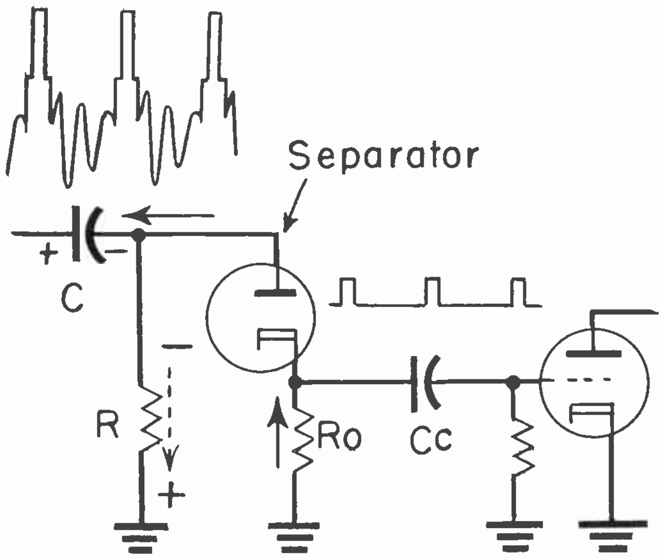

Fig. 7. A diode used as sync separator.

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Fig. 7 shows how a diode may be used as a sync separator when a composite video signal with sync pulses positive is applied through capacitor C to the diode plate. When the diode plate is made positive with reference to the cathode there is electron flow as shown by full-line arrows. This charges capacitor C in the marked polarity. The charge can escape only slowly through resistor R, with electron flow shown by the broken line arrow. Thus the plate of the diode is maintained negative with reference to the cathode, or the plate is negatively biased.

Electron flow now can occur only when voltage on the diode plate overcomes the negative bias. Only the tips of applied sync pulses will thus affect the diode plate, causing brief pulses of current to flow in diode load resistor Ro. The accompanying voltage pulses or sync pulses are applied through capacitor Cc to any following tube. Sync pulses separated in this manner are weak, and require amplification.

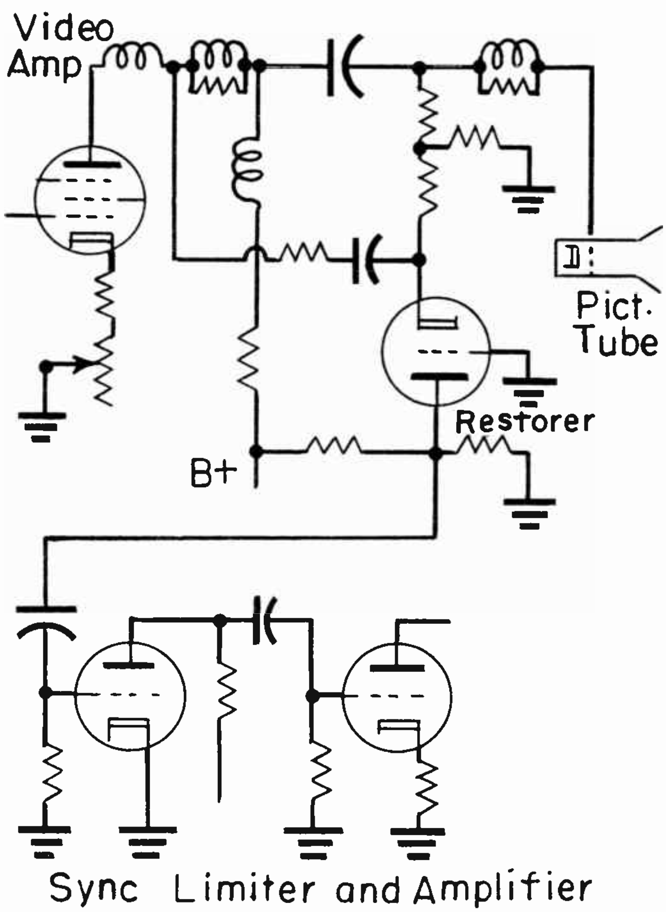

Fig. 8. A d-c restorer tube used also as a sync separator.

In quite a few television receivers, both old and new, the tube used for d-c restoration is employed also as a sync separator. A fairly typical circuit is shown by Fig. 8. As usual, the restorer cathode is fed a composite signal from the final video amplifier, with sync pulses negative in this signal. The restorer conducts only when its cathode is made negative by the negative sync pulses. Because the restorer grid is grounded, causing much the same action as in a grounded grid amplifier, signal polarity at the plate is the same as at the cathode and we have negative sync pulses going from the restorer plate to the first tube in the sync section.

Any d-c restorer connected and used in this manner passes negative sync pulses to its plate, with picture signals almost completely cut off. Consequently, the restorer acts as an effective sync separator, and may be followed in the sync section by limiters, amplifiers, or inverters as required by the receiver design. The action of restorer tubes is fully explained in the lesson on "D-c Restoration".

SYNC AMPLIFIERS. A sync amplifier tube may be a triode or a pentode operated with plate, screen, and grid bias voltages about like those used for similar tubes in i-f amplifier sections. As mentioned earlier, the purpose of the amplifier is to add strength to a weak composite signal taken from the output of a video detector or first video amplifier, or to add strength to sync pulses after they have been cut down by limiting or clipping action.

Biasing of amplifiers usually is by the grid-leak method to insure fairly uniform gain with normal variations of received signal strength. As you know, such uniformity results because bias becomes less negative and gain is increased on weak signals, while bias becomes more negative and gain decreases on strong signals.

A sync amplifier handling all kinds of sync pulses should have good response at the 60-cycle vertical frequency. Good response or gain at frequencies higher than those of equalizing pulses, about 32 kc, is undesirable because it would serve only to amplify the higher frequencies of picture signals. Pic-

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ture signals are not wanted in the sync section. All sync amplifiers invert the signal polarities between grid and plate. This is allowed for in design of the sync section.

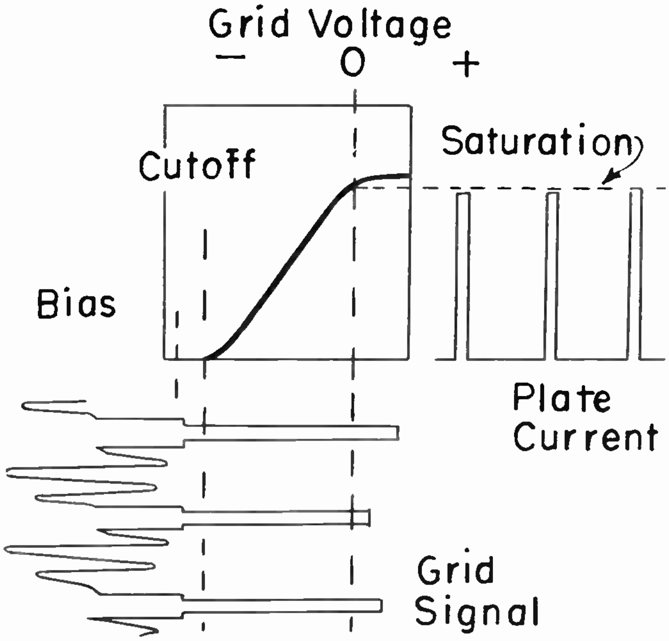

Fig. 9. Limiting by means of plate current cutoff combined with plate current saturation.

SYNC LIMITERS OR CLIPPERS. To hold pictures steady both vertically and horizontally it is obviously desirable that sync pulses remain of constant strength with changes of strength in received signals, changes of contrast control setting, and changes in average tone of pictures. Pulses may be reduced to uniform strength in tubes operated just as are limiters in f-m sound sections. That is, the tube may be negatively biased for plate current cutoff at some fixed value of negative pulse voltage, or it may be operated with such low plate and screen voltages as to cause plate current saturation at some fixed value of positive pulse voltage, or both methods may be used together. Limiting at both top and bottom of sync pulses would work out as illustrated by Fig. 9.

Limiting by saturation seldom is employed, because it is so wasteful of signal voltage and power. In fact, we may get along very well without any tube performing solely as a limiter, whether by plate current saturation or cutoff. Limiting or clipping at both top and bottom of sync pulses may be well performed by tubes whose primary functions are separation, amplification, or inversion.

Fig. 10 shows how limiting might be accomplished by a sync separator and sync amplifier. At the lower left is a composite signal as applied to the grid of the separator. Plate current cutoff is somewhat above the black level. This removes all picture varia-

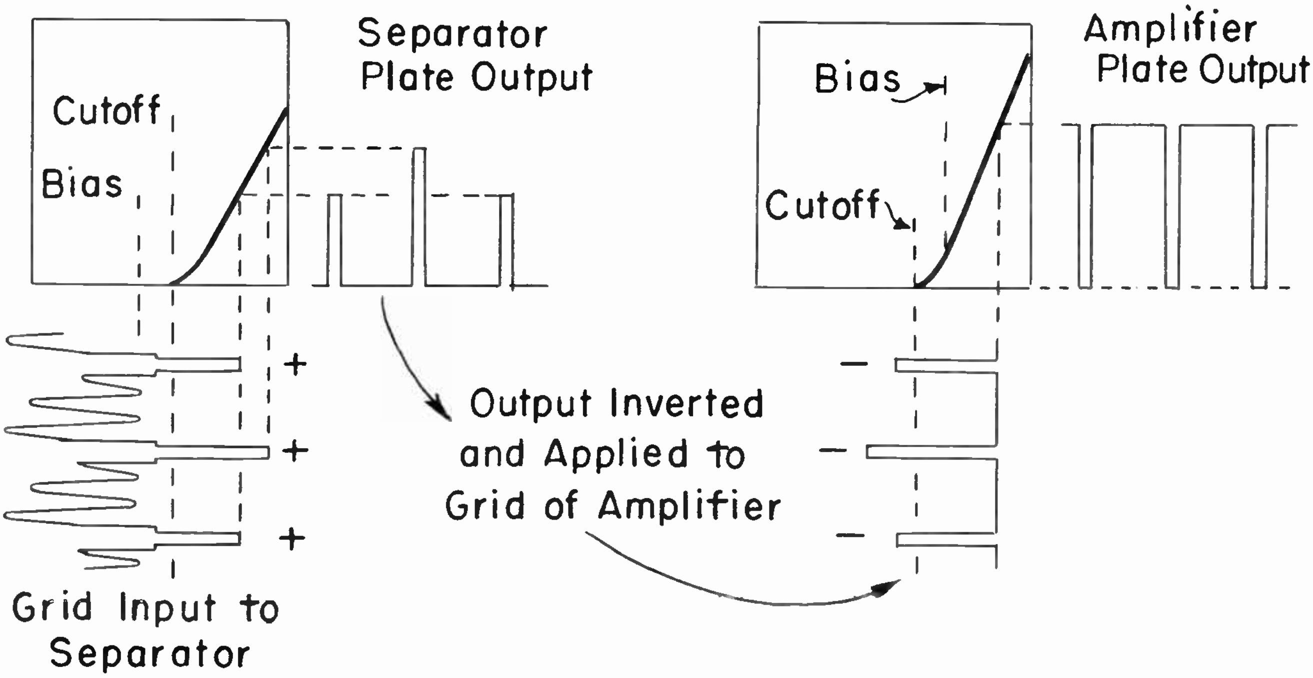

Fig. 10. Limiting may result from plate current cutoff in two successive stages designed primarily for purposes other than limiting.

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tions and levels the sync pulses along the line of cutoff. In the plate output of the separator we still have pulses of unequal heights or strengths.

Between grid and plate of the separator there is inversion of signal polarity. In the original composite signal the sync pulses are positive at their tips. At the separator plate the pulse voltages will be negative at their tips. These inverted pulses are applied to the grid of a following sync amplifier. Suitable biasing of the amplifier levels the sync pulse tips on the line of plate current cutoff. If the inverter pulses are applied to the amplifier grid as a d-c voltage, the leveling of the pulse bases will be preserved as shown on the amplifier plate output at the right in Fig. 10.

Even though pulse voltages from the plate of one tube pass through a coupling capacitor and appear as alternating voltage at the grid of a following tube, there will be reasonably effective leveling or limiting action. Pulse strength will not vary in the exaggerated manner of Fig. 10. Normal variations will be reduced by grid-leak biasing of tubes in the sync section, since such biasing tends to hold output voltages fairly constant when there are normal variations of input voltages.

With operation such as illustrated by Fig. 10 we might have a sync section composed of only a separator and an amplifier, assuming that amplifier output polarity is suitable for the sweep oscillators. If separation is accomplished in a d-c restorer tube, as shown by Fig. 8, we might do away with the separator of Fig. 10 and leave only the sync amplifier. If polarity is not correct for the sweep oscillators it will be necessary to add a tube acting as inverter. The inverter may or may not provide worth-while additional amplification.

SYNC OUTPUT FILTERS. In most television receivers the horizontal, vertical, and equalizing pulses pass together through all the tubes of the sync section. Connected to the output of the last tube in this section is one circuit which responds only to horizontal sync pulses, and a second circuit which responds only to vertical sync pulses.

In early types of home television receivers the two circuits for selecting horizontal and vertical synchronizing voltages were arranged as in Fig. 11. One circuit, called the differentiating filter, delivers triggering voltages to the horizontal sweep oscillator. The other circuit, called the integrating filter, delivers triggering voltages to the vertical sweep oscillator.

From a differentiating filter used as in Fig. 11 it is difficult to obtain triggering

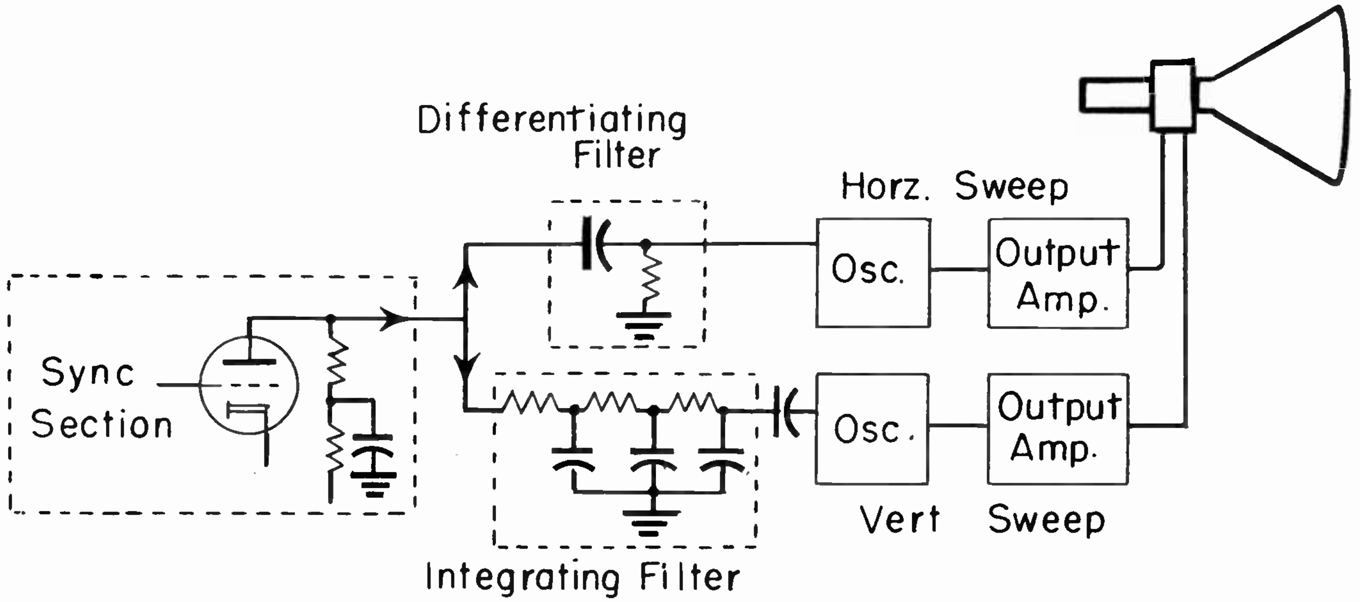

Fig. 11. Voltages for vertical and horizontal triggering may be produced when vertical and horizontal sync pulses are applied to suitable filters.

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voltages strong enough to hold the horizontal sweep oscillator in synchronization with received picture signals. Consequently, in modern receivers we no longer find this simple differentiating filter leading to the horizontal sweep oscillator. Instead there are automatic controls for horizontal sweep frequency and additional tubes which strengthen the triggering voltages. These things will be studied in following lessons.

Differentiating filters are, however, used at so many other points in receivers and testing instruments that their principle is well worth examining. Such a filter consists of a capacitor in series with applied alternating or pulsed voltage, and of a resistor shunted across the filter output, as in Fig. 11. The time constant of this capacitor-resistor combination must be much shorter than the duration of one alternation or one pulse of applied voltage.

Were sync pulses at the top of Fig. 12 applied to the input of a differentiating filter, output voltage would be of the form shown down below. To understand how such an output voltage is produced we must keep two facts in mind. First, this output voltage consists of potential differences or voltage drops across the shunted filter resistor. Second, these voltage drops can appear only while the resistor is carrying current into or out of the filter capacitor. Unless the capacitor is charging or discharging there will be no current in the resistor, and resistor voltage will be zero.

When there is an increase of applied voltage at the leading edge of a pulse, the filter capacitor is charged almost instantly to full pulse voltage, by current flowing in the resistor. Resistor voltage rises suddenly to a maximum in positive polarity. With the capacitor charged to full voltage of the applied pulse, charging current stops flowing in the resistor and resistor voltage drops back to zero. The capacitor remains fully charged during the remainder of the pulse because of continuing pulse voltage.

At the trailing edge of the pulse its voltage drops to zero, and there is nothing to hold the charge in the capacitor. The capacitor discharges through the filter resistor. Discharge current causes another increase of potential difference or voltage drop across the resistor. But because discharge current and accompanying voltage are opposite in polarity to charging current and voltage, this new voltage across the resistor shows as a negative or downward pip on the voltage curve. As the capacitor completes its discharge, current ceases in the resistor and voltage across the resistor returns to zero.

INTEGRATING FILTERS. Although modern television receivers do not employ simple differentiating filters in their horizontal sweep sections, nearly all of them do

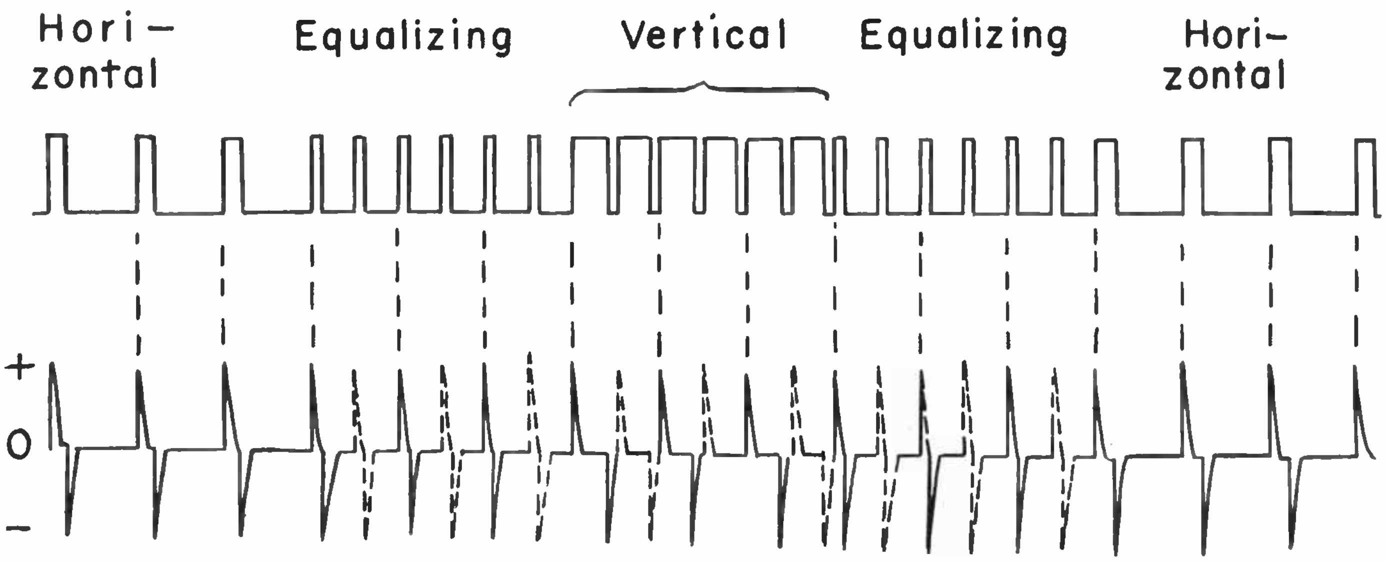

Fig. 12. When applied to a differentiating filter, leading edges of voltage pulses produce positive pips, while trailing edges produce negative pips.

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employ an integrating filter between the sync section and the vertical sweep oscillator. As you can see in Fig. 11, the integrating filter consists of resistors in series with applied voltage, and of capacitors shunted to ground.

When the same sync pulses which were applied to a differentiating filter in Fig. 12 are applied to an integrating filter we have a filter output voltage shown at the bottom of Fig. 13. Differences between output voltages from the two types of filters are due partly to the manner in which resistors and capacitors are connected.

A differentiating filter is one kind of "high-pass filter", so called because high frequencies pass more readily than low frequencies through the series capacitor. Then we have at the output only the very brief voltage pips such as would exist in a high-frequency alternating voltage.

The shunt capacitors of an integrating filter tend to pass high frequencies to ground, and only relatively low frequencies or slow changes of voltage show up at the output. This is a form of "low-pass filter". Low-pass filters are used also in power supplies.

Differences between actions of the two kinds of filters are due also to different time constants. In a differentiating filter the capacitor-resistor time constant is so short as to allow capacitor discharge in a period even shorter than that of one horizontal sync pulse. In each section of an integrating filter the capacitor-resistor time constant is so long that the capacitors can discharge very little during one pulse interval.

Returning now to Fig. 13, the changes of voltage shown at the bottom of this figure are those occuring across the filter capacitors. These voltages are caused by charging and discharging of the capacitors. Commencing at the left, note that each horizontal sync pulse puts a small charge and small voltage on the filter capacitors. The capacitors discharge almost completely between successive horizontal pulses.

Equalizing pulses cause much the same things to happen, except that these shorter pulses cause even smaller charges and voltages than horizontal sync pulses. There is practically complete discharge between successive equalizing pulses.

With the filter capacitors fully discharged we come to the first of six long pulses which together make up the serrated vertical pulse. During each long pulse the filter capacitors get much more charge and gain much more voltage than during the shorter horizontal and equalizing pulses. Further-

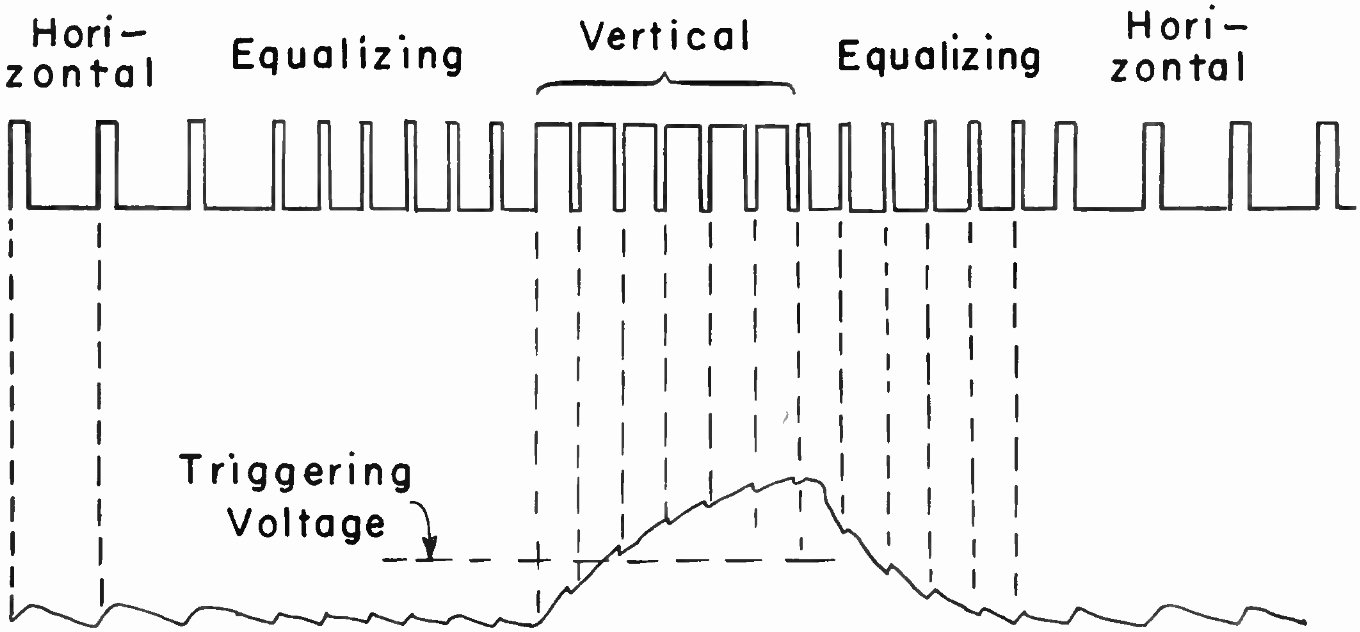

Fig. 13. How the several kinds of sync pulses act in an integrating filter.

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more, during the very short serrations in the vertical pulse there is time for very little discharge of the filter capacitors. As a consequence, during the entire vertical pulse there is continued rise of capacitor voltage.

This rising capacitor voltage is applied to the grid circuit of the vertical sweep oscillator. At some certain value of capacitor voltage, depending on design and adjustments in the oscillator circuits, the oscillator is triggered and goes through one cycle of oscillation to sweep the beam of the picture tube vertically for one field.

Capacitor voltage continues to rise until the end of the vertical sync pulse. Then, during following equalizing pulses, there are long discharges interrupted by very brief charges. At the completion of equalizing pulses, or at the end of equalizing and horizontal sync pulses during the vertical blanking period, the filter capacitors are fully discharged.

The action of an integrating filter illustrated step-by-step at the bottom of Fig. 13 is seen as at A of Fig. 14 by an oscilloscope connected to the filter input, across the first shunting capacitor. Separate steps of voltage change corresponding to successive sync pulses show quite clearly.

Upon connecting the scope to the second section of the filter, across the second capacitor, we have the trace at B. Steps of voltage are much less pronounced. At the output of the integrating filter we find the voltage trace shown at A of Fig. 1 in this lesson. Here the voltage changes smoothly throughout its rise and fall. The purpose of using several filter sections instead of only one series resistor and shunted capacitor is to obtain such smoothing. Then the vertical oscillator can be triggered at exactly correct instants during each of the fields which make up one picture frame.

NOISE SUPPRESSION IN SYNC SECTIONS. Were noise voltage only in the same polarity as picture signals the noise would mar picture reproduction without affecting synchronization, and were noise only in the same polarity as sync pulses it would not appear in pictures but would upset vertical and horizontal synchronization. Actually, noise causes pulses or alternations in both polarities, and can affect picture detail and synchronization at the same time.

In the sync section we are interested in suppressing noise voltages which are of the same polarity as sync pulses. Fig. 15 shows one of the simplest methods, one which requires only an additional diode. This diode may be in any combination tube having separate cathodes or a single grounded cathode, as in a twin diode or in a duodiode triode. It may even be a triode with grid and plate tied together to act as a diode.

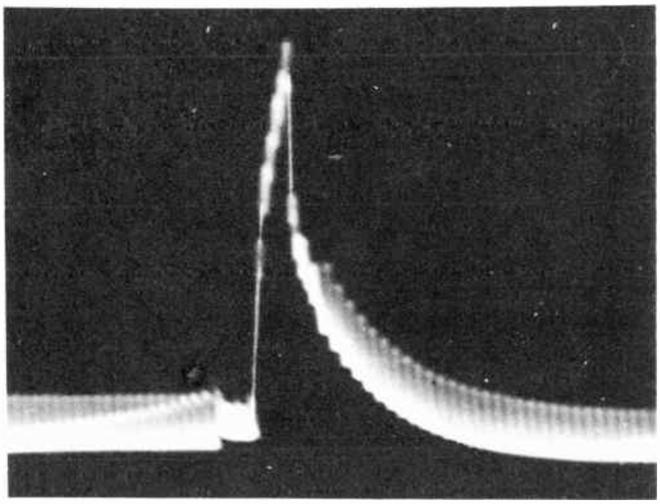

Fig. 14-A

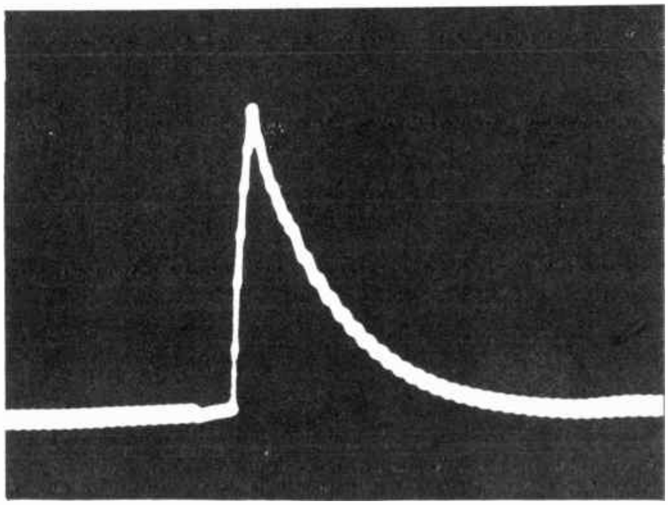

Fig. 14-B

Fig. 14. Voltages which appear across filter capacitors of an integrating filter.

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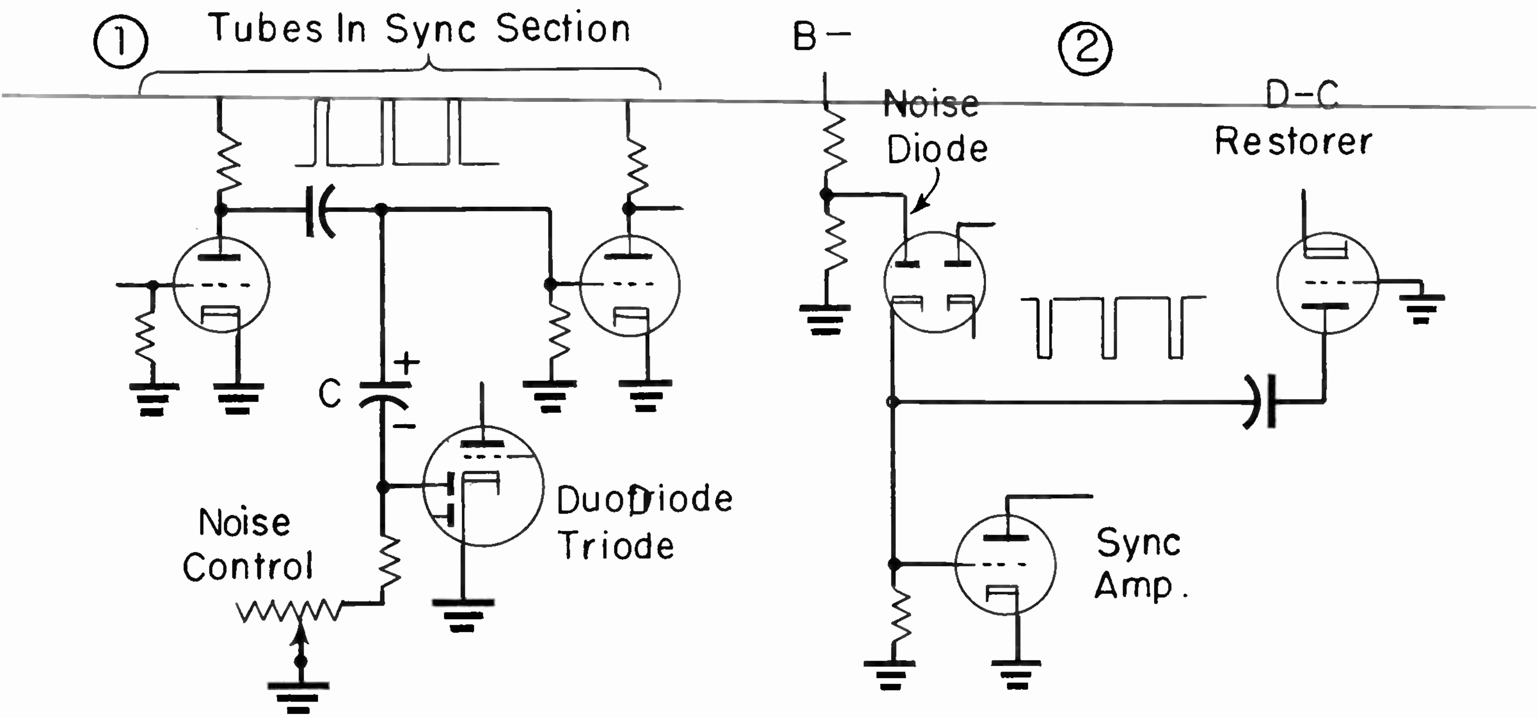

Fig. 15. How diodes may be used for noise suppression in sync sections.

With the arrangement of diagram 1 the plate of the noise suppression diode is connected to any point in the sync section where sync pulses are positive. The diode plate is negatively biased by a charge put on capacitor C by positive tips of sync pulses, and held there by slow leakage through the adjustable noise control resistor. This method of biasing a diode plate has been explained many times, in connection with gain controls and other circuits.

Negative bias voltage on the diode plate is adjusted to a value approximately equal to average peak-to-peak voltage of sync pulses. Then the diode remains non-conductive during sync pulses. But if a positive noise pulse is stronger than the average sync pulse, the excess of positive noise voltage overcomes the negative bias on the diode plate. Then the diode conducts and momentarily loads the sync circuit so heavily that the noise voltage is reduced to the level of sync pulses or slightly lower.

The method of noise suppression illustrated by diagram 2 may be used where sync pulses are negative, as when takeoff is from the plate of a d-c restorer tube. The plate of the noise suppression diode is negatively biased by connection to any suitable point in the d-c power circuits of the receiver, thus making the cathode of the diode positive in relation to the plate.

On a receiver employing this method of noise suppression a VTVM showed the cathode as 5.0 volts positive with reference to the diode plate. An oscilloscope voltage calibrator showed 5.5 peak-to-peak volts for sync pulses with the noise diode disconnected. With the diode connected, it then conducted on the portions of sync pulses in excess of 5.0 volts, since this excess made the diode cathode negative with reference to its plate. Any noise voltages in excess of 5.0 volts also would cause diode conduction, and in this manner the strength of noise would be held to the same 5.0-volt limit as sync pulses.

In Fig. 16 a noise suppressor diode is connected between two sync separators in such manner as to prevent passage of noise pulses from the first to the second separator. The composite video signal A, with sync pulses positive, is applied to the grid of the first separator. Cathode bias voltage developed in resistor Rk is applied to the cathode of the noise diode, making that cathode positive. However, the diode plate is maintained more positive than its cathode to an

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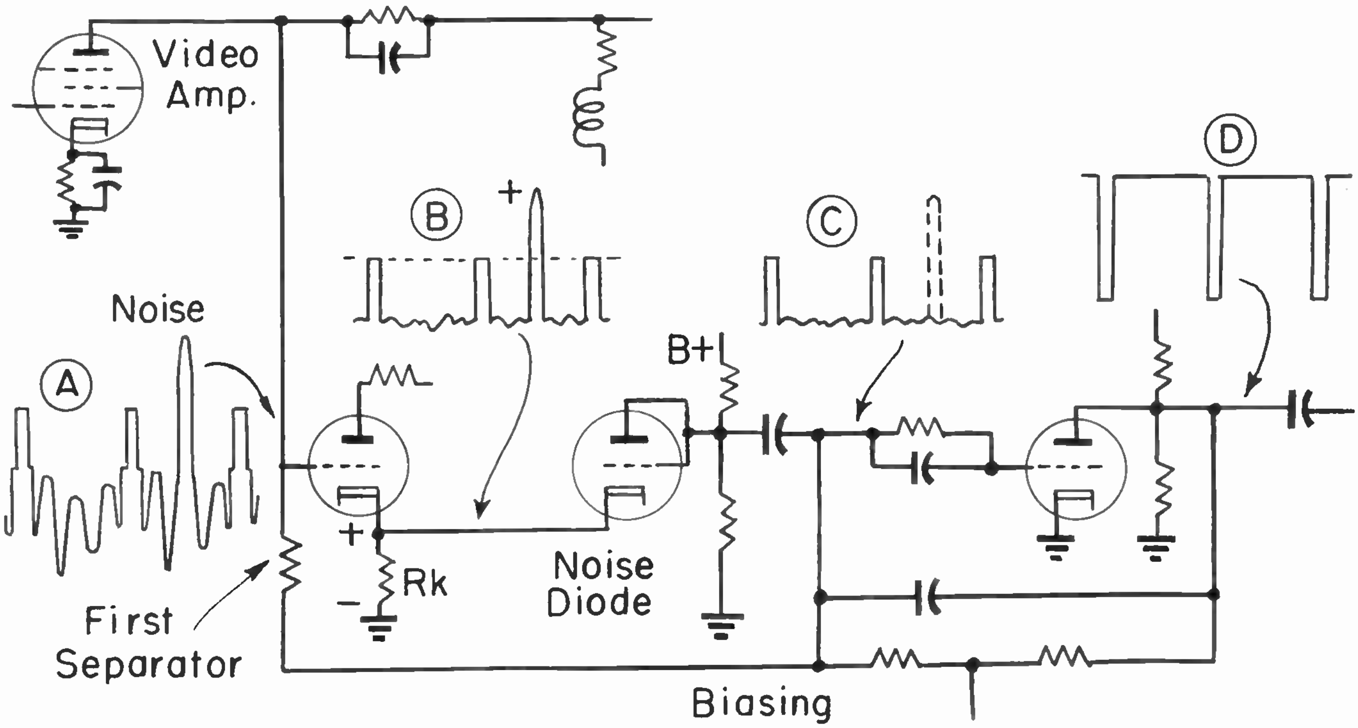

Fig. 16. The noise diode prevents passage of noise voltage pulses from first to second separator.

extent allowing conduction of normal sync pulses through the diode to the second sync separator.

When the strong positive noise pulse of signal A acts on the grid of the first separator there is increase of plate current and of current in resistor Rk, accompanied by a sharp increase of voltage across Rk. Excess positive voltage of the noise pulse, indicated at B, makes the cathode of the noise diode more positive than its plate. Then the diode becomes non-conductive during the noise period. As at C, the noise pulse is cut off and only normal sync pulses go to the grid of the second separator. Output from the second separator, with noise removed, is shown at D.

In Fig. 17 a triode is used as two diodes, one for video detection and the other for noise suppression. The cathode and grid act as cathode and plate of a diode type video detector which functions as usual. The cathode and plate of the triode act as cathode and plate of a diode for noise suppression. It must be kept in mind that any diode is conductive only while its cathode is negative with reference to the plate, or while the plate is positive with reference to the cathode.

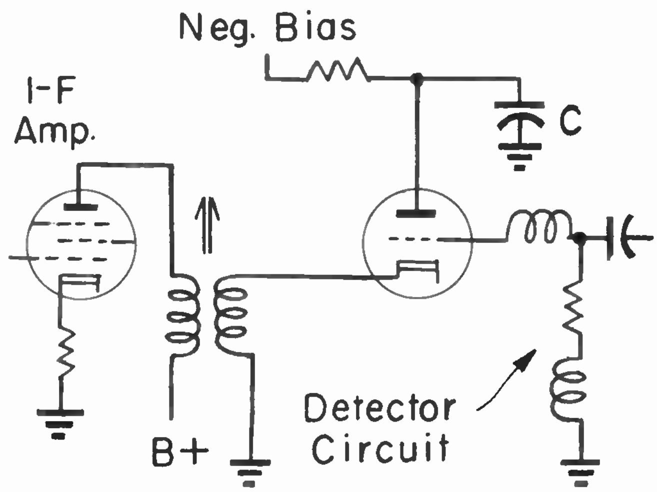

Fig. 17. A triode used as video detector and noise suppressor.

The triode plate is negatively biased to a value which prevents conduction through this plate on i-f signals of normal strength. However, negative alternations of strong noise pulses in the i-f signal make the triode cathode more negative than its plate, and there is conduction from the plate through capacitor C to ground during the noise pulses. Conduction current so loads the i-f amplifier as to greatly reduce its gain during noise pulses, and the noise passes through

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the video detector circuit at greatly reduced strength.

There are entirely different methods of noise suppression which aim to cancel noise voltages more or less completely by opposing them with voltages of opposite polarity. Opposite polarity in the cancelling voltage is secured by taking it from a different stage in the sync or video amplifier systems, thus making use of signal inversion which takes place between grid and plate of any tube.

The opposing voltage is originally derived from or produced by the noise pulse, therefore occurs at the same instant as the noise. It is necessary to employ some rather unusual circuit arrangements in order to cancel the noise without at the same time cancelling the sync pulses.

A practical application of the cancellation principle is illustrated by Fig. 18. The composite video signal A is applied to the grid of the video amplifier and also to the cathode of the noise suppressor triode. Sync pulses are negative in this composite signal, and they tend to make the cathode of the suppressor tube negative. This leaves the plate relatively positive, which would be the condition for conduction.

The grid of the noise suppressor tube is negatively biased to a degree which prevents conduction so long as the cathode is made negative only to the extent of normal negative sync pulses. But a relatively strong negative noise pulse makes the cathode so negative as to allow conduction during the pulse, and from the plate of the noise suppressor tube we have a negative noise pulse shown at B.

The composite signal goes through the video amplifier and comes from the amplifier plate with polarities inverted, as at C. Part of this composite signal, with its positive noise pulse, is taken from the video amplifier plate load through high resistance at R to the grid of the sync separator. At the same time the negative pulse developed at B is applied to the grid of this separator tube. The negative pulse reduces the positive noise pulse to

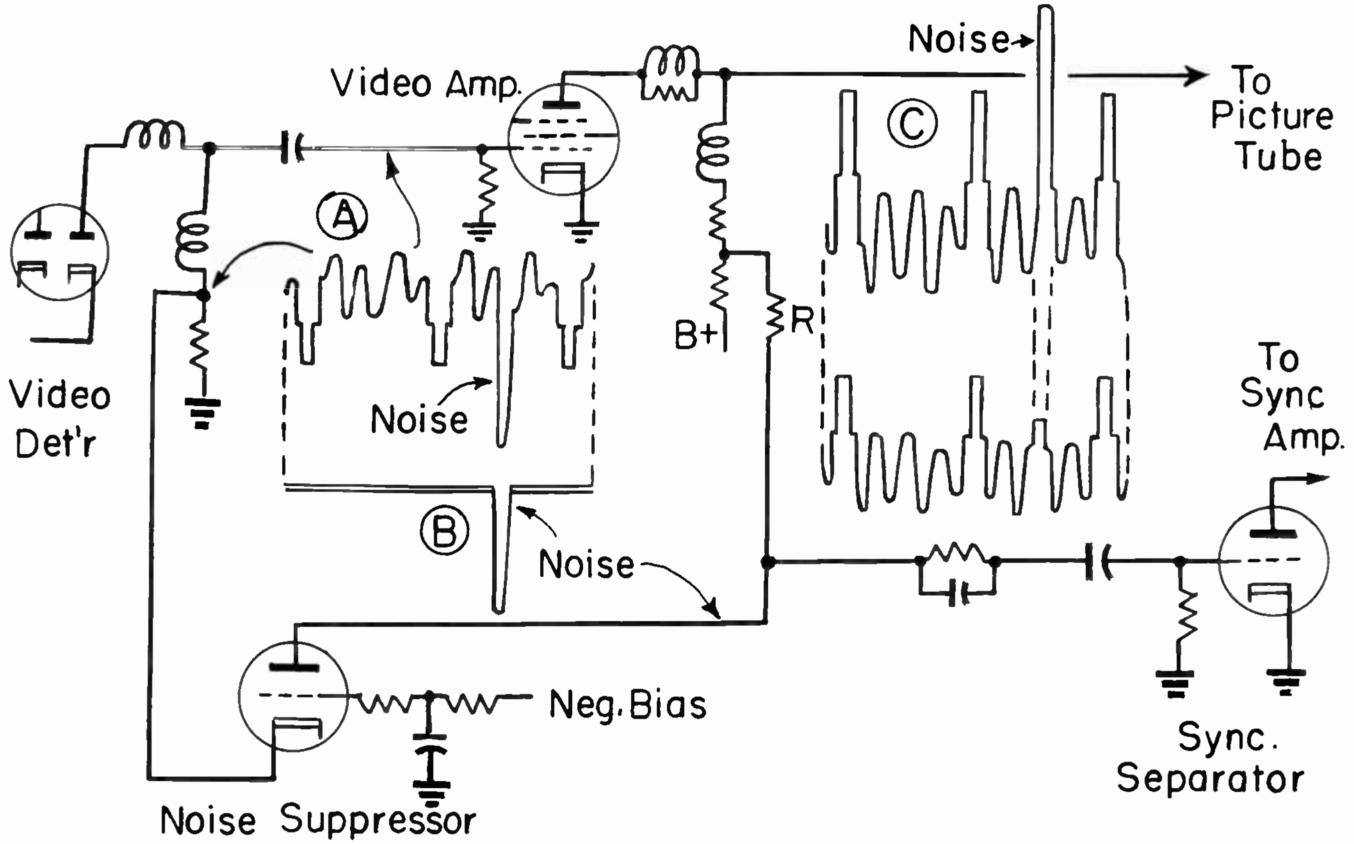

Fig. 18. A voltage of opposite polarity opposes any noise voltage at the grid of the sync separator.

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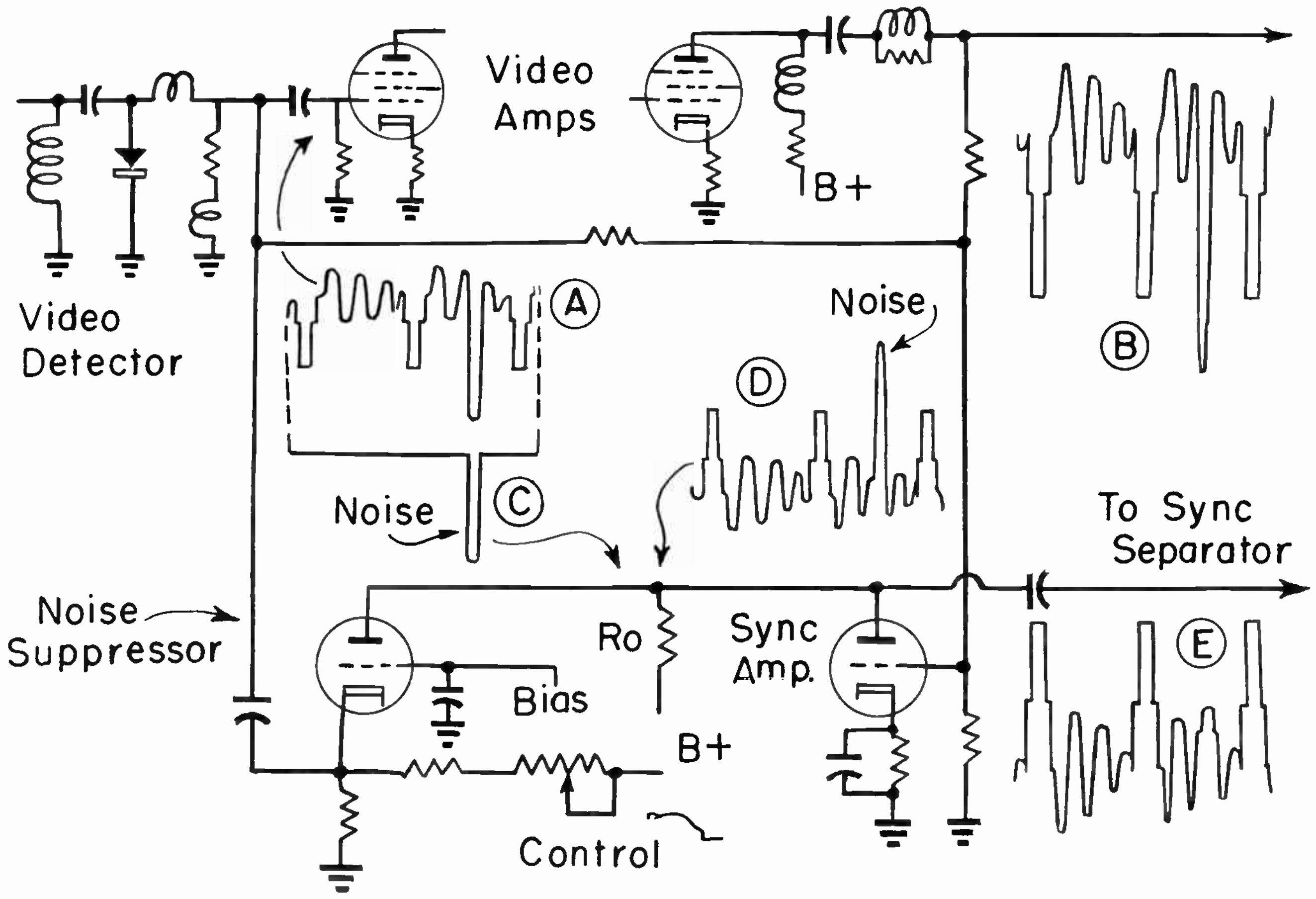

Fig. 19. Noise pulses are opposed by opposite voltages in the plate load for noise suppressor and sync amplifier.

a value so small that it no longer can upset synchronization. Note that regular sync pulses are unaffected, since they do not pass through the noise suppressor tube.

Fig. 19 shows another application of the principle of opposing a noise voltage with a voltage of opposite polarity. The composite video signal A is applied to the grid of the first video amplifier, is inverted at the plate of this tube, is inverted again at the plate of the second video amplifier, and thus is brought back to the original polarity, as at B.

The original composite signal A, with sync pulses negative, is applied also to the cathode of the noise suppressor triode. The grid of this triode is negatively biased, while its cathode is maintained positive by potential brought from a B-pulse line through the adjustable control. The combination of negative grid and positive cathode potentials prevents the tube from conducting during normally negative sync pulses, but the stronger negative noise pulses on the cathode counteract the original positive potential and cause conduction. The result is a negative pulse C at the plate of the noise suppressor.

The composite signals from A and B, with sync pulses negative, are applied also to the grid of the sync amplifier. Then at the plate of this amplifier we have sync and noise pulses positive, as at D. The positive noise pulse at D acts on plate load resistor Ro. But this resistor is also the plate load for the noise suppressor, and is acted upon simultaneously by the negative pulse C. This negative pulse largely cancels the positive noise pulse in the composite signal, and in output voltage E going to the sync separator there remains negligible noise effect.

Still another method of developing voltages which oppose noise pulses is shown by Fig. 20. The noise suppressors are two triodes, actually sections of a twin triode connected between the video amplifier and

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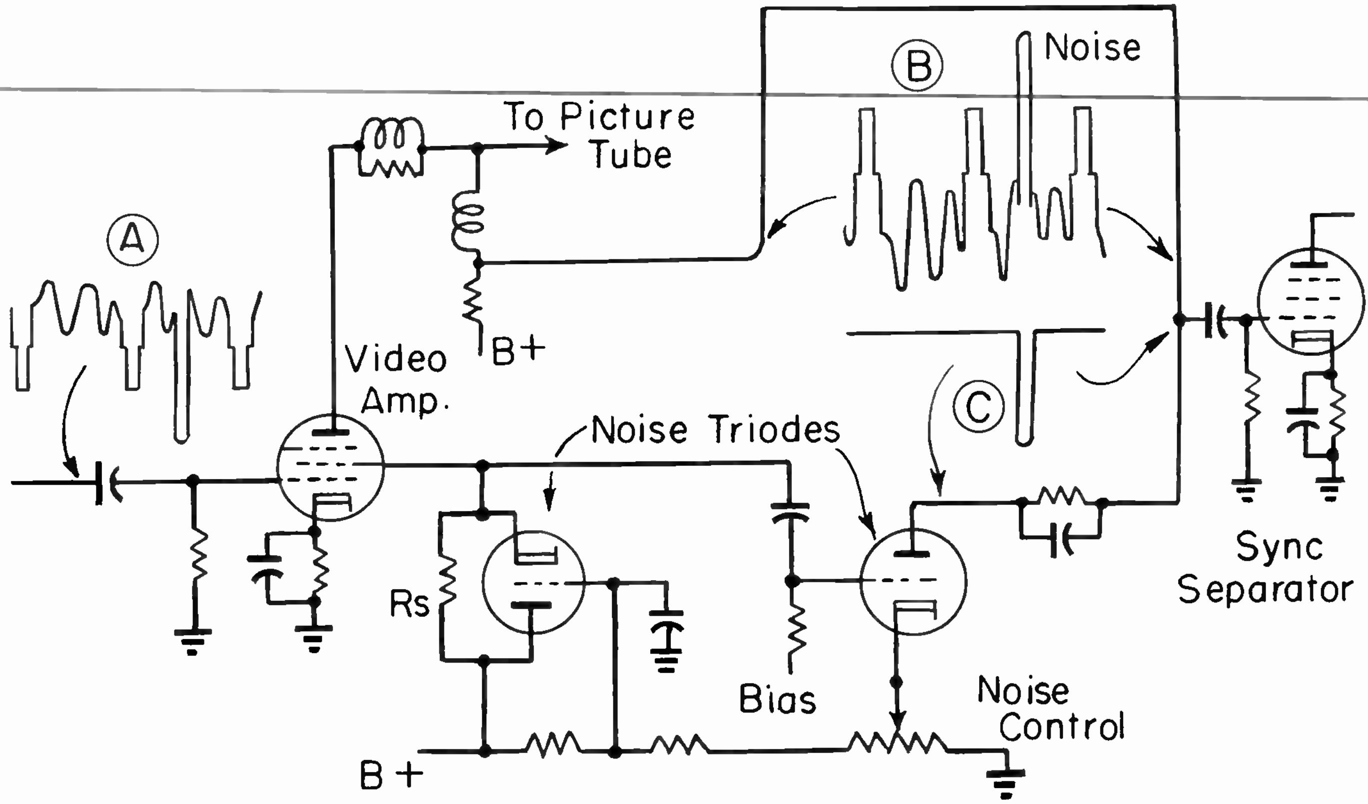

Fig. 20. Opposing voltages for noise cancellation are developed in the screen circuit of a video amplifier.

sync separator. In the composite signal A at the grid of the video amplifier the sync pulses are negative. After inversion in the amplifier the composite signal, together with a noise pulse, appears as at B, and is applied to the grid of the sync separator.

The first noise triode is in parallel with resistor Rs, the voltage dropping resistor for the screen of the video amplifier. When the negative noise pulse acts on the video amplifier grid it makes the grid so negative as to cut off plate and screen currents. The result is an instant increase of positive screen voltage, which, acting on the cathode of the first noise triode, makes this triode non-conductive. With the triode no longer providing an effective shunt across resistor Rs, screen voltage jumps to its maximum value. Note that this strongly positive pulse of screen voltage results from negative noise voltage at the grid of the video amplifier.

The pulse of positive voltage at the screen of the video amplifier is applied also to the grid of the second noise triode. This second triode has been held non-conductive by making its cathode positive (and the grid relatively negative) to an extent determined by adjustment of the noise control. But now the positive noise pulse on the grid of this second noise triode causes conduction, and at its plate appears the negative voltage pulse at C. This plate pulse is negative because the grid pulse is positive. The negative pulse C from the plate of the second noise triode goes to the grid of the sync separator at the same instant as the positive noise pulse accompanying video signal B. Thus there is cancellation of the positive noise pulse.

Fig. 21 shows how a heptode tube with five grids may be used as a combined noise suppressor and sync separator. Elements in this tube are arranged as in pentagrid converters used for combined oscillators and mixers in superheterodyne tuning systems. The elements are, in order, the cathode, first control grid, part of the screen, the second control grid, the remainder of the screen, suppressor grid, and plate. The tube may be one of the pentagrid converters or else a type designed especially for use in sync sections.

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LESSON 65 – THE SYNC SECTION

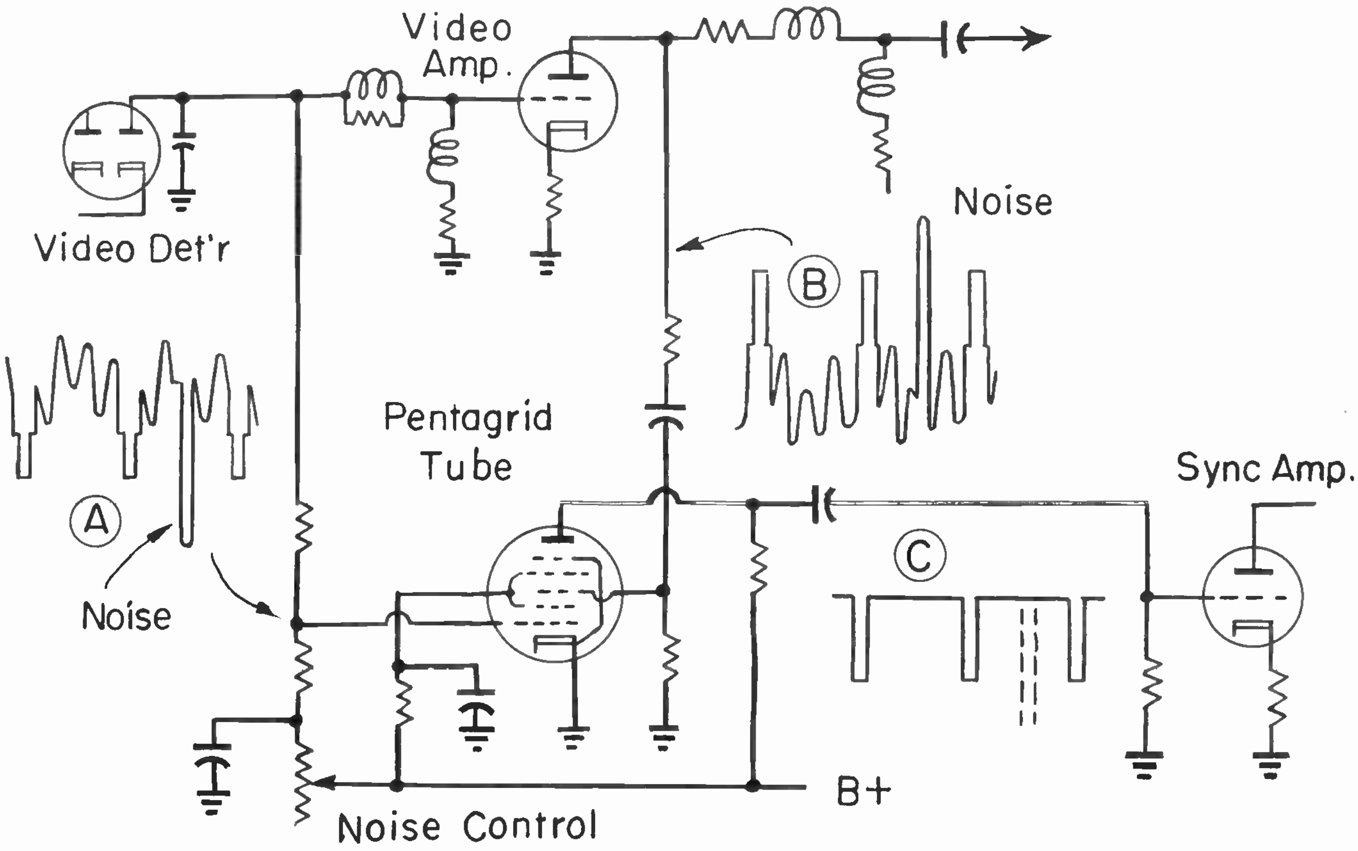

Fig. 21. A heptode or pentagrid tube used as combined noise suppressor and sync separator.

Composite signal A, from the output of the video detector, is applied to the first control grid of the heptode tube. Sync pulses are negative in this signal. The first control grid is biased, by means of the adjustable noise control, for operation so close to plate current cutoff that any noise voltage stronger or more negative than normal sync pulses does cause cutoff.

The composite signal from the video detector goes also through the video amplifier and, as at B is inverted at the amplifier plate. This signal, with sync pulses positive, is applied to the second control grid of the heptode tube. This second grid is made so strongly negative, by grid leak bias, that only the more positive portions of sync pulses from signal B cause conduction. Consequently, the tube acts as a sync separator.

A strongly negative noise pulse at A makes the first grid of the heptode so negative as to cut off all plate current in this tube. Then the positive noise pulse from the signal at B, acting simultaneously on the second control grid of the heptode, can cause no conduction. Consequently, no noise pulse voltage appears at the heptode plate, and we have the noise-free signal at C going to the sync amplifier.

In other sync sections generally similar to that of Fig. 21 the composite signal for the second control grid of the heptode is supplied from an additional sync amplifier instead of from a video amplifier. The grid of the added sync amplifier is fed the same composite signal, from the video detector, that goes to the first control grid of the heptode. This composite signal is inverted by the added sync amplifier, and from the plate of this amplifier is applied to the second control grid of the heptode. Otherwise the action and results are as explained in connection with Fig. 21.

There are, of course, still other ways for suppressing noise voltages in sync sections, and new methods are continually being developed. Some are simple, others complex. Most of them utilize principles which have

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been explained in connection with Figs. 15 through 21, although details and circuit combinations may differ.

Occasionally you will hear or read about a video amplifier being operated for noise limiting. This means that the grid of such an amplifier is biased to bring the black level voltage or composite signals close to the voltage for plate current cutoff. Then any strongly negative noise pulses drive the grid voltage beyond cutoff, and the noise pulses are reduced in strength at the plate of the video amplifier. Since black level voltage varies with signal strength and picture tone, this method by itself is not particularly effective, but may be of help when used in conjunction with other noise suppression circuits.

In several noise suppression systems there are adjustable controls which are service adjustments. These controls should be set while the receiver is tuned to fairly strong signals, usually in low-band channels 2 through 6. Try turning the control as far as possible first one way and then the other. At one of these positions the pictures should bend, twist, or wriggle on vertical lines, or become torn and displaced horizontally, or fail to lock into synchronization promptly when switching from one channel to another. These symptoms indicate that noise suppression action is cutting off too much of the regular sync pulses as well as any possible noise pulses.

Next, turn the control far enough back from this extreme setting to allow steady pictures and prompt locking on all channels. In localities where noise is no problem it may be advisable to leave the noise control set as far as possible in this latter direction, which reduces the effect on sync pulses and leaves these pulses of maximum strength for timing the sweep oscillators. Because there are so many different noise suppression systems, and so many controls, it is largely a matter of cut and try unless you have instructions applying to a particular receiver.

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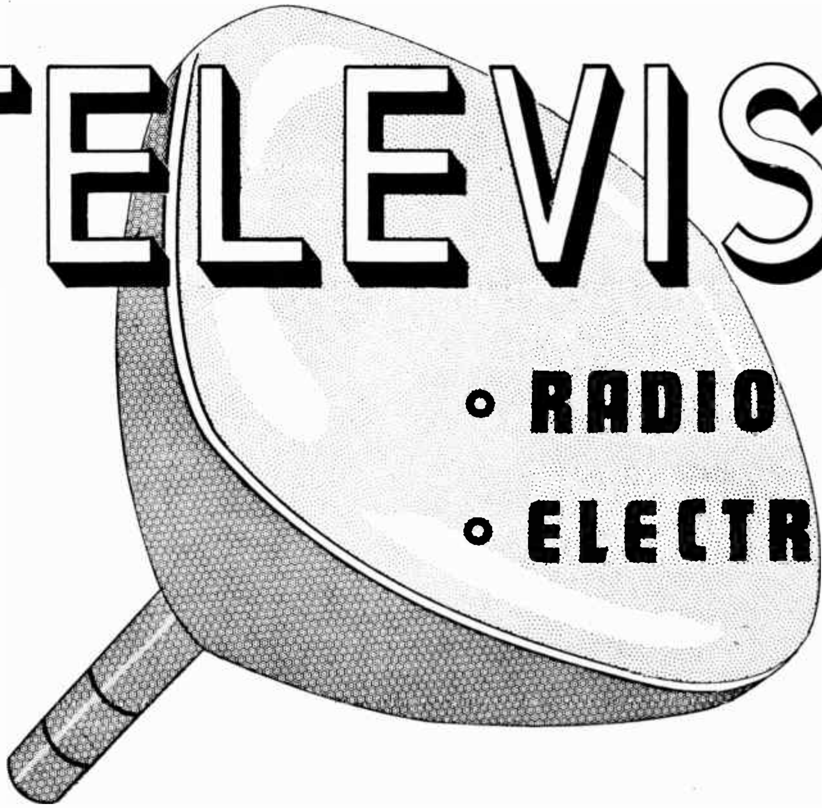

• RADIO
• ELECTRONICS

LESSON 66 — SWEEP OSCILLATORS

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Lesson 66

SWEEP OSCILLATORS

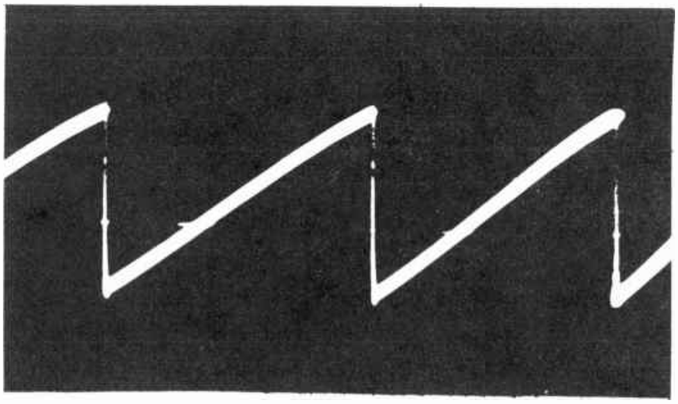

Fig. 1-A

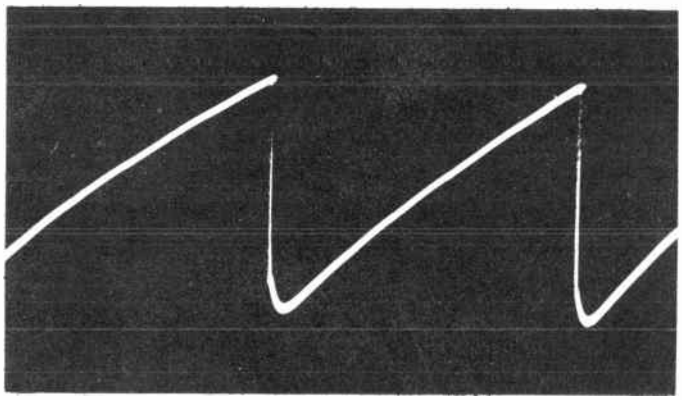

Fig. 1-B

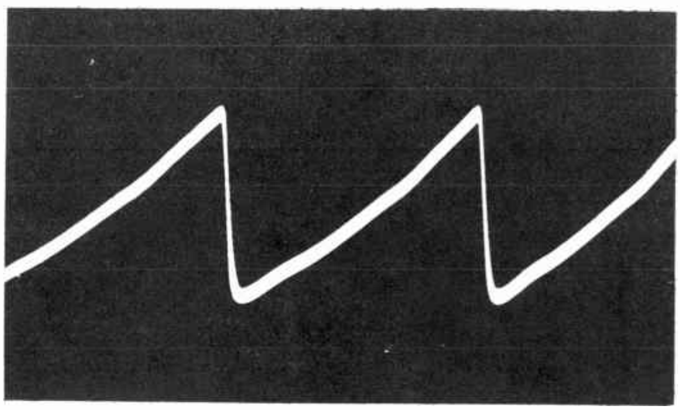

Fig. 1-C

Fig. 1. Sawtooth currents which appear in deflecting coils.

In the vertical and horizontal deflecting coils which are in the yoke around the neck of the picture tube must be produced sawtooth currects for deflecting the electron beam vertically and horizontally. These deflecting currents have waveforms such as illustrated by Fig. 1.

The long slopes in the sawtooth traces show current changing in the direction or polarity which causes downward sweep of the electron beam for one field, or sweep from left to right for one horizontal line. The sharp drops in the current waves show sudden reversals of current that cause retraces. The traces of Fig. 1 are from three different receivers, but they are essentially alike.

These sawtooth currents, and voltages producing them, are not the result of amplifying or otherwise modifying the sync voltages which appear at the output of the sync section. Sync voltages serve only to force the sawtooth currents to go through their cycles at the same instants or at the same frequency as vertical and horizontal sync pulses of a received signal.

Sawtooth voltages which eventually produce sawtooth deflecting currents originate in oscillator circuits and tubes which are parts of the vertical and horizontal sweep sections of the receiver. Some of the more essential parts of these sweep circuits are represented in Fig. 2.

Sawtooth voltages and currents still would originate at the sweep oscillators, and there would be both vertical and horizontal deflections of the electron beam, even with no sync pulses and no received signal. The only difference would be that sawtooth frequencies would not be held in synchronism with the missing sync pulses.

The sawtooth voltages appear first at capacitors marked Cs in Fig. 2. The long slopes of these sawtooth are due to increases of voltage across the capacitors as the capacitors are charged. The sharp drops are decreases of capacitor voltage during discharge.

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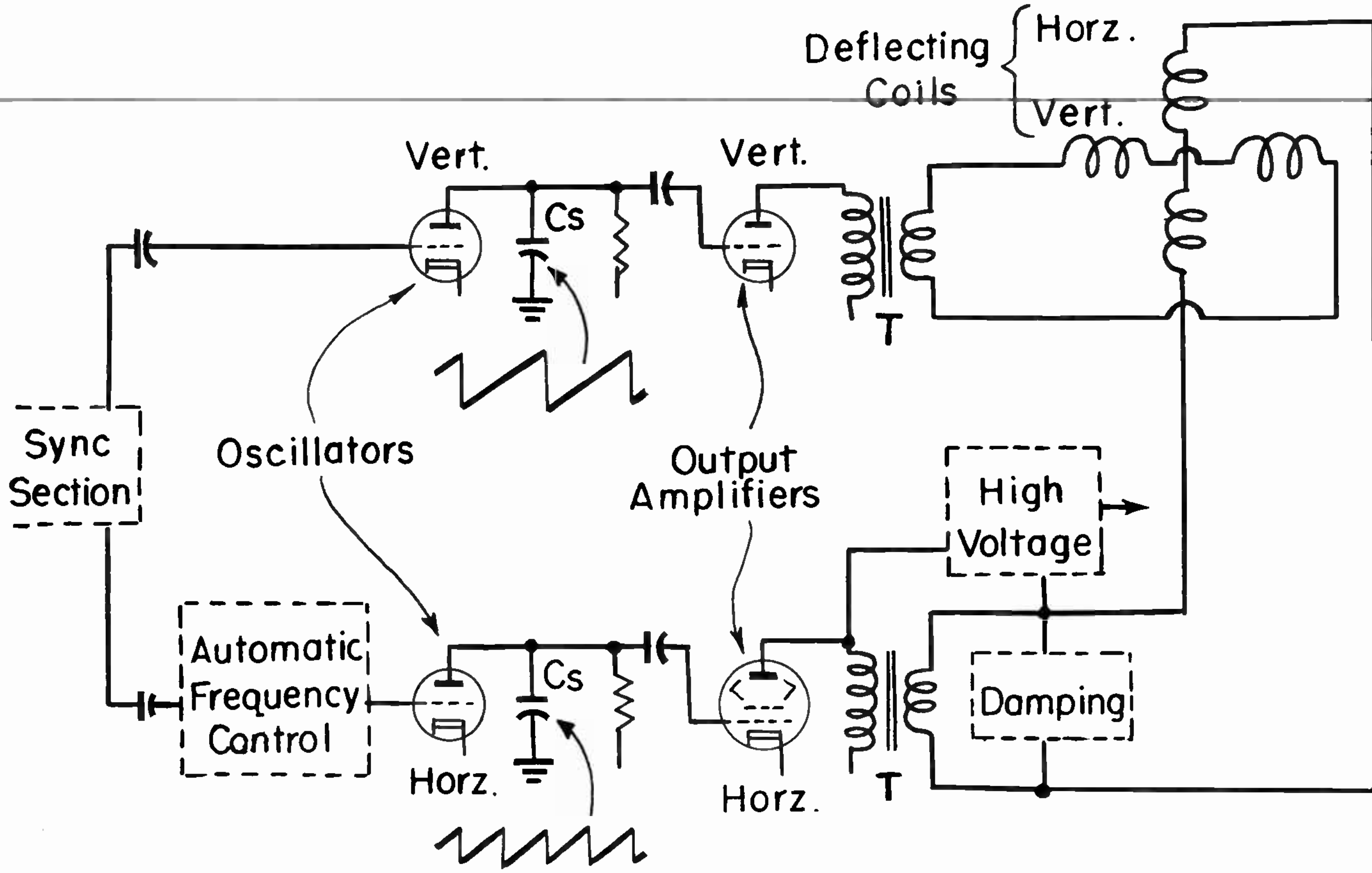

Fig. 2. Principal parts of vertical and horizontal sweep sections.

Charging and discharging of a sawtooth capacitor are controlled by the oscillator tube. The tube acts similarly to a switch connected as in Fig. 3. With the switch open (diagram A) capacitor Cs charges from the B-supply through resistor Rs, with electron flow in the direction of arrows. The rate of charge depends on the time constant of capacitance at Cs and resistance at Rs. Were the switch to remain open long enough, the capacitor would charge to the full voltage of the B-supply

In diagram B the switch is closed. Now there is practically instantaneous discharge of the capacitor through the switch, with electron flow as shown by arrows. If the switch were opened immediately after each discharge there would be recharging of capacitor Cs as in diagram A. Opening and closing the switch at suitable times would allow charging and discharging of the capacitor, and voltage across the capacitor would vary in sawtooth waveform.

A tube will act like an open switch while the grid is so negative as to cause plate current cutoff. The tube will act like a closed switch when the grid is made positive, which allows conduction from cathode to plate. What we need is a circuit which causes the grid of a tube to go strongly negative at the instant when the "switch" should open to allow charging of the sawtooth capacitor.

Then the grid of the tube must be held at or beyond the negative voltage for plate current cutoff during the period required for completion of capacitor charge. This will be the period of a vertical field or of a horizontal line. Finally, the grid must go positive at the instant when the tube is to become conductive, when the "switch" is to close and allow the capacitor to discharge. This will be the instant at which a vertical or horizontal retrace begins.

There are two principal types of sweep oscillator circuits which will cause a tube to become alternately conductive and nonconductive in the manner required for pro-

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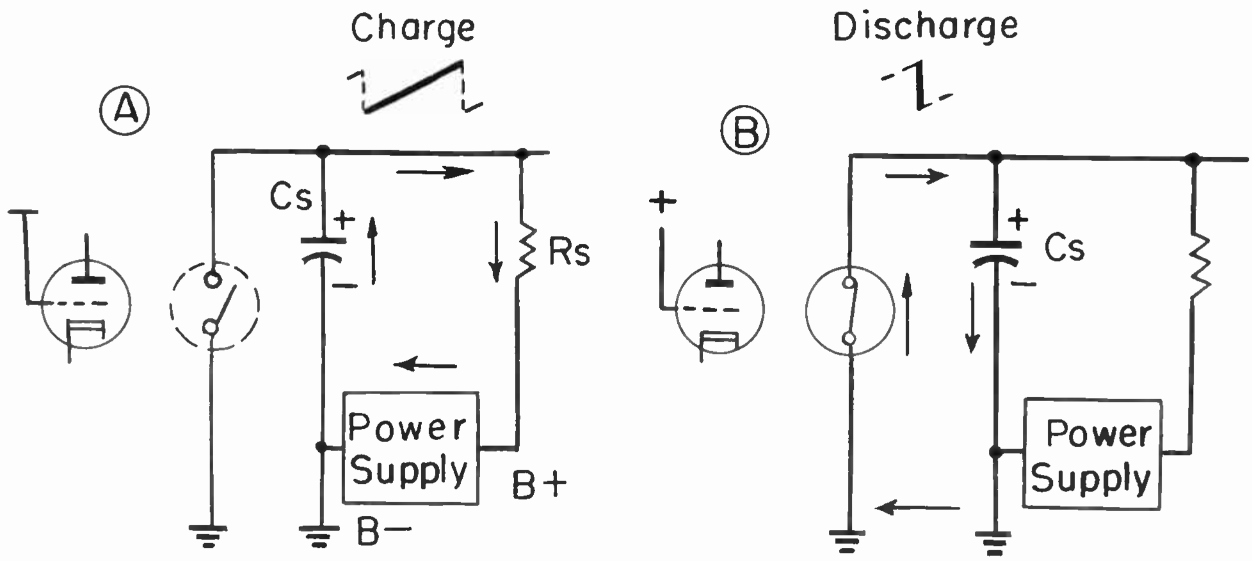

Fig. 3. Charge and discharge of sawtooth capacitors are controlled by oscillator tubes acting like switches.

ducing a sawtooth voltage. One circuit is called a blocking oscillator, the other is called a multivibrator. Either kind may be used in vertical sweep sections, and either may be used in horizontal sweeps. We shall look first at the blocking oscillator.

BLOCKING OSCILLATORS. Fig. 4 is a blocking oscillator circuit such as used in many vertical sweep sections. The name blocking refers to the action by which the grid is held so negative as to maintain plate current cutoff while capacitor Cs is charging. Any tube held non-conductive by a highly negative grid and resulting cutoff of plate current is said to be blocked.

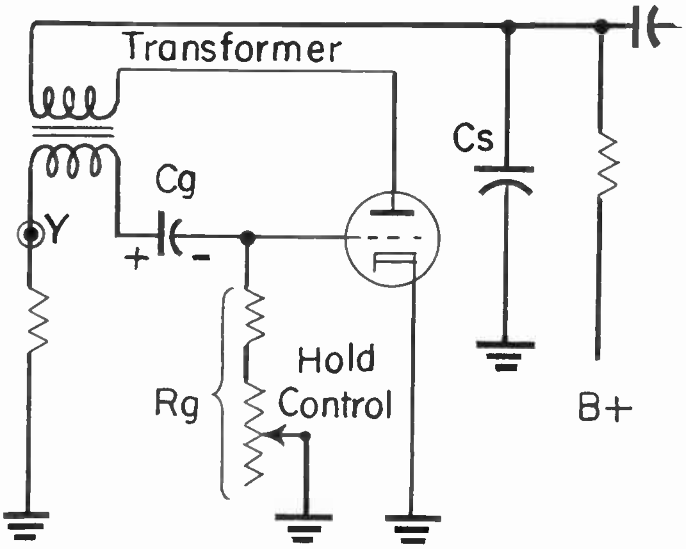

Fig. 4. The circuit of a blocking oscillator.

Blocking or plate current cutoff results from capacitor Cg and resistor Rg acting in much the same way as for grid-leak biasing. A strong positive pulse applied to capacitor Cg charges this capacitor in the marked polarity, with the highly negative charge voltage toward the grid. This cuts off the plate current and makes the tube non-conductive, like an open switch. Cutoff continues while capacitor Cg discharges slowly through resistors at Rg until grid voltage returns to a value which allows resumption of plate current.

How long the tube remains blocked depends on the time constant of capacitor Cg and resistor Rg. The longer this time constant, the longer the blocking continues. The time constant may be varied by adjustment of part of the resistance Rg. The adjustable resistor is called the hold control.

So long as the tube remains blocked and non-conductive there is charging of sawtooth capacitor Cs. When blocking ends and the grid becomes positive there is discharge of Cs through the tube. Now, since adjustment of hold control resistance varies the time during which the oscillator tube remains conductive, this adjustment varies also the time during which the sawtooth capacitor continues to charge, and varies the time between discharges of the sawtooth capacitor.

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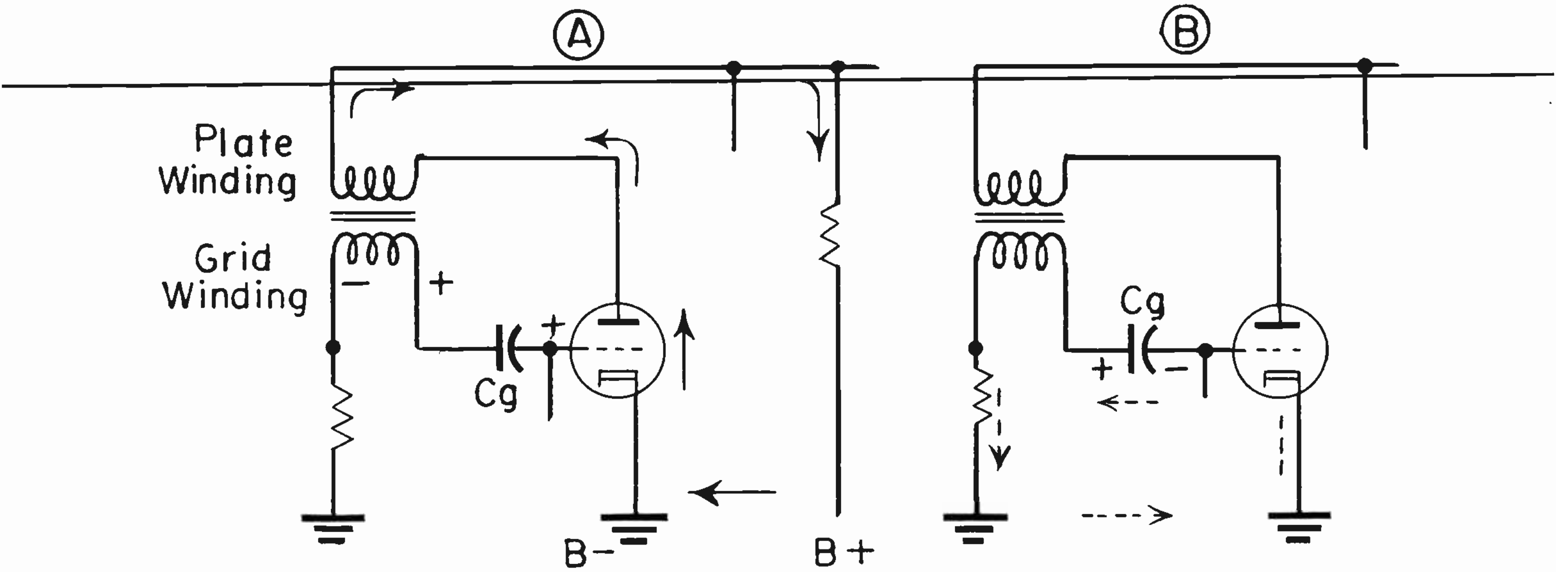

Fig. 5. Current in the plate circuit induces emf and current in the grid circuit.

The time from one discharge to the next discharge of the sawtooth capacitor is the time of one sawtooth voltage cycle. The time per cycle and the frequency of sawtooth voltage is varied by adjustment of the hold control.

Note that we have not yet made use of sync voltages from the sync section of the receiver. So far as production of sawtooth voltage is concerned we need no sync voltages. Any sweep oscillator will go through its cycles whether or not sync pulses are present. Now let's see what happens to voltage at the grid of the blocking oscillator to cause one cycle of sawtooth voltage in the plate circuit.

1. When the receiver is turned on, and B-voltage thus applied, plate current commences to flow and increases in the oscillator tube and its plate circuit. This plate current follows the patch marked with full-line arrows in diagram A of Fig. 5.

2. The increasing current flows in the plate winding of the feedback transformer. This change of current in the plate winding induces an emf in the grid winding.

3. The grid winding is connected into the grid-cathode circuit of the tube in such direction that the induced emf is positive at the winding terminal connected through capacitor Cg to the grid of the tube.

4. The positive potential passes through capacitor Cg just as through a blocking capacitor. The grid is made positive and the tube becomes conductive, but only for an instant.

5. The emf induced in the grid winding causes immediate flow of current in the grid-cathode circuit as shown by broken-line arrows in diagram B of Fig. 5. This current charges capacitor Cg in the marked polarity, and the grid becomes negative.

6. The negative grid reduces plate current. This decrease of plate current is a change in a direction opposite to that formerly causing the grid to go momentarily positive, and emf now induced in the grid winding makes the grid negative to a degree even greater than caused by the initial negative charge on capacitor Cg. The grid is driven negative far beyond the voltage for plate current cutoff, and is held there by the negative charge on capacitor Cg.

7. The charge on capacitor Cg can escape only through resistors at Rg, with discharge current following the path of broken-line arrows on diagram A of Fig. 6. This is the period of plate current cutoff, with the tube non-conductive.

8. While the tube is held non-conductive, sawtooth capacitor Cs is charged by current

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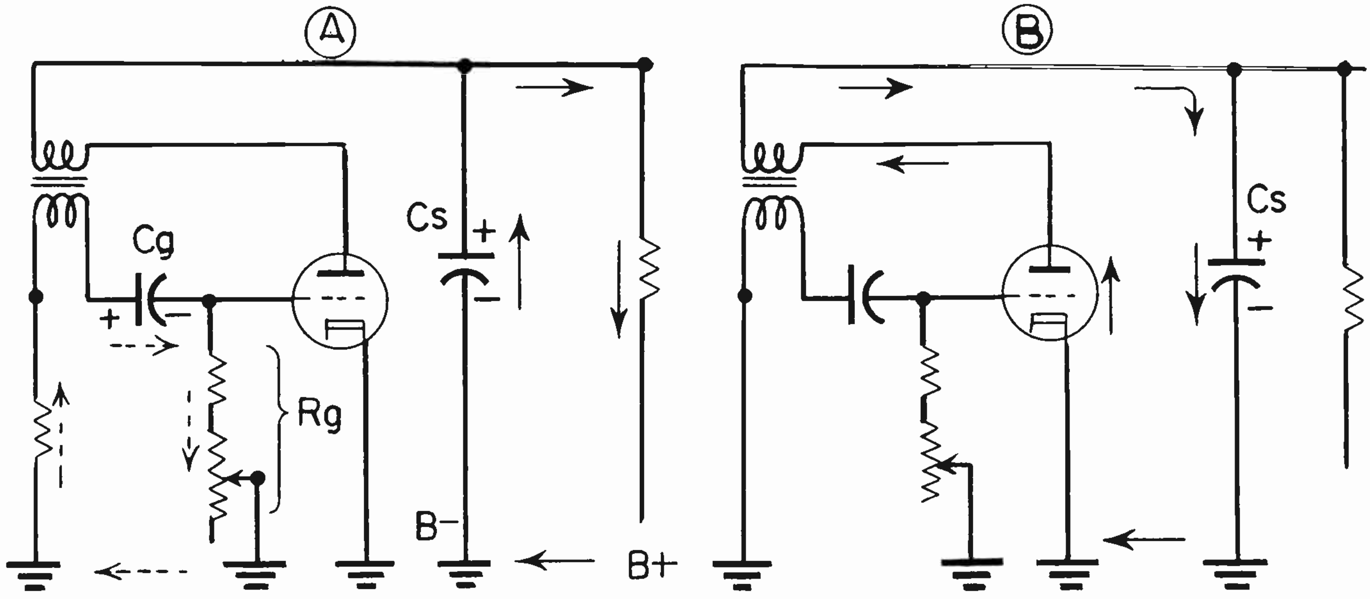

Fig. 6. The grid capacitor discharges while the sawtooth capacitor charges, then comes discharge of the sawtooth capacitor.

flowing in the path marked by full-line arrows in diagram A. Note that charge voltage at the top of capacitor Cs is positive. This positive voltage acts through the plate winding of the transformer on the plate of the tube. The top of capacitor Cs and the plate of the tube are at the same potential, because of the conductive connection between them.

9. While the grid of the tube becomes less negative due to discharge of capacitor Cg through resistors at Rg, the plate is becoming more positive due to charging of capacitor Cs. Eventually the plate of the tube becomes sufficiently positive that, with lessened negative voltage at the grid, there is conduction.

10. The instant the tube becomes conductive there is discharge of sawtooth capacitor Cs, with discharge current following the path of full-line arrows in diagram B of Fig. 6. Discharge current flows through the plate winding of the feedback transformer in the same direction as at A of Fig. 5. This induces in the grid winding an emf which is positive toward the grid. The positive grid potential makes the tube conductive and permits complete discharge of the sawtooth capacitor.

This completes one cycle in production of sawtooth voltage. The cycle has ended with the oscillator grid positive, which is the condition for commencing another cycle. This whole performance repeats over and over so long as power is applied.

Now we shall check the action of a blocking oscillator by observing voltages at the grid and the plate by means of an oscilloscope. The traces of Fig. 7 were taken at the grids of blocking oscillators in the sweep sections of three different sets. Although there are minor variations of waveform, they are generally similar and all indicate satisfactory operation.

Each sweep cycle in the traces of Fig. 7 commences with a small upwardly extending pip of voltage. This is the mometary positive voltage that charges the grid capacitor. The brief positive voltage is followed instantly by a long drop, which shows how the grid goes far negative to cut off plate current.

As the charge of the grid capacitor leaks away, the grid becomes less negative. This is shown by the trace rising rapidly at first, then more and more gradually as the rate of capacitor discharge slows down with lessening of negative grid voltage. The long curving rise of grid voltage ends at another positive voltage pip that starts another cycle.

The trace of Fig. 8 shows changes of current, not voltage, at the plate of a blocking

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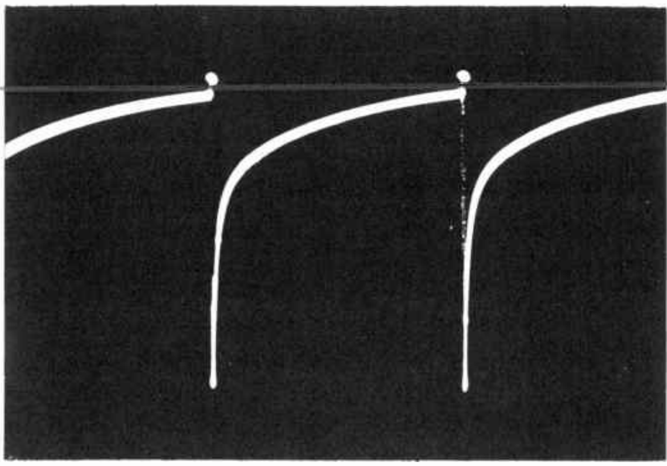

Fig. 7-A

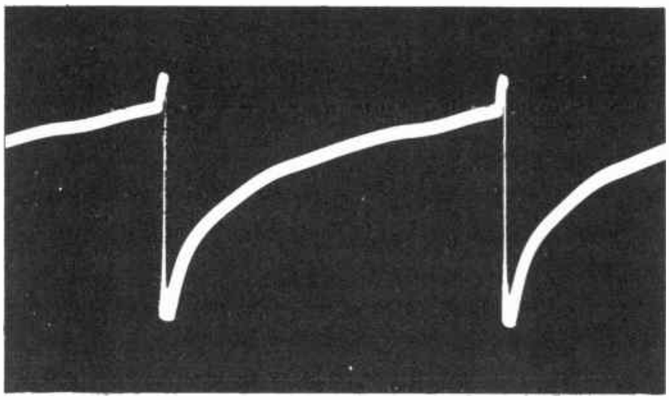

Fig. 7-B

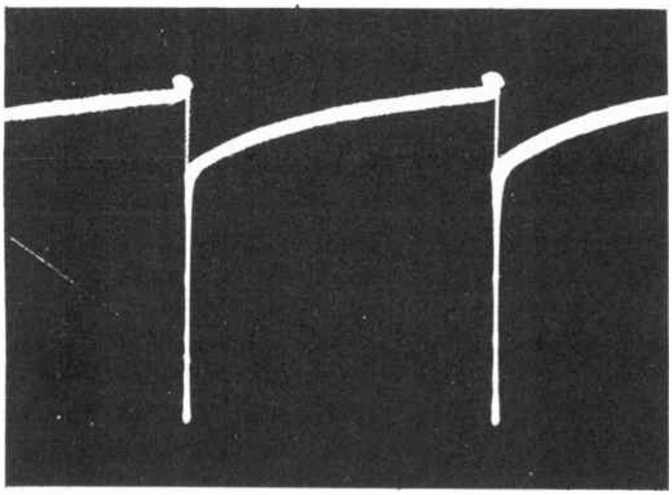

Fig. 7-C

Fig. 7. The oscillator grid goes positive, then strongly negative, followed by discharge of the grid capacitor.

oscillator. Every time the oscillator grid goes briefly positive there is a high but equally brief pulse of plate current. This, of course, is discharge current flowing from the sawtooth capacitor through the tube. The plate current is cut off almost instantly as the grid is driven negative. Cutoff continues until another strong pulse of current at the beginning of a following cycle.

We know that each pulse of plate current must cause an accompanying decrease of plate voltage, because more current means more voltage drop in plate circuit resistance, and less voltage remains at the plate itself. Then every current pulse of Fig. 8 must be accompanied by a negative spike of plate voltage as shown at A of Fig. 9. You realize, naturally, that in speaking of plate voltage as being sometimes negative and again positive we are talking about the alternating component of voltage in the plate circuit. D-c plate voltage from the B-supply always remains positive.

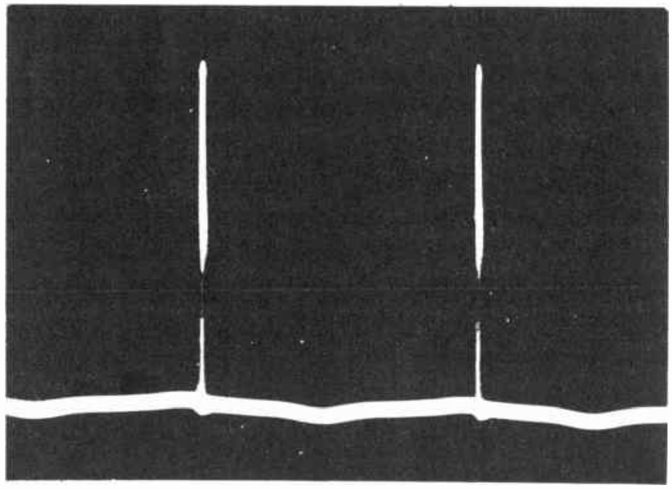

Fig. 8. Oscillator plate current flows in momentary pulses.

While plate voltage is changing as at A of Fig. 9, voltage of the sawtooth capacitor is changing as at B. The capacitor is discharging every time there is a negative spike of plate voltage, because each negative spike results from a pulse of discharge current. The capacitor is charging between discharges.

The oscilloscope cannot see separately the voltages at A and B because the sawtooth capacitor and plate of the oscillator tube are conductively connected together, and voltage at one must appear also at the other. What the oscilloscope sees is the combination of plate and capacitor voltages as shown at C and D. These are plate voltage traces from two different receivers.

The scope shows everything that happens in the grid and plate circuits of the blocking

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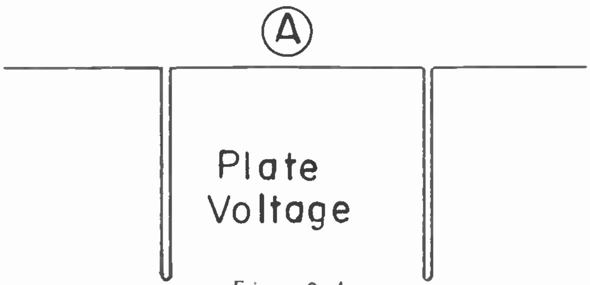

Fig. 9-A

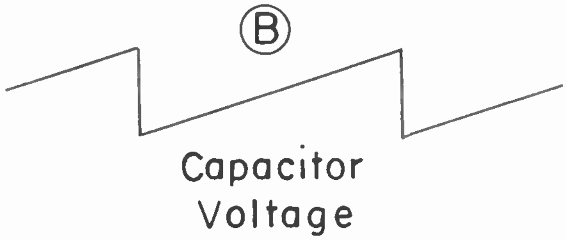

Fig. 9-B

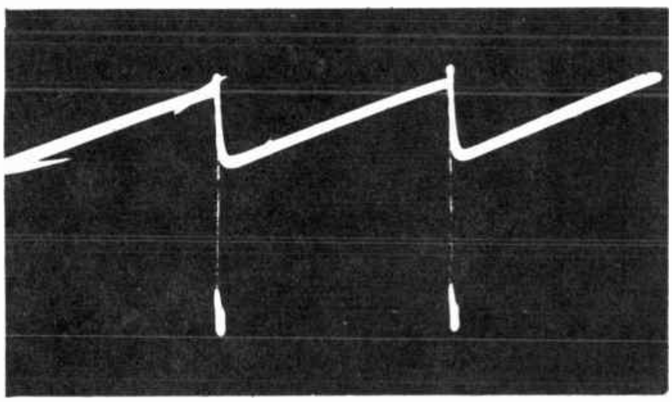

Fig. 9-C

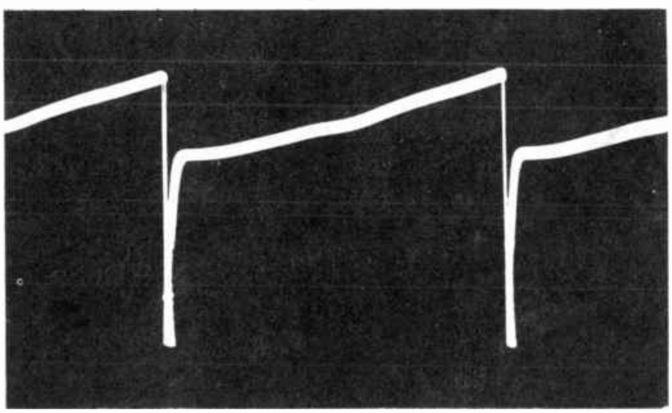

Fig. 9-D

Fig. 9. Voltages at the oscillator plate and at the sawtooth capacitor.

oscillator, just as these events were explained in connection with Figs. 5 and 6. Should anything interfere with correct action of the oscillator you should be able to identify the probable causes by watching traces of grid and plate voltages. Such ability to recognize faults depends on your understanding of how the circuits should behave during normal operation.

DISCHARGE TUBES. Discharge current from the sawtooth capacitor in a blocking oscillator circuit flows through the plate winding of the feedback transformer. Inductance and counter-emf in this winding tend to slow the rate of capacitor discharge and thus to increase the time for retrace. This effect is not particularly objectionable or even noticeable in vertical sweep circuits, where operating frequency is only 60 cycles per second.

When blocking oscillators are used in horizontal sweep circuits the feedback transformers are of special types having short inductance-resistance time constants. Some of these will be seen while studying automatic frequency controls for horizontal oscillators. Another method, not often used in sets of recent design, employs a discharge tube in connection with the blocking oscillator, usually in the form of a twin triode serving both functions.

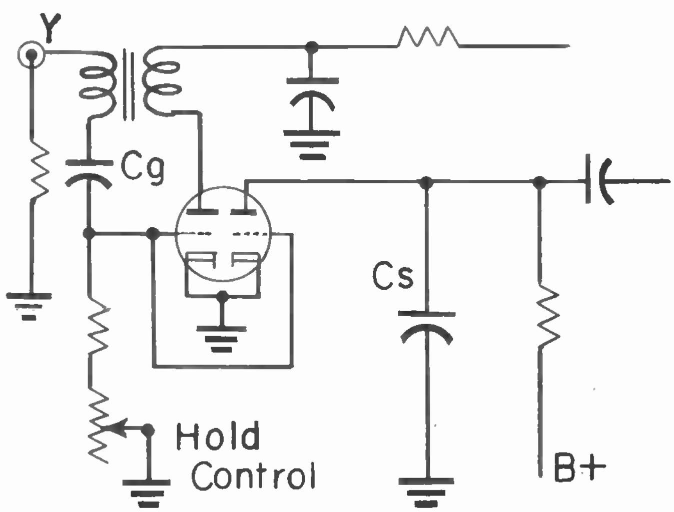

Fig. 10. A discharge tube or section of a tube connected to a blocking oscillator.

Connections for a discharge tube are shown by Fig. 10. The two grids are connected together and so are the two cathodes. Therefore, the oscillator and discharge tube have the same grid-cathode circuits, and every change of grid voltage at the oscillator must appear also at the grid of the discharge tube. Sawtooth capacitor Cs charges while

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oscillator action holds the discharge tube non-conductive. This capacitor discharges when oscillator action makes the discharge grid positive. Discharge current flows only through the discharge tube, not through the feedback transformer and plate circuit of the oscillator.

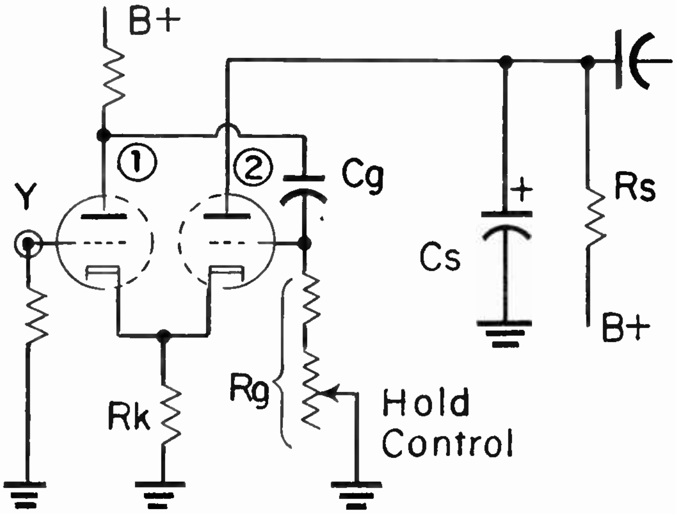

Fig. 11. The circuit of a cathode-coupled multivibrator oscillator.

MULTIVIBRATOR OSCILLATORS. The most widely used multivibrator circuit is that in which two triodes or two sections of a twin triode are coupled by voltages appearing in a cathode resistor which is common to both triodes. This is the cathode-coupled multivibrator whose circuit is shown by Fig. 11 and whose action is explained in the lesson on "Service Oscilloscopes". We may review the action briefly as follows.

1. When power is turned on there is increase of plate current in triode 1 and in cathode resistor Rk. Voltage across Rk biases both grids negatively. There is plate current cutoff in triode 2 because this triode is operated at low plate voltage.

2. While triode 2 is cut off, capacitor Cs is charged by electron flow through resistor Rs. Charging makes potential more positive at the top of Cs and at the plate of triode 2. This increase of positive plate potential overcomes cutoff which has been due to negative grid voltage, and makes triode 2 conductive.

3. Capacitor Cs now discharges through triode 2 and resistor Rk. Discharge current flowing in Rk causes voltage drop which drives both grids sufficiently negative for plate current cutoff in both triodes.

4. Sudden cutoff of current in triode 1 allows its plate voltage to become more positive. The pulse of positive voltage charges capacitor Cg, just as with grid-leak biasing, and the grid of triode 2 becomes so negative as to cause cutoff. The grid is held negative by slow discharge of capacitor Cg through resistance at Rg.

5. While triode 2 is held at cutoff, sawtooth capacitor Cs recharges as in step 2 above. This makes the plate of triode 2 more positive at the same time that its grid is becoming less negative. This allows conduction, capacitor Cs discharges, and the whole performance repeats over and over.

Lengths of charging periods for the sawtooth capacitor, intervals between discharges, and the corresponding frequency of sawtooth cycles depend on the time constant of Cg and Rg. This time constant, and the sawtooth frequency, are varied by adjustment of the hold control resistor.

Oscilloscope traces of Fig. 12 show how a cathode-coupled multivibrator goes through its cycles. At A are voltage pulses across cathode resistor Rk. Since Rk is pure resistance, changes of cathode current would be the same as these voltage changes. The trace at B, of voltage at the plate of triode 1, shows the sharp positive pulses which are caused by cutoff. It is sudden decreases of plate current that cause these sharp rises of plate voltage.

The trace at C shows voltage at the grid of triode 2. Here we see this grid going far negative, returning quickly most of the way toward positive, then continuing slowly along the curve which shows discharge of capacitor Cg through resistance of Rg and the hold control. This discharge ends as the grid goes momentarily positive just before another negative dip.

Trace D of Fig. 12 shows voltage at the plate of triode 2 and the top of sawtooth capacitor Cs, which are conductively connected together. Here we see negative dips

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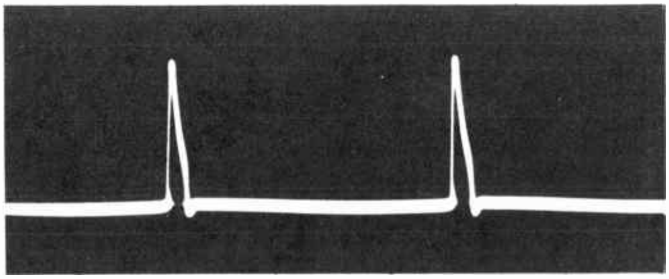

Fig. 12-A

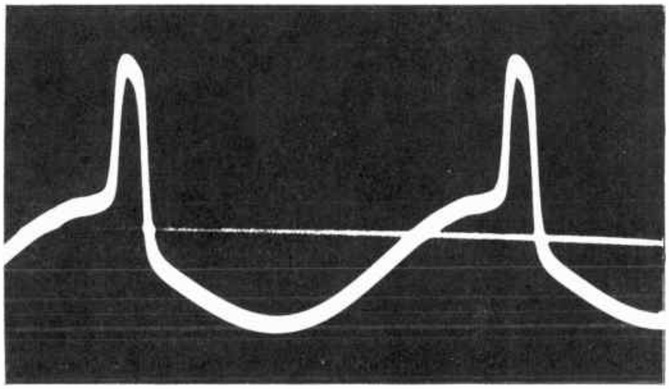

Fig. 12-B

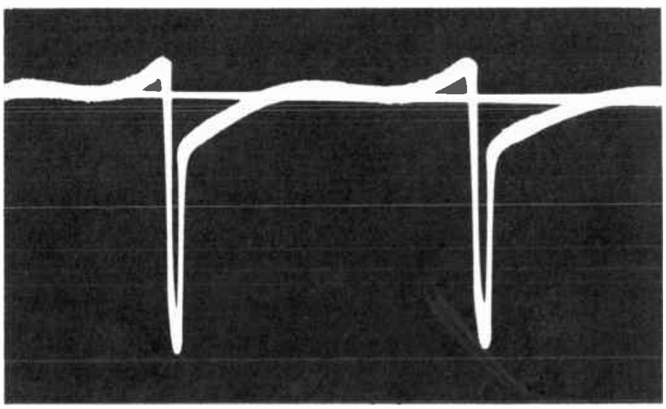

Fig. 12-C

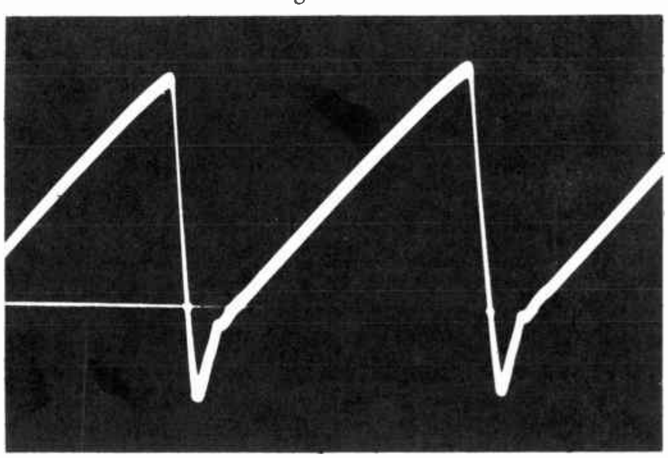

Fig. 12-D

Fig. 12. How the oscilloscope shows performance of the cathode-coupled multivibrator.

due to sudden discharge of the sawtooth capacitor, followed by upward slopes during the following period of recharge. This is the sawtooth voltage which we desire from the oscillator.

There are numerous modifications of the cathode-coupled multivibrator which are important from the design standpoint but do not greatly affect voltage traces shown by the scope during service work. As an example, the chief differences between the cathode-coupled multivibrators of Figs. 11 and 13 are that, in the latter figure, the hold control is connected to the cathodes instead of to ground, and cathode resistor Rk is bypassed with a capacitor.

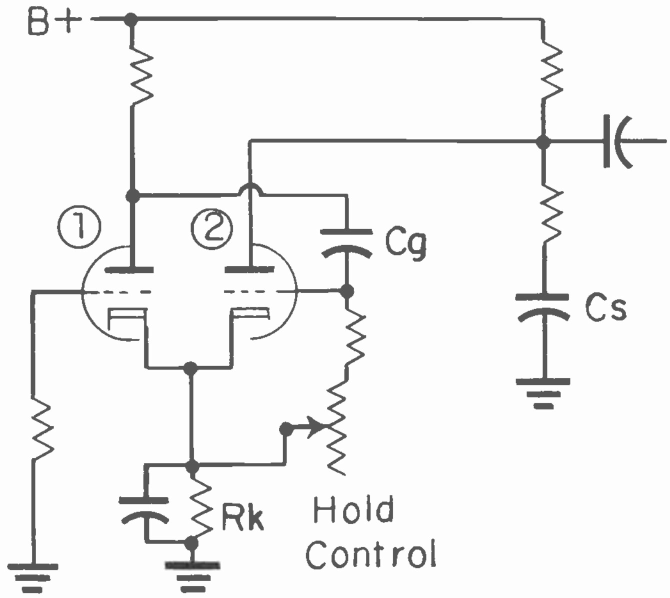

Fig. 13. One modification of the cathode-coupled multivibrator circuit.

Waveforms taken from the multivibrator of Fig. 13 are shown by Fig. 14. At A is a voltage pulse across the cathode resistor. At B is a positive pulse at the plate of triode 1. The trace at C is of voltage at the grid of triode 2. Here we have the familiar positive pips which charge the grid capacitor. These are followed by long negative dips, then by upward slopes as the grid capacitor discharges. Trace D shows voltage at the plate of triode 2 and at the top of sawtooth capacitor Cs. This is another familiar waveform, with negative dips of plate voltage followed by rising slopes caused by recharging of the sawtooth capacitor.

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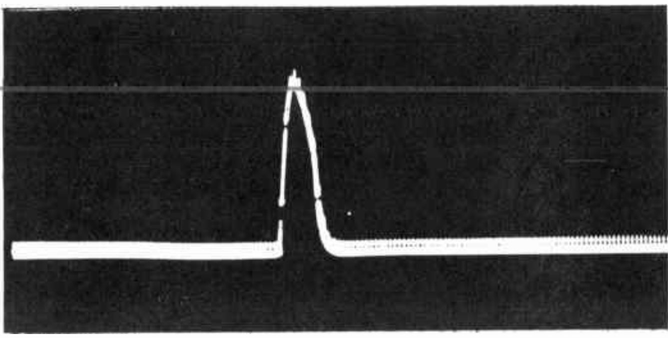

Fig. 14-A

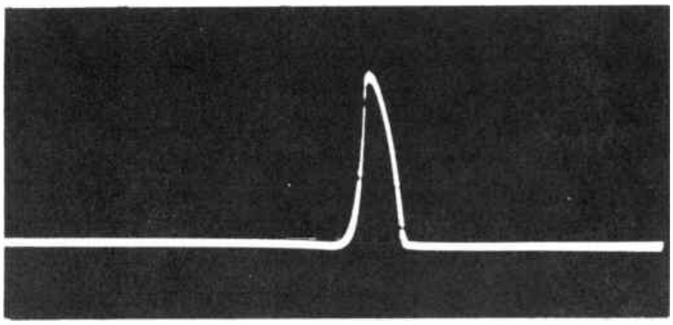

Fig. 14-B

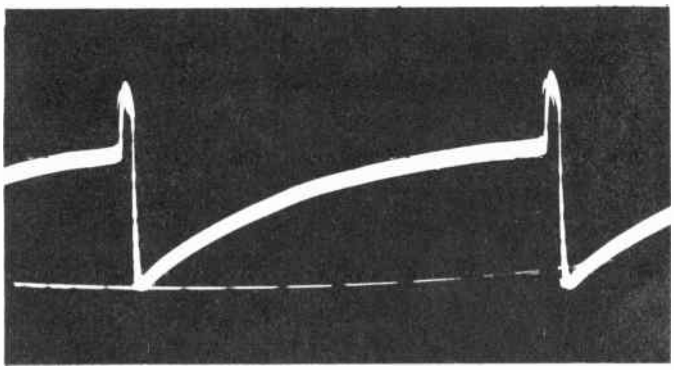

Fig. 14-C

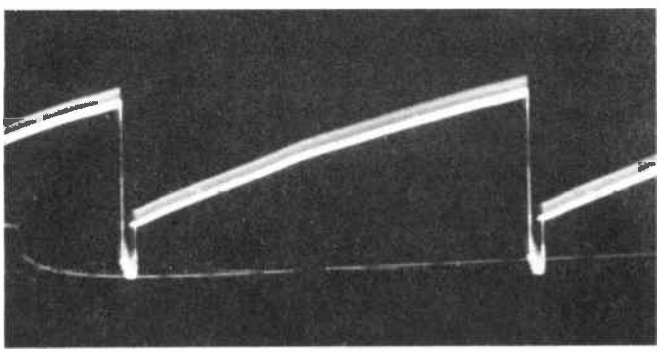

Fig. 14-D

Fig. 14. Circuit modifications do not greatly alter the waveforms at grids, plates, and cathodes of sweep oscillators.

In a number of multivibrator circuits coupling between the two sections is by means of capacitors rather than by a cathode resistor common to both. An example is illustrated by Fig. 15. The plate of triode 2 is connected to the primary of the output transformer, whose secondary feeds the deflecting coils. This triode acts as one section of the multivibrator and at the same time as a sweep output amplifier. It may be part of a twin triode or else a separate triode-connected beam power tube.

Capacitor-coupled multivibrators quite often are used in vertical sweep circuits, but are not so common as cathode-coupled types in horizontal sweeps. The action in Fig. 15 is as follows.

1. When power is turned on there is increase of plate current and drop of plate voltage at triode 2.

2. The drop of plate voltage acts through capacitor Cg on the grid of triode 1 to make that grid more negative.

3. The negative grid reduces plate current and allows plate voltage to become more positive at triode 1.

4. This positive-going plate voltage acts through capacitor Cc on the grid of triode 2, making that grid more positive and thus increasing plate current in triode 2. This brings us back to step 1 above, where there is increase of plate current in triode 2.

5. Voltages and currents continue to change in the polarities mentioned until there is plate current cutoff in triode 1. Current remains cut off while capacitor Cg discharges through the hold control resistances.

6. It is during this cutoff period that sawtooth capacitor Cs is charged from the B-supply. At the end of the cutoff period, triode 1 becomes conductive and capacitor Cs discharges through this triode.

Voltages at the plate of triode 1 and at the grid of triode 2 are shown by trace A of Fig. 16. This waveform shows sudden discharge and gradual recharge of the sawtooth capacitor. The trace at B shows resulting voltage at the plate of triode 2. Positive peaks of this plate voltage act through capacitor Cg to produce positive peaks at the grid of triode 1. These positive peaks show

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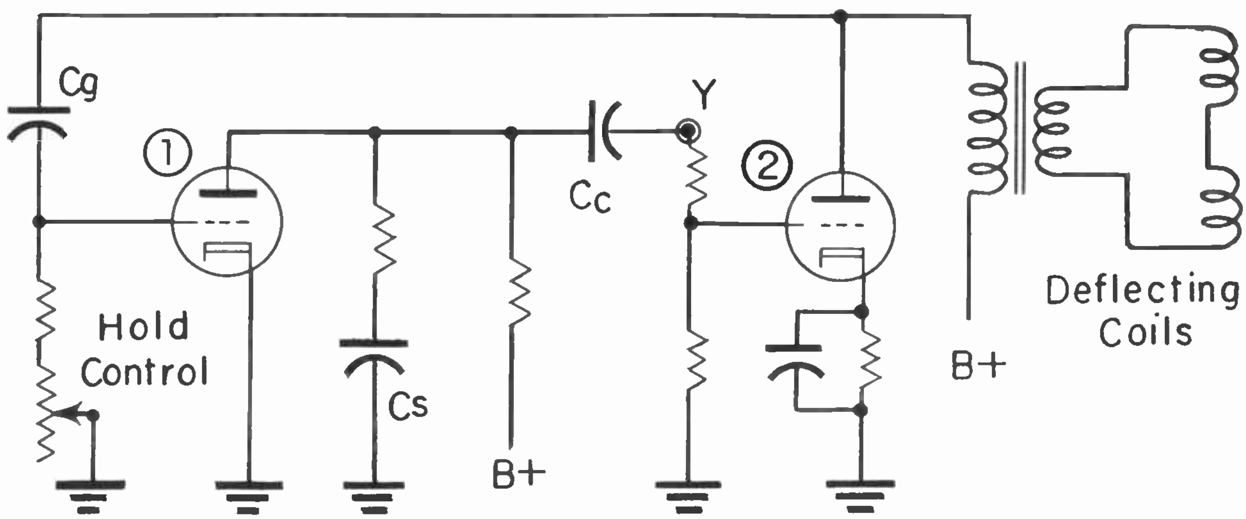

Fig. 15. A capacitor-coupled multivibrator in which one of the tube sections acts also as a vertical sweep amplifier.

clearly on the voltage trace at C, taken at the grid of triode 1. The curves which slope upward between peaks of this grid voltage show discharge of capacitor Cg during the time in which triode 1 remains cut off.

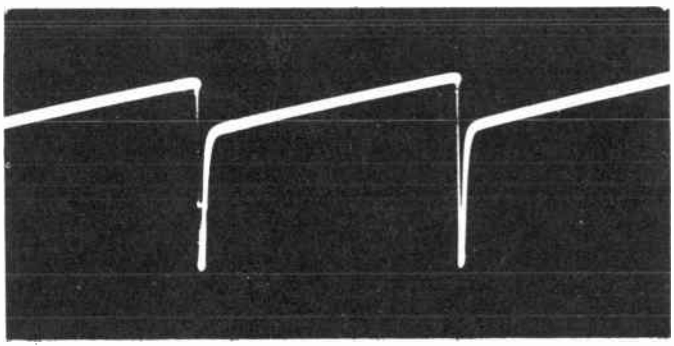

Fig. 16-A

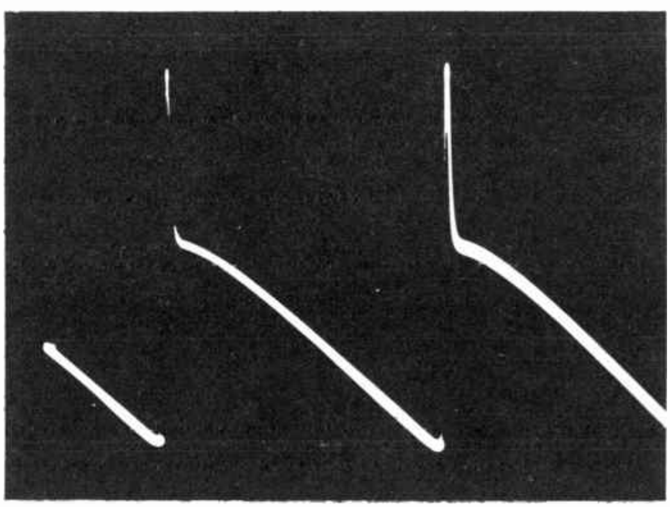

Fig. 16-B

Compare the waveforms of Fig. 16 with those of Figs. 7 to 9, also 12 and 14. At points which are essentially equivalent in the several sweep oscillator circuits we find waveforms which are decidedly similar. For instance, at grids connected to hold controls and grid capacitors all the waveforms show momentary positive peaks of grid voltage, followed by negative cutoff voltages, then relatively slow discharges of the grid capacitors.

Note also that sawtooth voltages always appear first in circuits connected to sawtooth capacitors, and continue thereafter all the way to outputs. Although there are minor variations of waveforms from the various kinds of sweep oscillator circuits, the characteristics are so generally similar that you

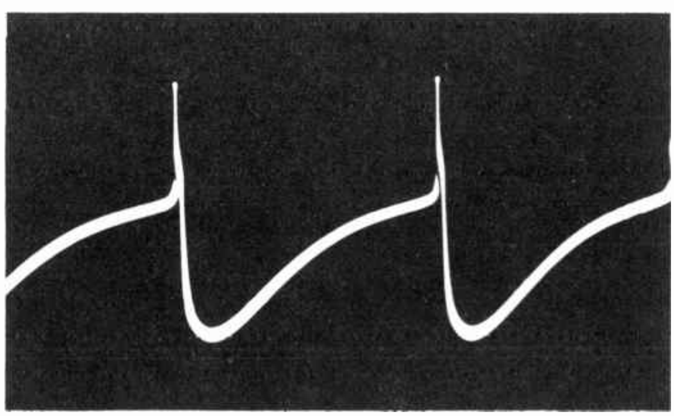

Fig. 16-C

Fig. 16. Voltage waveforms taken from the capacitor-coupled multivibrator.

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should have no difficulty in distinguishing between satisfactory and unsatisfactory performance.

It is of interest to know that the name multivibrator comes from the fact that these oscillators will "vibrate" or oscillate at many different frequencies. At least, this is true of the original multivibrators from which television types have been adapted. In those original r-f oscillators the fundamental frequency could be accurately controlled by synchronization with a source of standard frequency. Then the multivibrator would produce multiple harmonic frequencies of equal percentage accuracy.

FREE RUNNING FREQUENCIES. We have seen how all types of sweep oscillators operate at certain sawtooth frequencies, without any help from synchronizing voltages. These unsynchronized frequencies, determined only by capacitance-resistance time constants in grid circuits, are called free running frequencies. They are operating frequencies which are free from effects of sync voltages. It is because sweep oscillators are capable of operating at their free running frequencies that vertical and horizontal deflections of the electron beam continue in the absence of sync pulses and received signals.

The free running frequency of either a blocking oscillator or a multivibrator may be varied by changing the time constant of the grid capacitor and resistor. This time constant could be altered by varying the capacitance or the resistance. However, to provide sufficient range of adjustment it is simpler and less costly to use variable resistors rather than variable capacitors. Consequently, free running frequencies of sweep oscillators nearly always are varied by adjustable resistors - called hold controls.

We should not confuse free running frequencies with natural frequencies. Natural frequency of a blocking oscillator is the resonant frequency corresponding to inductance in the feedback transformer and other conductors, combined with capacitances in tubes, wiring, and other circuit elements. It is the frequency at which the blocking oscillator would operate were there no blocking action to hold grid voltage at plate current cutoff for fairly long periods. Incidentally, it is natural frequency of a blocking oscillator that determines retrace times.

The natural frequency of a multivibrator would be the resonant frequency of inductances and capacitances in tubes, conductors, and other circuit parts. Because multivibrator circuits lack the rather large inductances of feedback transformers, natural frequencies of multivibrators are far higher than those of blocking oscillators. Actually, the L-C resonant frequencies in multivibrator circuits ordinarily are so high that energy losses would prevent oscillation. Circuit capacitances and resistances may cause multivibrator oscillation at frequencies up to several hundred kilocycles.

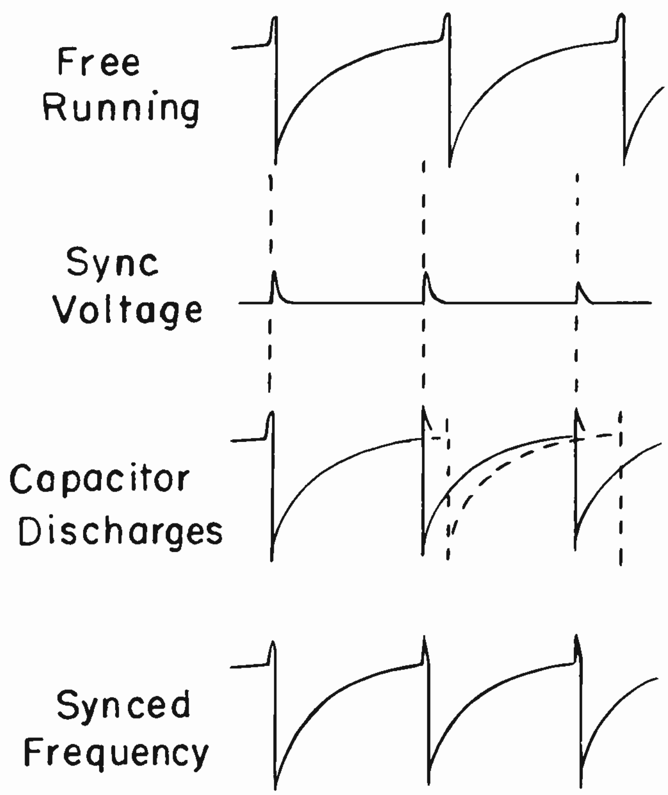

Fig. 17. How sync voltages trigger the oscillator and bring it into time with sync pulses and received signals.

SYNCHRONIZING THE SWEEP OSCILLATORS. What happens when pulses of synchronizing voltage are applied to any sweep oscillator is illustrated by Fig. 17. First of all, by means of hold control adjustment, the free-running frequency must be made just a little slower than that of sync pulses to be

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used. This free-running frequency is represented by the top curve, while sync voltage frequency is represented immediately below. Intervals between free-running pulses are longer than between sync pulses, therefore free-running frequency is lower or slower than sync frequency.

As you recognize, the curves of Fig. 17 are grid voltage curves or traces of sweep oscillators. The sawtooth capacitor would be discharged when these grid voltages go through their brief positive peaks at the free-running frequency. When pulses of positive sync voltage are applied to the oscillator grid they make the grid positive before it would become positive at the free-running frequency. This allows discharge of the sawtooth capacitor, and starts a new sweep cycle. This is the action called triggering of the oscillator by the sync pulses or sync voltages.

After each discharge of the sawtooth capacitor it immediately commences to recharge. But before recharging progresses as far as at the free-running frequency, another positive sync voltage causes another discharge, Consequently, intervals between discharges and periods of recharge now are controlled by intervals between sync pulses, and the oscillator sawtooth frequency must become the same as the sync frequency.

Fig. 18 illustrates some facts of importance in relation to synchronization of sweep oscillators.

a. If the hold control is adjusted to make free-running frequency only a little slower than sync frequency, synchronization can be maintained by pulses of moderate strength.

b. When sync pulses occur too far before the oscillator would break down at the free-running frequency there will be no synchronization. This is because the sync pulse voltage combines itself with voltage of the grid capacitor, and if voltage of this capacitor is too far negative at the instant of a sync pulse, the positive pulse cannot overcome the negative capacitor voltage. This difficulty would result from an excessively long free-running frequency, caused by misadjustment or by defects in grid capacitors or resistors.

c. Stronger sync pulse voltages from the sync section of the receiver can force the oscillator into synchronization even though free-running frequency is excessively long.

d. Weak sync pulses cannot possibly trigger the oscillator, because they cannot make grid voltage sufficiently positive to allow capacitor discharge. This would indicate faults in the sync section or anywhere ahead of that section.

e. Noise pulses, when sufficiently strong and of positive polarity, can take over the triggering of sweep oscillators and cause momentary sweep frequencies which are independent of both free-running and sync pulse effects.

f. Negative pulses, whether due to sync voltages or to noise, cannot trigger the sweep oscillator. Negative pulses simply make the grid still more negative, and can have no effect on allowing discharge of the sawtooth capacitor.

In Fig. 18 it is assumed that sync voltages are applied to the grid circuit of the

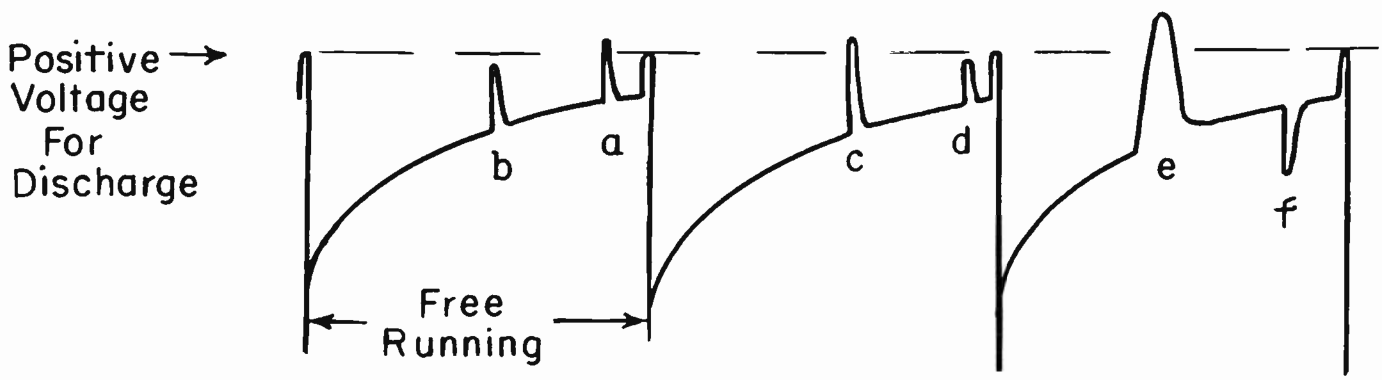

Fig. 18. Some voltage pulses can trigger the sweep oscillator, other pulses cannot.

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tube in whose plate circuit is the sawtooth capacitor. Since the grid of this tube must go positive in order to allow discharge of the sawtooth capacitor, the sync voltages must be of positive polarity. Positive sync voltages must be applied to blocking oscillators at points marked Y on Figs. 4 and 10.

In Fig. 11 the sync voltage pulses are applied at Y to the grid of triode 1. The sawtooth capacitor Cs is not in the plate circuit of triode 1, but is in the plate circuit of triode 2. Then the grid of triode 2 must be driven positive at the instant of each sync pulse. Because there is inversion between the grid of triode 1 and the grid of triode 2, sync pulses applied to the grid of 1 at point Y must be negative in order to produce correctly timed positive voltage pips at the grid of triode 2.

Sync pulses for the multivibrator of Fig. 15 are applied, at point Y, to the grid of triode 2. Since the sawtooth capacitor is in the plate circuit of triode 1, and there is inversion between the two triodes, sync voltages must be negative at point Y in order that they may be positive at the grid of triode 1.

HOLD CONTROL ADJUSTMENT. In nearly all receivers there are adjustable hold control resistors for vertical and horizontal sweep oscillators. The two adjustments often are provided by a dual potentiometer with two concentric knobs on the double shaft. The two controls may be on the front panel, readily accessible to the operator, or they may be concealed by a small cover or removable panel. In some receivers the hold controls are service adjustments located at the rear or on top of the chassis.

There are receivers having an adjustable hold control for the vertical sweep, but none for the horizontal sweep. This occurs when designers feel that automatic control for horizontal sweep frequency is sufficiently effective to bring this frequency into time with horizontal sync pulses under all operating conditions.

The adjustments which we have called hold controls, and which are similarly named in the great majority of receivers, sometimes go by the names of sync controls, phasing controls, speed controls, or frequency controls.

When a vertical hold control is out of adjustment, pictures move slowly or rapidly either upward or downward on the screen, and are steadied by turning the control one way or the other. Vertical sweep frequency much too low may cause pictures to divide as in Fig. 19, with a vertical blanking interval between the bottom of a picture which is at the top of the screen and the top of the picture, which is at the bottom. Vertical sweep frequency much too high may, as in Fig. 20, cause one part of a picture to appear superimposed over another part.

Fig. 19. One result of vertical sweep frequency which is too low.

Fig. 20. Excessively high vertical sweep frequency may cause this effect.

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Fig. 21. The picture tube screen appears this way just before there is horizontal synchronization or lockin.

The usual effect of a misadjusted horizontal hold control is illustrated by Fig. 21. A greater or less number of dark bars slope downward to the right, as in the picture, or downward to the left. The direction of slope depends on whether the control is set for free-running frequency too high or too low. The bars actually are horizontal blanking intervals, and in the spaces between are nearly complete pictures or patterns. As adjustment is corrected, the bars become fewer and more nearly upright until, when synchronization occurs, the bars disappear and the complete picture becomes steady on the screen. If horizontal frequency is very far out with reference to sync frequency, there may be the effect illustrated by Fig. 22.

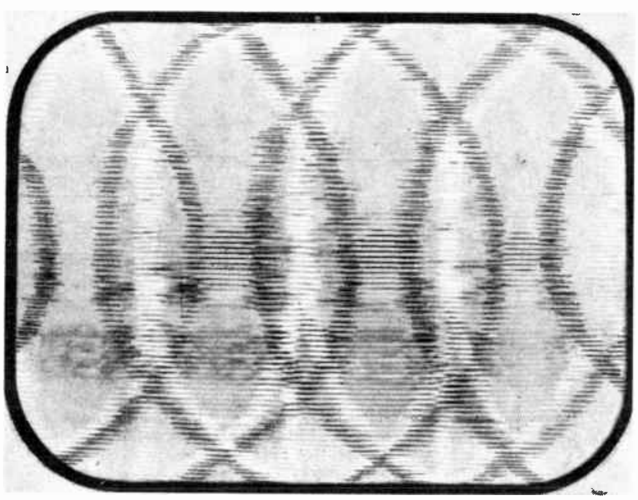

Fig. 22. This may result from faults in the horizontal hold control circuit.

Adjustment of hold controls should be required, at least in theory, only when circuits constants change due to aging of tubes and to gradual variations of value in resistors and capacitors. When the sync signal takeoff is at a point beyond the contrast control, strength of sync pulses may vary with contrast settings. The hold controls then may need readjustment when contrast is intentionally made low. Adjustments may be made as follows for controls which are operators' adjustments or service adjustments.

1. Adjust for a steady picture on any channel.

2. Rotate the control adjustment counterclockwise to a point where the picture just drops out of synchronization, then back in a clockwise direction until the picture just pulls into sync. Note the position of the control knob at which this pull-in occurs.

3. Rotate the adjustment clockwise for drop-out, then back just enough to secure pull-in. Note the position of the knob at which this second pull-in occurs.

4. Leave the adjustment set midway between the two pull-in positions.

5. If the picture drops out when the control is rotated one way, but not the other way, leave the adjustment turned in the direction where there is no drop-out.

6. Turn the power switch off and then back on. If there is not prompt pull-in, try altering the control setting or repeat the previous steps, and try again.

7. Change to other channels and back again. Pictures should pull into sync with no delay on any channel. Otherwise try to identify the channel for which sync action seems to be weakest or slowest and repeat steps 2, 3, and 4 while tuned to that channel.

If a vertical hold cannot be adjusted for prompt lock-in on all channels, trouble probably exists in the vertical oscillator circuits or possibly in the sync section. If the horizontal hold cannot be adjusted satis-

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factorily, the fault may be in the horizontal sweep oscillator or possibly in the sync section, but more probably is in the automatic control system for horizontal sweep frequency.

Should it be impossible to make satisfactory adjustment of both vertical and horizontal sweep at the same time, it is unlikely that faults exist in both sweep oscillators. Look for trouble in the sync section. If pictures are rather weak when they do hold, check for weakness in the video signal ahead of the sync takeoff. Persistent difficulty in holding either vertical or horizontal sync often is due to defects of grid capacitors on the sweep oscillator to which is connected the hold control. The slightest leakage in this capacitor will upset the sync action.

VERTICAL SWEEP AMPLIFIERS. In Fig. 2 the vertical and horizontal sweep sections include output amplifiers as well as oscillators. Separate output or sweep amplifiers are used after blocking oscillators, cathode-coupled multivibrators, and many capacitor-coupled multivibrators. In Fig. 15 we looked at one capacitor-coupled multivibrator in which a single tube or section of a tube acts as part of the oscillator system and at the same time as an output amplifier.

Beam power tubes, power pentodes, and triodes of both medium and heavy duty types

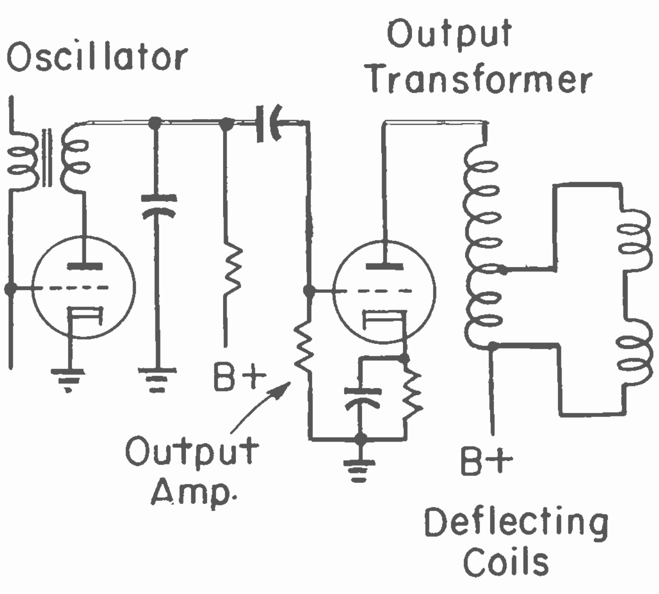

Fig. 23. An auto-transformer for coupling to vertical deflecting coils.

are used as vertical output amplifiers. The triodes may be twin types or else single heavy-duty power types.

As in Fig. 23, the coupling between any type of vertical output amplifier and the vertical deflecting coils often is an auto-transformer which provides the necessary step-down ratio of primary to secondary voltages and step-up ratio of currents. In other cases the transformer may be the more familiar style having primary and secondary insulated from each other.

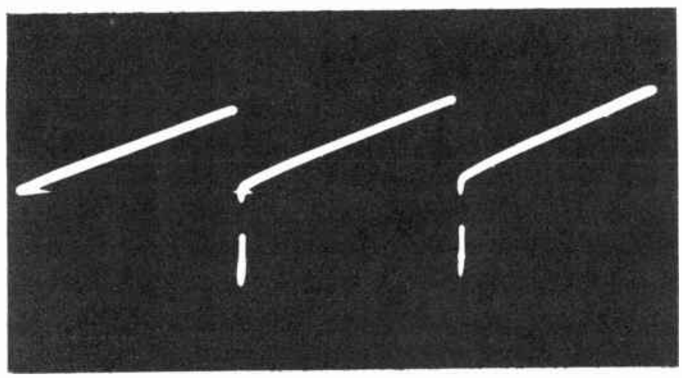

Fig. 24-A

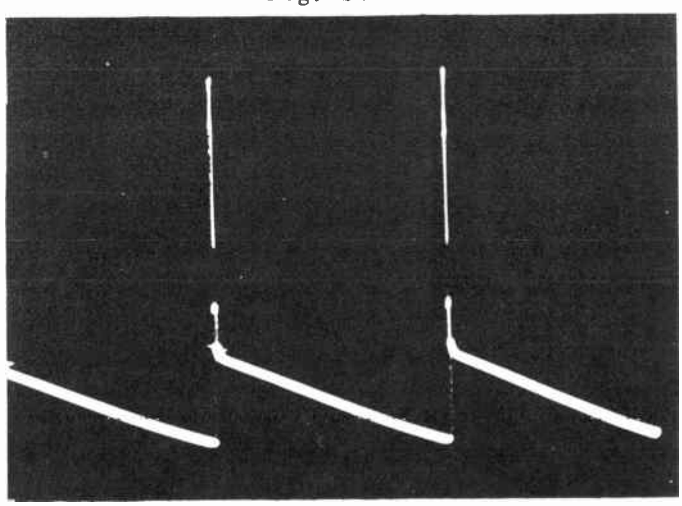

Fig. 24-B

Fig. 24. Voltages at grid and plate of a vertical output amplifier.

At A of Fig. 24 is a voltage waveform applied from a sweep oscillator to the grid of a vertical output amplifier. At B is the voltage trace at the plate of the same amplifier. Of course, this latter trace shows also the voltage across the primary of the vertical output transformer. Fig. 25 shows voltage waveforms across vertical deflecting coils in two different receivers. Waveforms of

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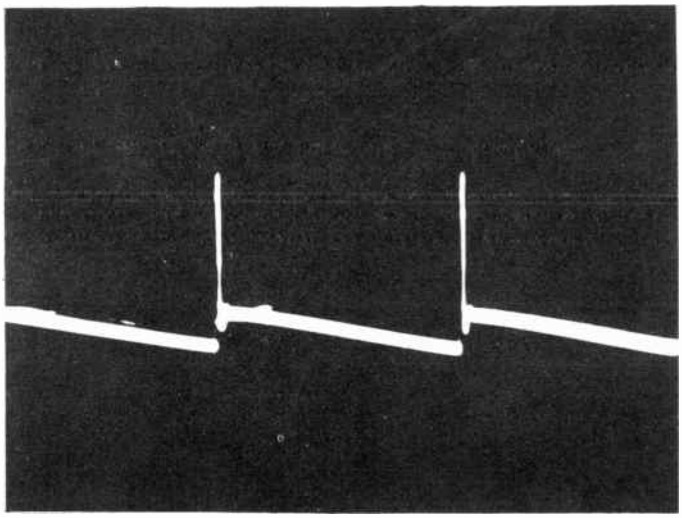

Fig. 25-A

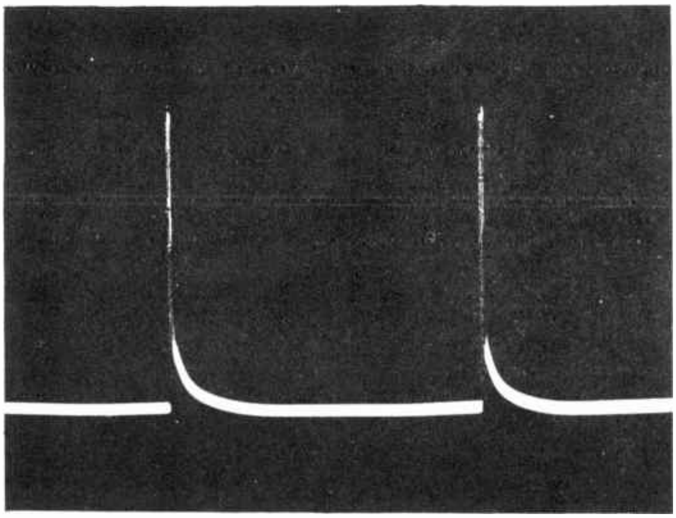

Fig. 25-B

Fig. 25. Voltages across vertical deflecting coils in the yoke on a picture tube.

Figs. 24 and 25 are typical of those in vertical amplifying and magnetic deflecting systems in all receivers.

Horizontal sweep amplifiers for magnetic deflection are closely associated with high-voltage power supplies, damping, and certain types of linearity and size controls. We shall consider these horizontal amplifiers in connection with the related subjects.

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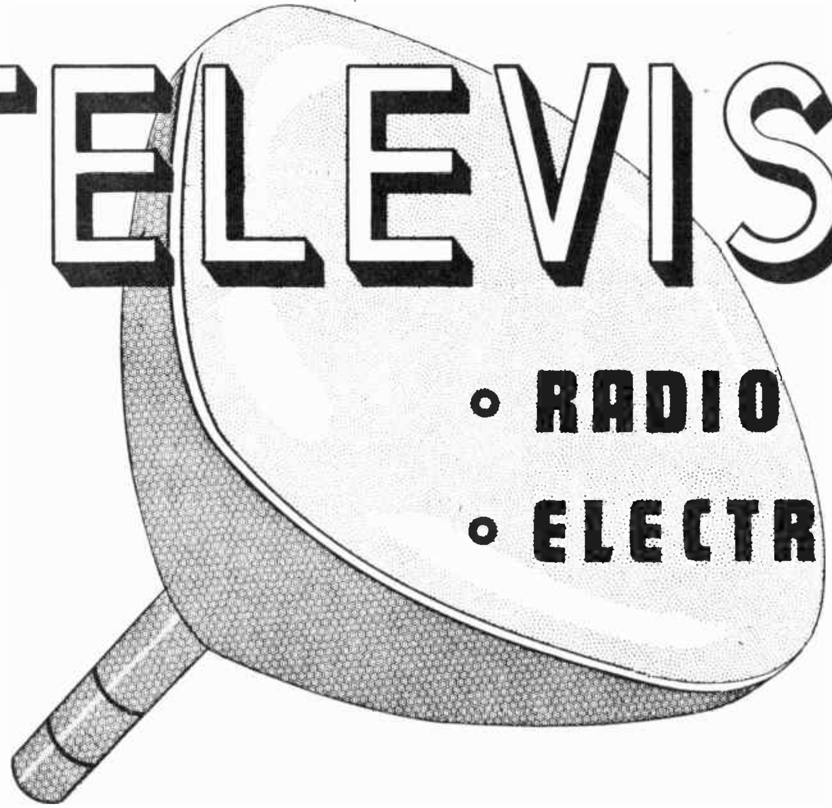

LESSON 67 — AUTOMATIC FREQUENCY CONTROLS

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Lesson 67

AUTOMATIC FREQUENCY CONTROLS

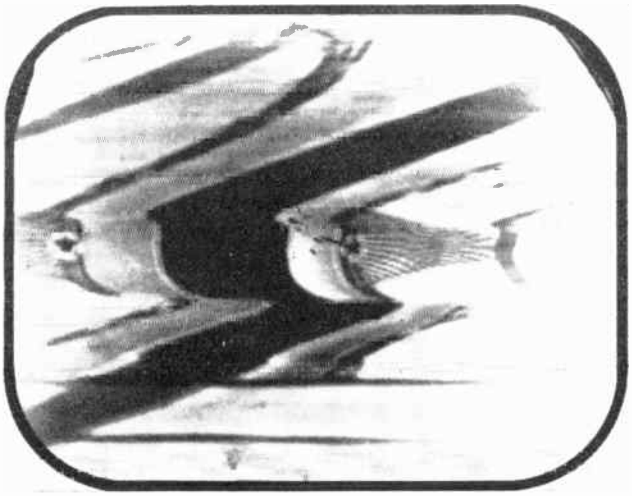

Fig. 1-A

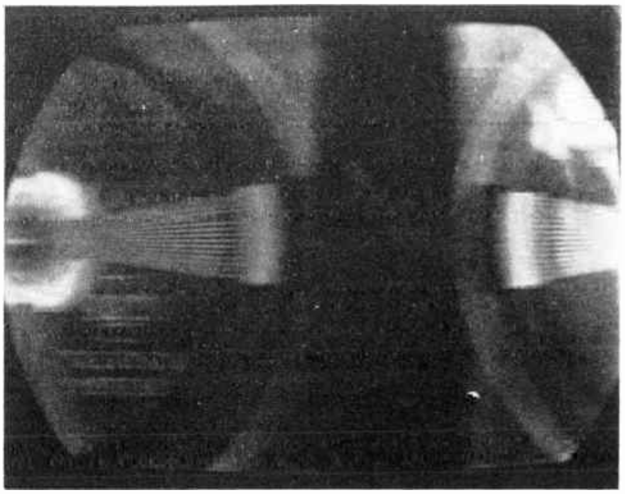

Fig. 1-B

Fig. 1. Pictures and patterns like these often mean trouble in the horizontal afc system.

When you see pictures and patterns such as those of Fig. 1 the trouble is more than likely to be in the automatic frequency control for horizontal sweep. Maybe the fault is nothing more than misadjustment, but again there may be defects in capacitors, resistors or other circuit elements.

Automatic frequency control, abbreviated afc, is necessary in the horizontal sweep section chiefly because of noise. When short, sharp noise voltages get through the sync section in spite of attempts at suppression and cancellation they act like horizontal sync pulses. These noise pulses could trigger the horizontal oscillator were it not held synchronized by the afc system.

Although noise pulses of short duration could upset horizontal synchronization, they have little effect on vertical sync frequency. The reason is that time constant of the vertical integrating filter is so long that brief noise voltages cannot alter the instants of triggering. Only when noise voltage is unusually strong and of long duration does it upset vertical synchronization, then causing pictures to roll up or down on the screen. Consequently, it is rare to find automatic control for vertical sweep frequency.

All but a few horizontal afc systems now in use employ the same fundamental principle, illustrated by Fig. 2. The afc circuit is connected between the sync section and the

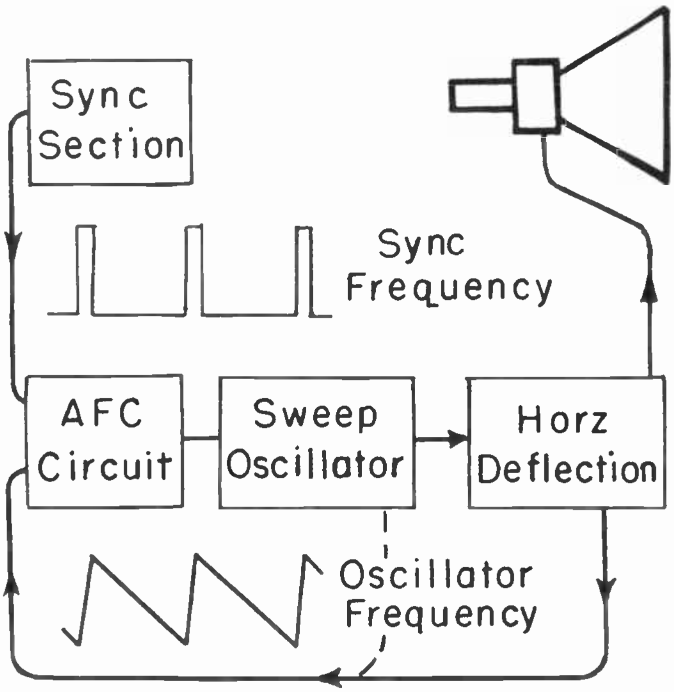

Fig. 2. Nearly all afc systems combine oscillator output frequency with sync pulse frequency for a correction voltage applied to the oscillator.

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sweep oscillator. Synchronizing pulses from the sync section are applied to the afc circuit. Since these sync pulses are derived from the received signal they must at all times be exactly in time with the signal.

To the afc circuit is applied also a voltage of sawtooth or other waveform taken from the oscillator output or from the deflection system which is beyond the oscillator. This voltage must, of course, be precisely in time with actual frequency of the oscillator, whether or not the oscillator is synchronized with received signals.

The sync pulses and oscillator output voltage combine in the afc circuit to form a correction voltage which is applied to the grid circuit of the sweep oscillator, and which varies the oscillator bias. Varying the grid bias changes the operating frequency of any sweep oscillator. Accordingly, the correction voltage can increase or decrease the oscillator frequency as may be required when the oscillator tends to run too slow or too fast.

If oscillator output voltage brought back to the afc circuit is exactly in time with sync pulses there is no correction effect. But should the oscillator tend to run slower than sync pulses a correction voltage will be of polarity which increases oscillator frequency. When the oscillator tends to run faster than sync pulses the correction voltage reverses its polarity and decreases the oscillator frequency.

Time constants of capacitors and resistors in afc circuits are long enough that correction voltage cannot change when synchronization fails during only a few pulses from the sync section. The oscillator must drift out of synchronization during a considerable number of consecutive horizontal line periods before correction voltage builds up or drops off to any great extent.

We might say that oscillator frequency is regulated by the average effect of sync pulses continuing in a regular manner, and cannot be affected by any one or two pulses.

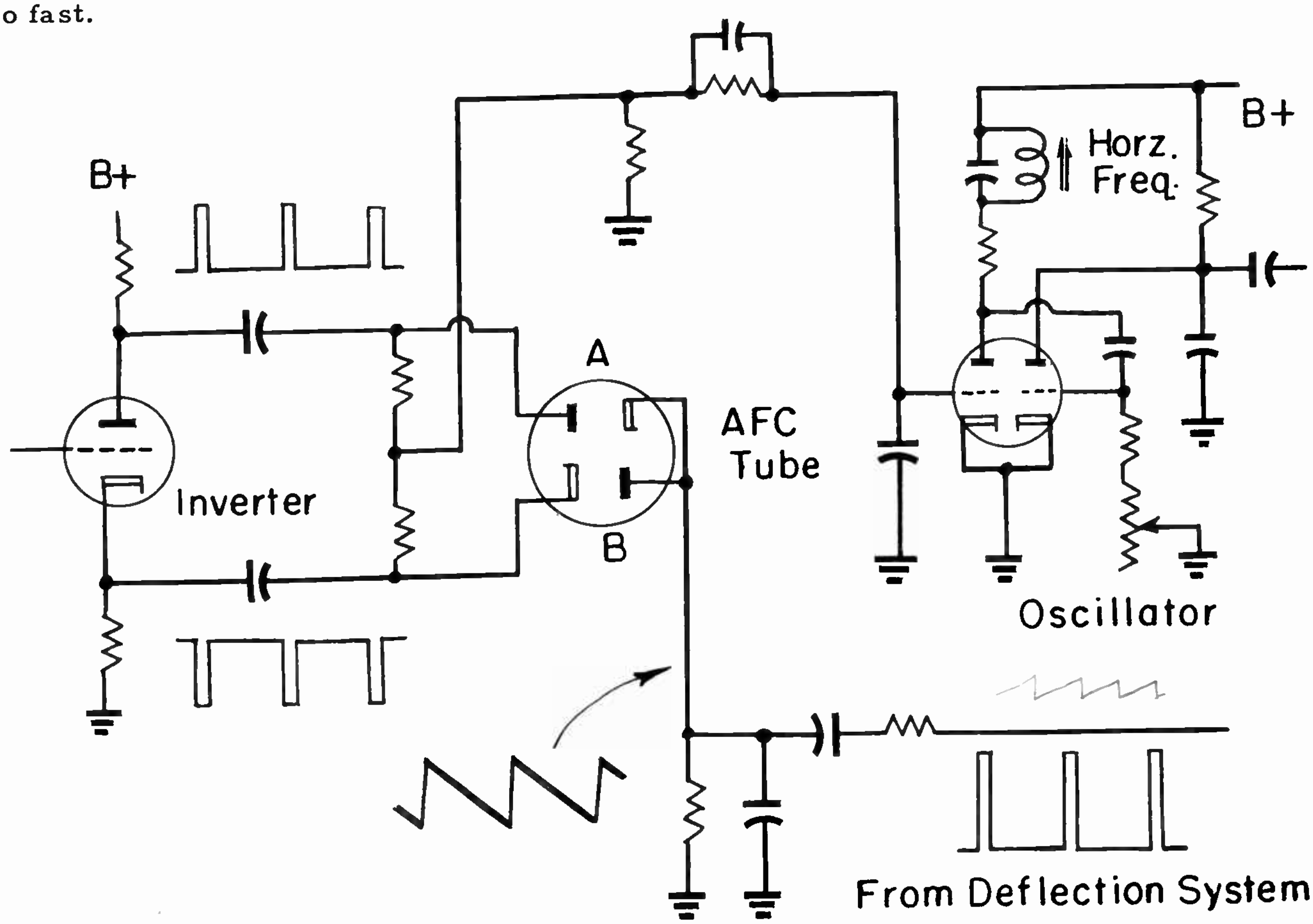

Fig. 3. The afc tube is a phase detector. The oscillator is a multivibrator.

This being the case, noise pulses occuring at irregular instants can have little or no effect on correction voltage and cannot cause triggering of the sweep oscillator.

PHASE DETECTORS FOR AFC. One of the most widely used horizontal afc circuits is shown by Fig. 3. The last tube in the preceding sync section is a triode, called an inverter or sometimes a phase splitter. The afc tube is a twin diode which, used in this manner, is called a phase detector. The control system is shown connected to the grid of the first section of a multivibrator sweep oscillator.

At the plate of the inverter are sync pulses of positive polarity, and at the cathode are sync pulses of negative polarity. The positive pulses are applied to the plate of diode A, and the negative pulses to the cathode of diode B. Opposite diode elements, cathode A and plate of B, are connected together. To these joined elements is applied a sawtooth voltage derived from some point beyond the oscillator, which here is from the deflection system.

In the deflection system are brief pulses of positive voltage which accompany sawtooth deflecting currents in any output transformer and yoke coils. By means of resistors and capacitors between the deflection system are afc tube the voltage pulses are changed to a sawtooth waveform. In many receivers a sawtooth voltage is taken directly from the sawtooth capacitor and output plate of the sweep oscillator.

In a receiver employing this phase detector method of control the oscilloscope sees negative sync pulses at the inverter grid, A of Fig. 4. These pulses are inverted and become positive at the plate, trace B. There is no inversion between grid and cathode, so at the cathode we have negative pulses shown at C.

In the same receiver feedback pulses, A of Fig. 5, are taken from the secondary winding of the transformer which feeds the horizontal deflecting coils. The derived sawtooth voltage at the joined cathode and plate of the afc tube appears as at B.

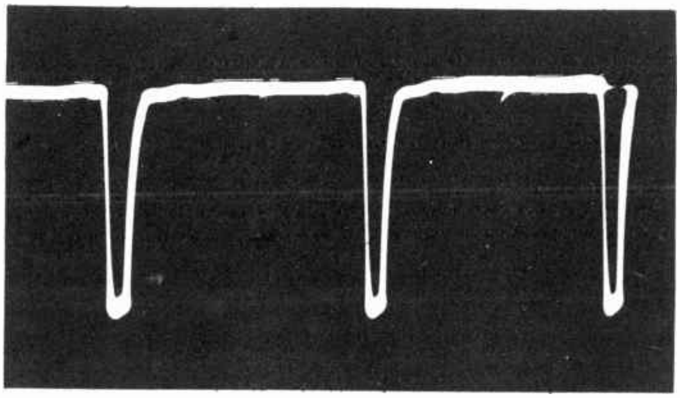

Fig. 4-A

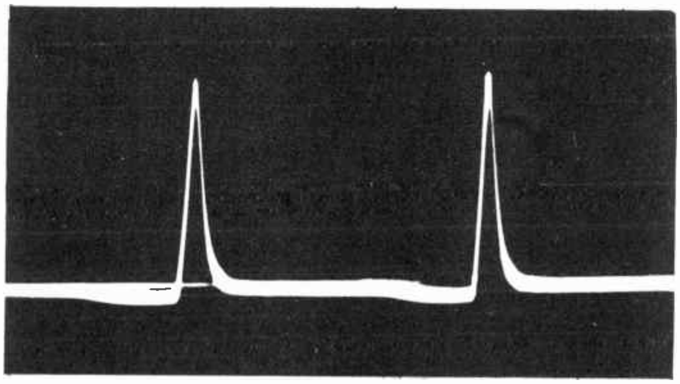

Fig. 4-B

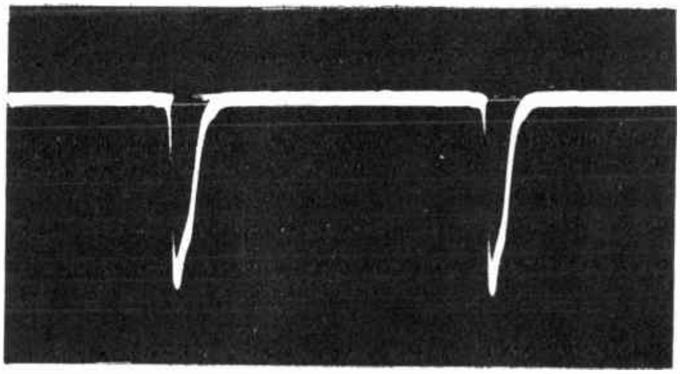

Fig. 4-C

Fig. 4. Voltage waveforms at grid, plate, and cathode of the inverter.

Neither diode can conduct except during pulses of sync voltage from the inverter. This is because the inverter delivers a positive sync voltage to the plate of diode A and a negative sync voltage to the cathode of diode B. These are the polarities necessary at plates and cathodes in order that there may be conduction in any tube.

Polarities at the cathode of diode B and plate of diode A, conductively connected together, are determined by the sawtooth voltage. This sawtooth is alternating, it goes first positive, then negative. During positive

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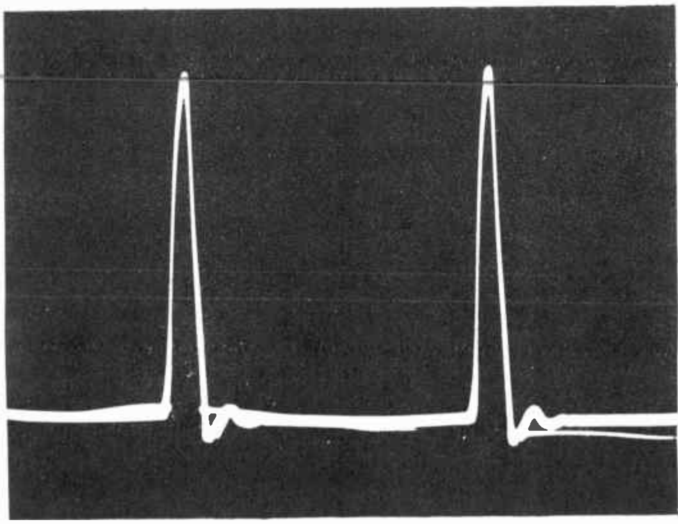

Fig. 5-A

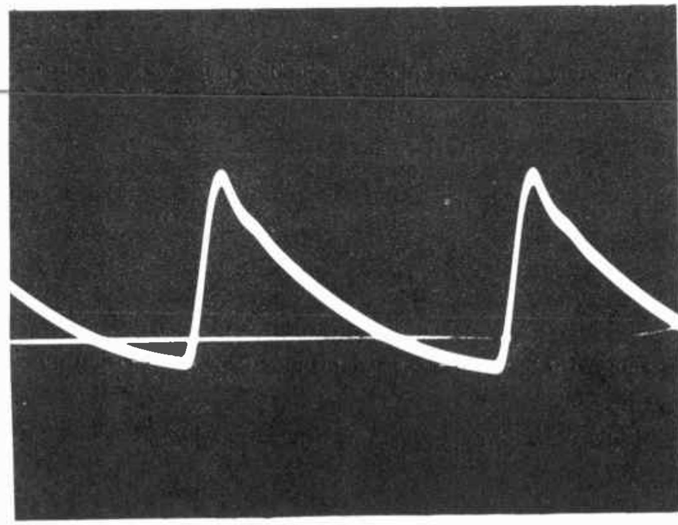

Fig. 5-B

Fig. 5. Voltage pulses from the deflecting circuits are changed to a sawtooth for the afc tube.

alternations of sawtooth voltage both the cathode of diode A and the plate of B are made positive. This tends to allow conduction in diode B, but not in A. When the sawtooth goes negative it makes the cathode of A and plate of B both negative. This tends to allow conduction in A but not in B.

Fig. 6 shows results of these polarities at elements of the diodes. Remember, conduction occurs only during the periods of sync pulses. One of these brief periods is shown between vertical broken lines. During conduction periods the plate of diode A always is positive and the cathode of B always is negative.

While oscillator frequency or "speed" is correct, zero voltage of the sawtooth occurs during conduction periods. This makes the cathode of diode A and the plate of B of zero potential. There is conduction in diode A because its plate is positive in relation to its zero cathode. There is equal conduction in diode B because its cathode is negative in relation to its zero plate, which is equivalent to having the plate positive in relation to the cathode.

Should the oscillator tend to run slow, cycles of sawtooth voltage occur later than when synchronization is correct. Then negative sawtooth voltage exists during the conduction (pulse) period, making the cathode of diode A and the plate of B negative. Now we

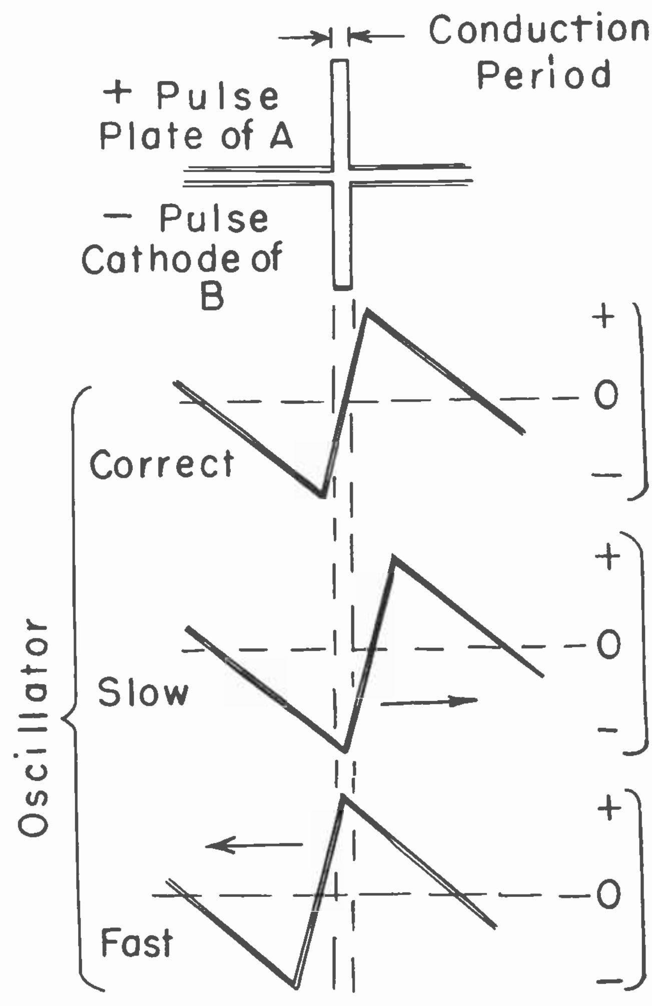

Fig. 6. The sawtooth shifts in phase or time so that conduction occurs when the sawtooth is zero, negative, or positive as the oscillator speed is correct, slow, or fast.

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have in diode A, during the conduction period, a positive plate and negative cathode, causing maximum conduction in this diode. But in diode B both plate and cathode are negative, so there is negligible conduction.

Should the oscillator tend to run too fast, sawtooth cycles occur earlier than with correct synchronization, as shown at the bottom of Fig. 6. Now there is positive sawtooth voltage during the conduction period, making the plate of diode B and the cathode of A both positive. In diode B we now have a positive plate and negative cathode, allowing strong conduction in this diode. In diode A both plate and cathode are positive, so there is negligible conduction. Here is a summary of what has happened so far.

more current, makes the second grid more negative in relation to the cathode and also places a greater charge on the capacitor between first plate and second grid. Then this capacitor must discharge for longer time before grid voltage returns to a value which ends plate current cutoff and allows conduction. The longer period between conductions means lower operating frequency. Were the first grid made more negative the whole action would reverse, and operating frequency would increase.

Excess of current in diode A of Fig. 7 makes the first grid of the multivibrator more negative. This increases oscillator frequency, makes it faster. But the negative grid resulted originally from control action

	SYNC PULSE EFFECTS		SAWTOOTH EFFECTS		
OSCILLATOR FREQUENCY	Plate of A	Cathode of B	Cathode of A	Plate of B	DIODE CURRENTS
Correct	+	-	o	o	Equal
Slow	+	-	-	-	More in A
Fast	+	-	+	+	More in B

Since the control diodes are rectifiers their conduction currents are direct. Direct currents do not flow through capacitors, so these diode conduction currents can flow only in the portions of the control circuit shown by Fig. 7. Conduction current in diode A follows the path of full-line arrows through resistor Ra, resistor Rg, ground, and resistor Rc. Conduction current in diode B follows the path of broken-line arrows through resistors Rc, Rg, and Rb. Resistor Rg is between grid and cathode of the oscillator, by way of ground connections. Therefore, any voltage developed across Rg becomes bias voltage for the first grid of the multivibrator.

When the grid of the first section in a multivibrator is made more positive there is decrease of oscillation frequency, because of the following train of events. The positive grid increases current in the plate circuit and in the cathode resistor. More voltage drop across the cathode resistor, due to

due to slow running of the oscillator. Thus we find that when the oscillator commences to run slow, the control acts to make it faster.

Excess of current in diode B flows upward in resistor Rg, makes the first grid of the oscillator positive, thus lowering the frequency of slowing the oscillator. The positive grid resulted from the oscillator running too fast. We find that the control acts to slow the oscillator when it tends to run too fast. When the oscillator has been brought back to correct frequency or speed, control action ceases.

The noise filter, in connection with capacitor Cg of Fig. 7, smooths the pulsating currents from the diodes and also prevents any remaining noise voltages from affecting oscillator grid bias and frequency. The filter acts also to delay the charge and discharge of capacitor Cg, whose average voltage fixes average bias voltage of the oscillator.

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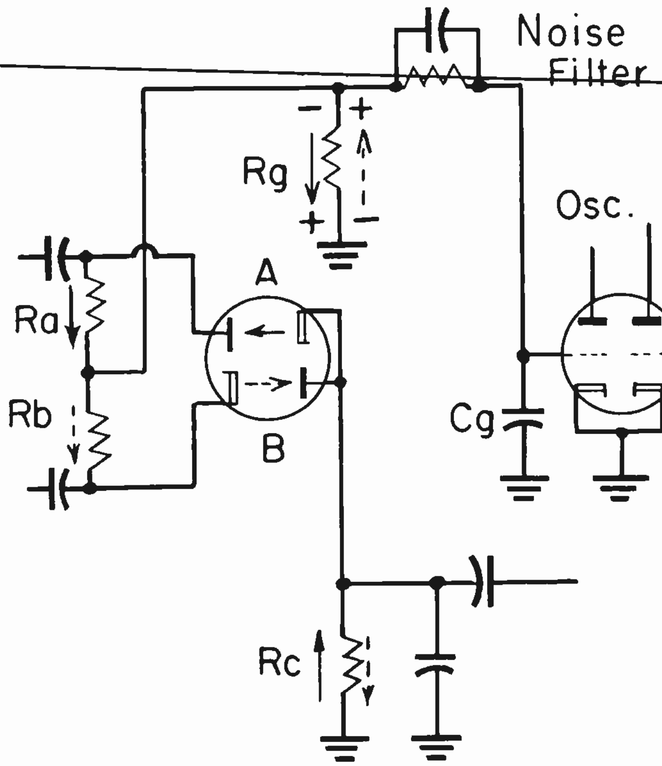

Fig. 7. Paths followed by direct currents in the diode circuits.

Whether or not this type of afc system is operating may be checked with a vacuum tube voltmeter set for d-c voltage measurement and connected between the first or input grid of the multivibrator and ground or B-minus. Varying the horizontal hold control will alter actual frequency of the oscillator. The afc system will try to make a correction.

Adjusting the hold control for more resistance will slow the oscillator, because this increases the time constant of the capacitor-resistor combination on the second or discharge grid. Afc voltage at the first grid then should become more negative or less positive, since this is the change required to make the oscillator run faster. Opposite adjustment of the hold control makes the oscillator fast, and should cause the first grid to become more positive, thus tending to slow the oscillator. The total swing shown by a VTVM may be several volts.

Peak voltages of positive and negative sync pulses from inverter to control tube need not be equal and seldom are equal while the oscillator is synchronized. Unequal pulse voltages cause unequal conductions in the two diodes. Then there will be continual current in one direction through oscillator bias resistor Rg of Fig. 7, and some normal bias voltage other than zero. Current in the biasing resistor still will be increased or decreased as the oscillator tends to change frequency. Bias voltage on the first grid will vary as may be necessary to maintain synchronization.

FREQUENCY ADJUSTMENT WITH PHASE DETECTOR AFC. Looking back at Fig. 3 you will see, in the B-supply line to the first plate of the oscillator, a parallel resonant circuit marked "Horizontal Frequency". Other names are horizontal lock, horizontal phase, and horizontal ringing. The word ringing originally was used in telephony, and now in radio and television, when referring to oscillating voltages and currents which result from resonance of inductances and capacitances in any circuit. Ringing may or may not be at the desired or correct operating frequency of the system where it occurs.

The horizontal frequency control on our multivibrator plate is tuned by an adjustable slug for resonance at the horizontal line frequency of 15,750 cycles per second. The parallel resonant circuit is "shocked" into oscillation at its own frequency by sudden changes of multivibrator plate voltage. Currents at the tuned resonant frequency circulate in the coil and capacitor quite independently of slight changes of multivibrator frequency.

The resonant voltage produced in the horizontal frequency coil-capacitor combination is very nearly of sine-wave form. It is added to or modulates the d-c plate voltage for the oscillator. Consequently, it becomes difficult for the multivibrator to operate at any frequency other than that for which the control circuit is tuned, which is 15,750 cycles per second. Tuning the frequency control thus assists in keeping sweep frequency in time with sync pulse frequency.

The frequency control is adjusted to allow most stable synchronization while the hold control is at or near the center of its range. Tune the frequency control thus.

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LESSON 67 – AUTOMATIC FREQUENCY CONTROLS

1. Place the hold control at the approximate center of its adjustment range.

2. Adjust the frequency control to sync the picture horizontally.

3. Rotate the hold control clockwise while noting how far it must be turned to cause drop-out, then back to a point where pull-in occurs.

4. Rotate the hold control counter-clockwise, then back, noting the positions for drop-out and pull-in.

5. Drop-out and pull-in should occur with the hold control turned about equal distances away from its mid-position. Otherwise make readjustment of the frequency control to secure this action.

The frequency control adjustment is effective in compensating for slight changes of capacitance and resistance, and of tube characteristics, which occur with aging of parts in the afc and oscillator circuits.

There are numerous modifications of the afc system employing a phase detector with a multivibrator sweep oscillator. One is illustrated by Fig. 8. Bias control or correction voltage here is taken from the joined cathode and plate of the diodes instead of from the mid-connection between load resistors Ra and Rb. Sawtooth voltage applied to the joined cathode and plate of the diodes is obtained from the sawtooth capacitor and second plate of the multivibrator.

Diode A is conductive during positive sync pulses applied to its plate, while diode B is conductive during negative sync pulses applied to its cathode. Which diode has greater conduction depends on time shift or phase shift of sawtooth voltage in relation to sync pulses, just as in the circuit described earlier. Bias voltage for the first grid of the multivibrator is developed across capacitor Cg, which charges, discharges, and reverses its polarity in accordance with values and polarities of conduction currents in the two diodes.

TRIODE PHASE DETECTOR. Fig. 9 shows connections and performance of an afc system which employs many of the principles of the method illustrated by Figs. 3 and 8, but has certain important differences. The most noticeable difference is in use of a triode rather than a twin diode as control tube. The inverter and multivibrator oscillator are no different than those in the system which we have been studying.

Positive sync pulses 1, are taken from the inverter plate and applied to the afc grid. To this grid is applied also a sawtooth voltage, 2, obtained from the plate of the second

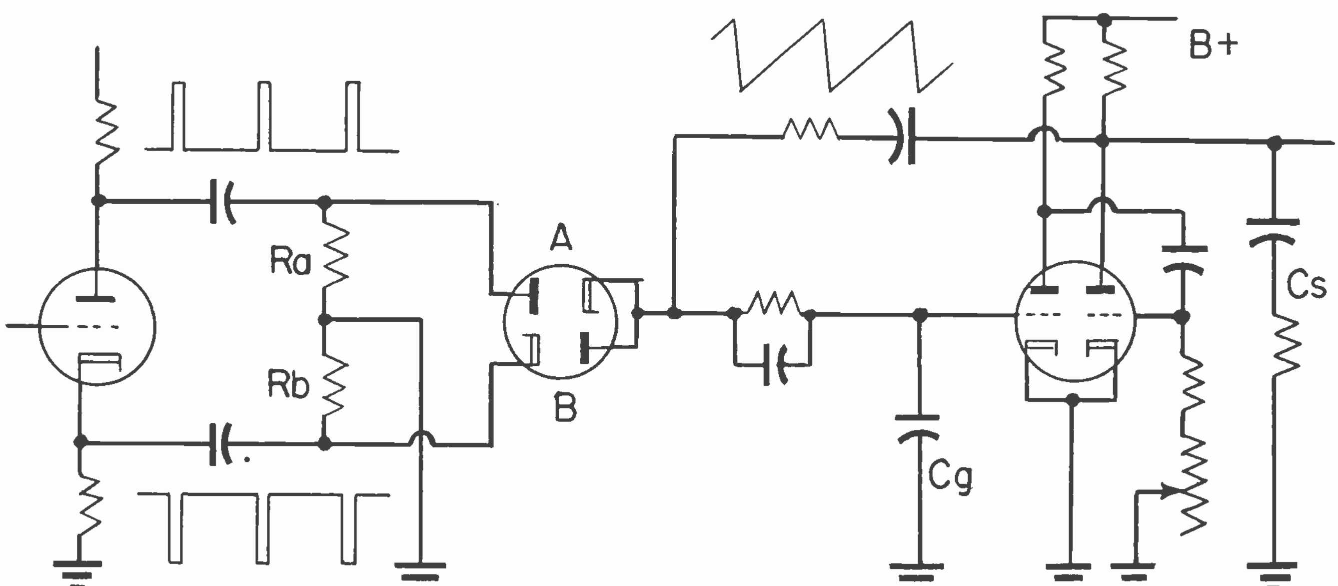

Fig. 8. One modification of the afc system which employs a phase detector.

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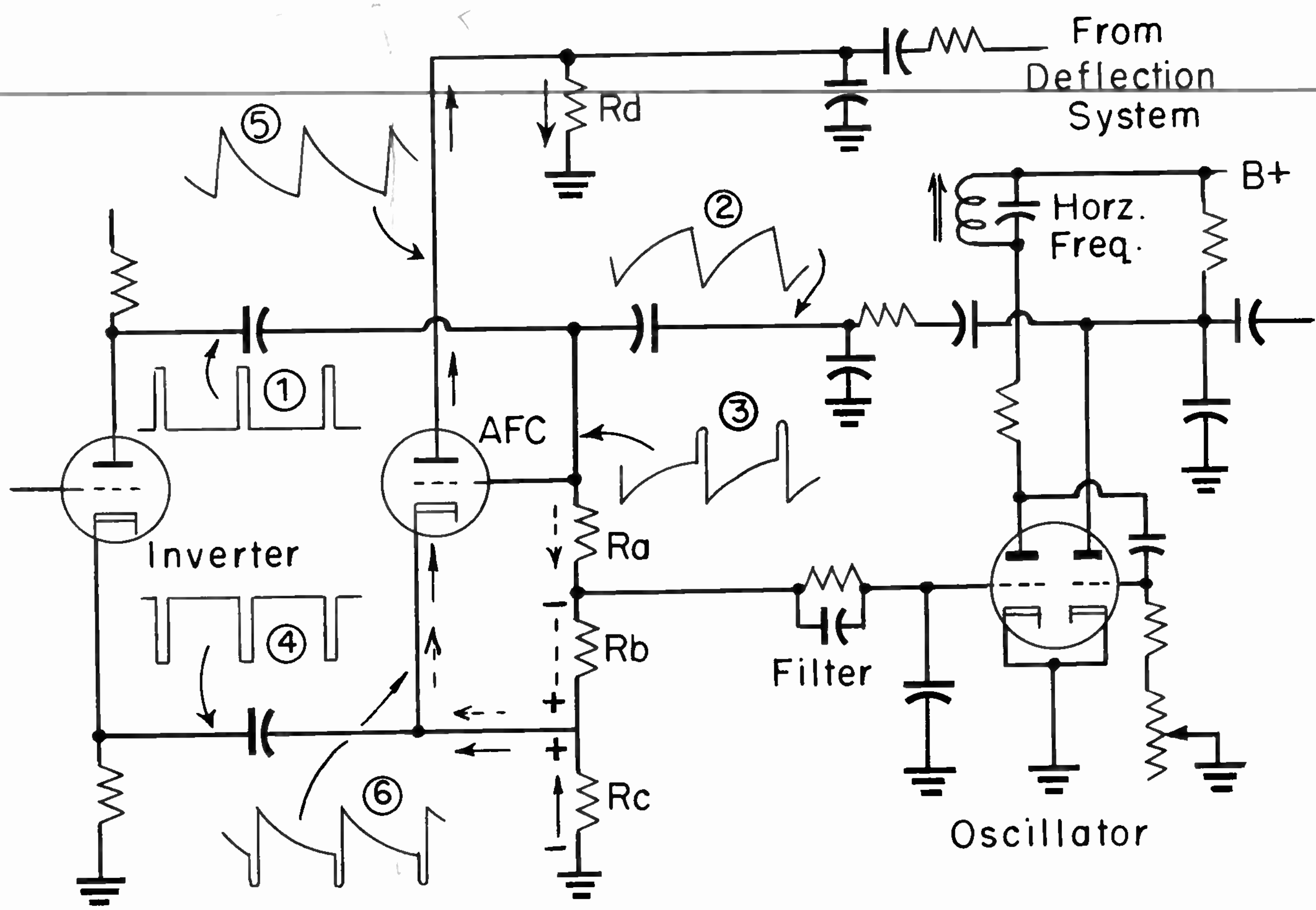

Fig. 9. In this afc circuit the phase detector is a triode.

section of the oscillator. The pulses and sawtooth voltage combine at the afc grid about as shown by the waveform at 3. Positive peaks or alternations of this composite waveform cause flow of grid current in the path of broken-line arrows, through resistors Ra and Rb.

Negative sync pulses, 4, from the inverter cathode are applied to the cathode of the afc tube. To the plate of this tube is applied the sawtooth voltage 5. This sawtooth is obtained from negative pulses in the circuit that includes the horizontal deflecting coils or else from a secondary winding on the horizontal output transformer. Voltages of waveforms 5 on the plate and 4 on the cathode of the afc tube determine the plate current waveform 6. Plate current flows as shown by full-line arrows, from the plate through resistor Rd to ground, from ground through resistor Rc, and back to the cathode.

The d-c return circuit for the first grid of the oscillator extends through the noise filter resistor and to the top of resistor Rb, thence through Rb and Rc to ground and back to the oscillator cathode. Voltage due to afc grid current in Rb tends to make the oscillator grid negative, because the negative end of Rb is toward the oscillator grid. Voltage due to afc plate current in Rc tends to make the oscillator grid positive, because the positive end of Rc is toward the oscillator grid.

Bias voltage on the oscillator grid will be the difference between opposing voltages on Rb and Rc, and will be of polarity depending on which of these resistors has greater current and greater voltage drop. When sawtooth (oscillator) voltage and sync pulses are in synchronization, grid and plate currents in the afc tube are such as to cause equal and opposite voltages in resistors Rb and Rc. These voltages cancel, and no correction voltage is developed to change oscillator grid bias and frequency.

Should the oscillator tend to run slow the sawtooth voltages change their phase or

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timing in relation to sync pulses. The shift is such as to increase the afc grid current more than plate current. This makes the oscillator grid more negative and increases oscillator frequency. Should the oscillator tend to run fast, the phase shift of sawtooth voltage in relation to sync pulses is such as to increase afc plate current more than grid current, thus making the oscillator grid more positive. This decreases oscillator frequency.

AFC BY VARIATION OF SYNC PULSE WIDTH. In the afc systems which have been described, frequency correction results from varying the grid bias on a multivibrator. A d-c correction voltage is the difference between two voltages of opposite polarity in a twin diode or in grid and plate circuits of a triode. Now we shall examine another widely used afc system, in which grid bias of a blocking oscillator is varied by d-c voltage from a triode in which conduction is varied by changing the duration of voltage pulses applied to the triode grid.

A typical circuit is shown by Fig. 10. The d-c grid return for the oscillator extends through resistors Rb and Rg to ground, and from ground back to the oscillator cathode. Whatever voltage appears across resistor Rg will be part of the grid voltage or bias voltage on the oscillator. Variation of voltage across Rg will alter the oscillator bias and frequency.

When grid bias of a blocking oscillator is made more negative the oscillator frequency is lowered or the oscillator runs slower. This is because the more negative bias holds the oscillator at cutoff for longer periods. Making the grid less negative increases the frequency or makes the oscillator run faster, because cutoff is maintained for shorter periods. Note that these grid polarities for changing the frequency of a blocking oscillator are opposite to the polarities required at the first grid of a multivibrator for similar changes of frequency. They are, however, the same as polarities required at the second grid of a multivibrator for given changes of oscillator frequency.

First we shall see how plate current in the afc triode can change the oscillator grid

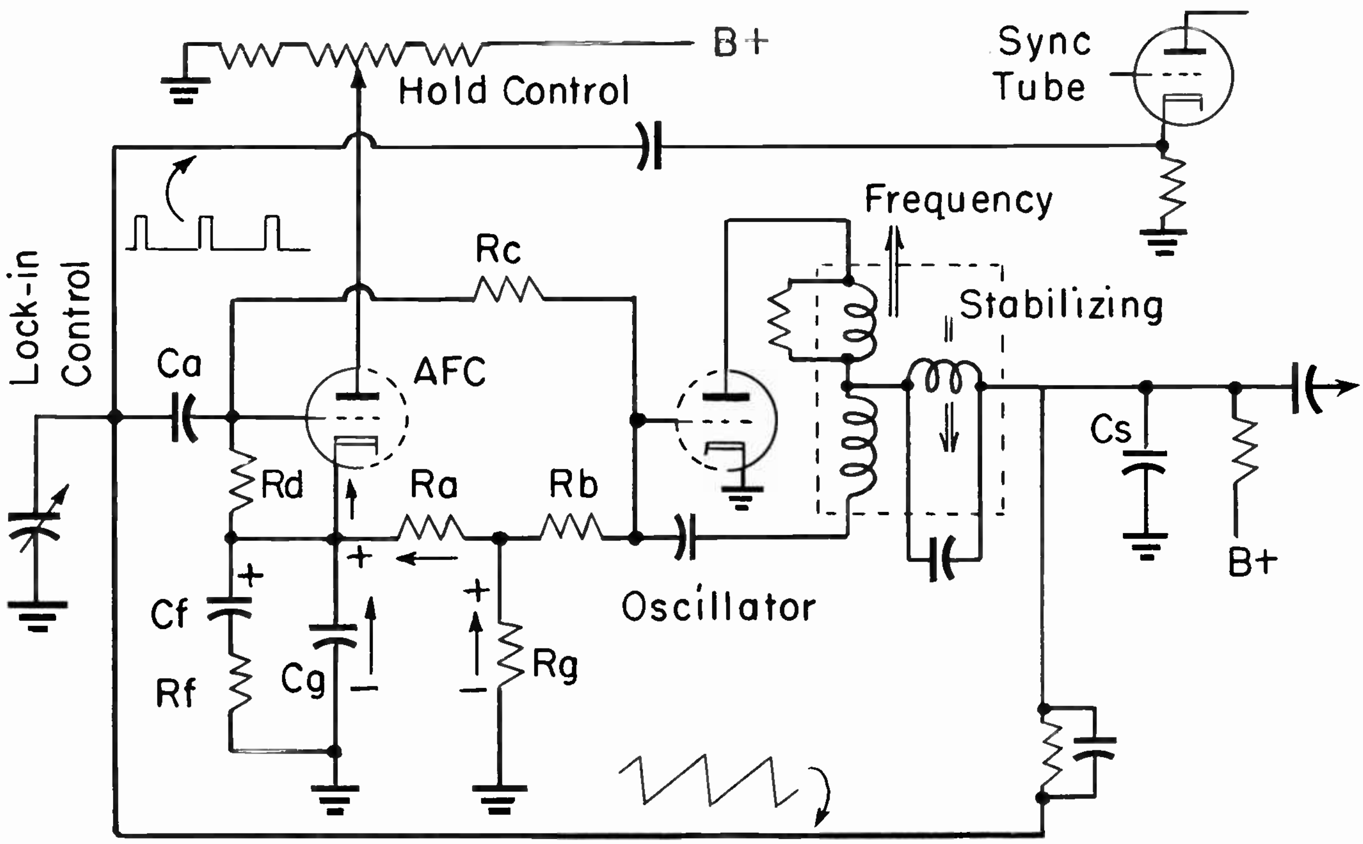

Fig. 10. An afc system in which a triode regulates frequency of a blocking oscillator.

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bias. To begin with, plate current in the afc triode must flow toward its cathode in the direction of full-line arrows. The direction of plate current through resistors Rg and Ra makes the top of Rg and the cathode positive with reference to ground. This voltage across Rg and Ra charges capacitor Cg. In parallel with Cg is the series combination of another capacitor, Cf, and a resistor Rf. Capacitors Cg and Rf charge together, and they discharge through Rg. Although discharge current reverses in the capacitors, flowing toward ground, it remains in the original direction in Rg and Ra as discharge currents flow away from ground. Consequently, polarities as marked on the diagram remain unchanged.

The capacitors are charged by pulses of plate-cathode current through the afc triode. Time constants of the capacitors and associated resistors are long enough that capacitor charges and voltage remain nearly constant during many horizontal line periods. However, the time constants are not so long that changes of pulse current strength continuing for greater periods cannot increase or decrease the capacitor charges and voltage. Since voltage across resistors Ra and Rg must remain the same as capacitor voltage, and since Rg is in the oscillator grid return, changes of capacitor charges and voltage will alter the bias and frequency of the oscillator.

Now we shall examine the manner in which variations of oscillator frequency cause changes in strength of plate current pulses in the afc triode, thus altering oscillator grid bias to correct the frequency.

To the grid of the afc triode, through capacitor Ca, are applied positive sync pulses from a tube in the sync section, also a sawtooth voltage obtained from the output of the oscillator, at sawtooth capacitor Cs. While the oscillator is correctly synchronized with the received signal we have the combination voltage at the top of Fig. 11. The center of each sync pulse is at a positive peak of the sawtooth. Half or approximately half of the sync pulse remains on top of the sawtooth. The remaining portion of the sync pulse is down at the sharp drop of sawtooth voltage.

Should the oscillator tend to run slow, the sawtooth voltage will occur later with reference to sync pulses, as in the center diagram. Then, were the oscillator slow enough, the entire sync pulse would be on the positive peak of the sawtooth. Should the oscillator tend to run fast, the sawtooth would occur sooner in relation to sync pulses, as in the bottom diagram. Then nearly all of the sync pulse voltage would be down in the valley of the sawtooth and only very little would remain on the sawtooth peak.

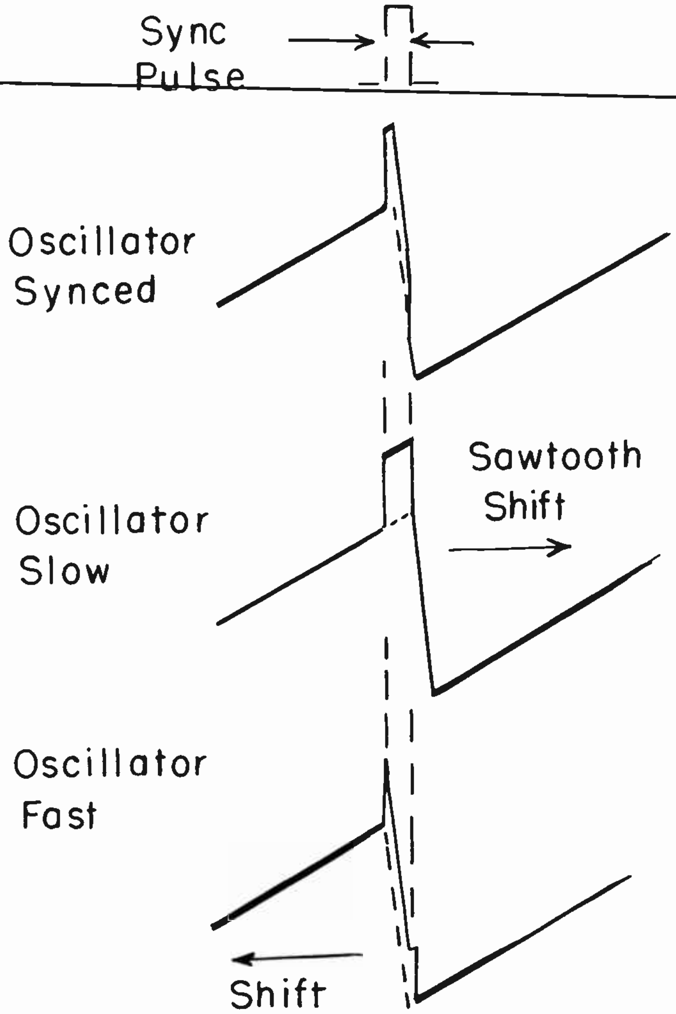

Fig. 11. Time shift or phase shift of the sawtooth leaves more or less of the sync pulse voltage added to the positive peak of the sawtooth.

These changes of afc grid voltage with variations of oscillator frequency are seen by the oscilloscope as in Fig. 12. At A is the sawtooth with a sync pulse of width that exists when the oscillator is correctly synchronized. When the oscillator tends to run slow, the portion of the sync pulse remaining on top of the sawtooth becomes wider, as at

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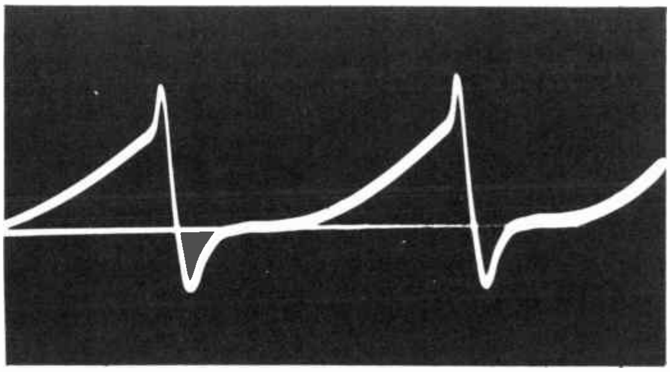

Fig. 12-A

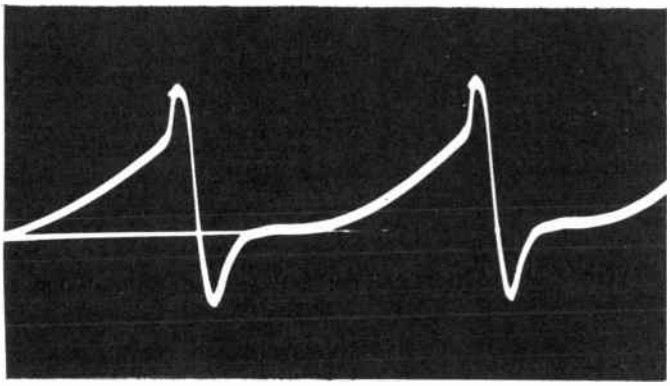

Fig. 12-B

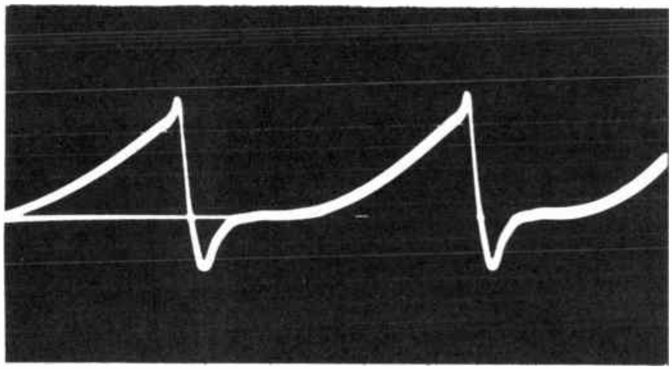

Fig. 12-C

Fig. 12. How the oscilloscope sees changes of sync pulse width at the positive peak of the sawtooth voltage.

B. That is, the pulse voltage exists for a longer time. If the oscillator tends to run fast the sync pulse almost disappears, as at C.

With an afc system operating correctly you can see these changes by connecting the scope through a frequency compensating probe to the afc grid. The oscillator frequency may be varied by adjusting the horizontal hold control. The afc system will attempt to prevent the frequency variation, as in Fig. 12.

Now we may look again at Fig. 10. At Rc is a resistor, of several megohms, between the grids of the oscillator and afc triode. This resistor, in connection with others at Rd, Ra, and Rb, forms a voltage divider applying part of the average grid voltage on the oscillator to the grid of the afc triode. Average grid voltage on any blocking oscillator is highly negative. The portion of this negative voltage reaching the afc grid makes this grid so negative as to cut off all current due to sawtooth voltage, and leave only peaks of current due to sync pulses which are more positive than positive peaks of the sawtooth.

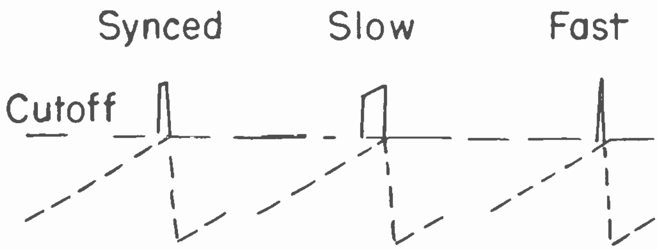

Fig. 13. With cutoff at the peak voltage of the sawtooth, conduction occurs only during sync pulse voltages of various durations or "widths"

The result of cutoff in the afc tube is shown by Fig. 13. Only the sync pulse voltages remain effective in causing pulses of plate-cathode current in the afc triode. The height or voltage of the sync pulses remains practically constant. But the times during which these pulse voltages act on the afc grid will vary, as denoted by different widths of the pulses.

While the oscillator is correctly synced, pulse voltage on top of the sawtooth exists for about half the time of an original sync pulse. When the oscillator tends to become slow the pulse voltages are wider and pulse voltage is applied to the afc grid for longer times. When the oscillator tends to become fast the pulses are very narrow, with pulse voltage existing for only very brief periods at the afc grid.

The pulses of voltage at the afc grid cause pulses of plate current that charge capacitors Cg and Cf of Fig. 10. When the oscillator commences to slow down, each pulse of grid voltage continues for a longer time. There is a longer pulse of resulting plate current. This increases capacitor charge and

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voltage. The oscillator grid becomes less negative, and oscillator frequency is brought back to normal. The opposite effects occur when the oscillator commences to run too fast.

The hold control for this afc system is a front panel or operator's adjustment on nearly all receivers. This control varies the positive voltage on the plate of the afc triode. This varies the conduction current for any given grid voltage, and increases or decreases capacitor charge and voltage. In this manner the hold control has direct affect on oscillator frequency. More afc plate voltage increases the frequency, less plate voltage decreases oscillator frequency.

The lock-in adjustment, a variable capacitor on the afc grid, is a service adjustment. Its purpose is to compensate for differences in characteristics of original and replacement tubes. This adjustment is not always provided.

In the can containing the oscillator transformer of Fig. 10 are three windings. The two connected to plate and grid of the oscillator form an auto-transformer providing feedback from plate to grid, as in all blocking oscillators. For these windings there is an adjustable core which may be called the frequency control or given other names.

The third winding in the oscillator can is shunted by a capacitor to form a parallel resonant circuit tuned by a separate adjustable core. This resonant circuit is adjusted for the horizontal line frequency of 15,750 cycles per second, and generates its own sine wave voltage in the manner described earlier for a parallel resonant circuit in the plate lead to a multivibrator oscillator. The sine wave voltage adds itself to the sawtooth normally present at the oscillator plate and sawtooth capacitor.

The parallel resonant circuit on the oscillator transformer of Fig. 10 is marked stabilizing. Various other names are used. The stabilizing coil was not used with early applications of this afc system, but is found in practically all recent designs.

As you might expect, there are many modifications of the afc system which regu-

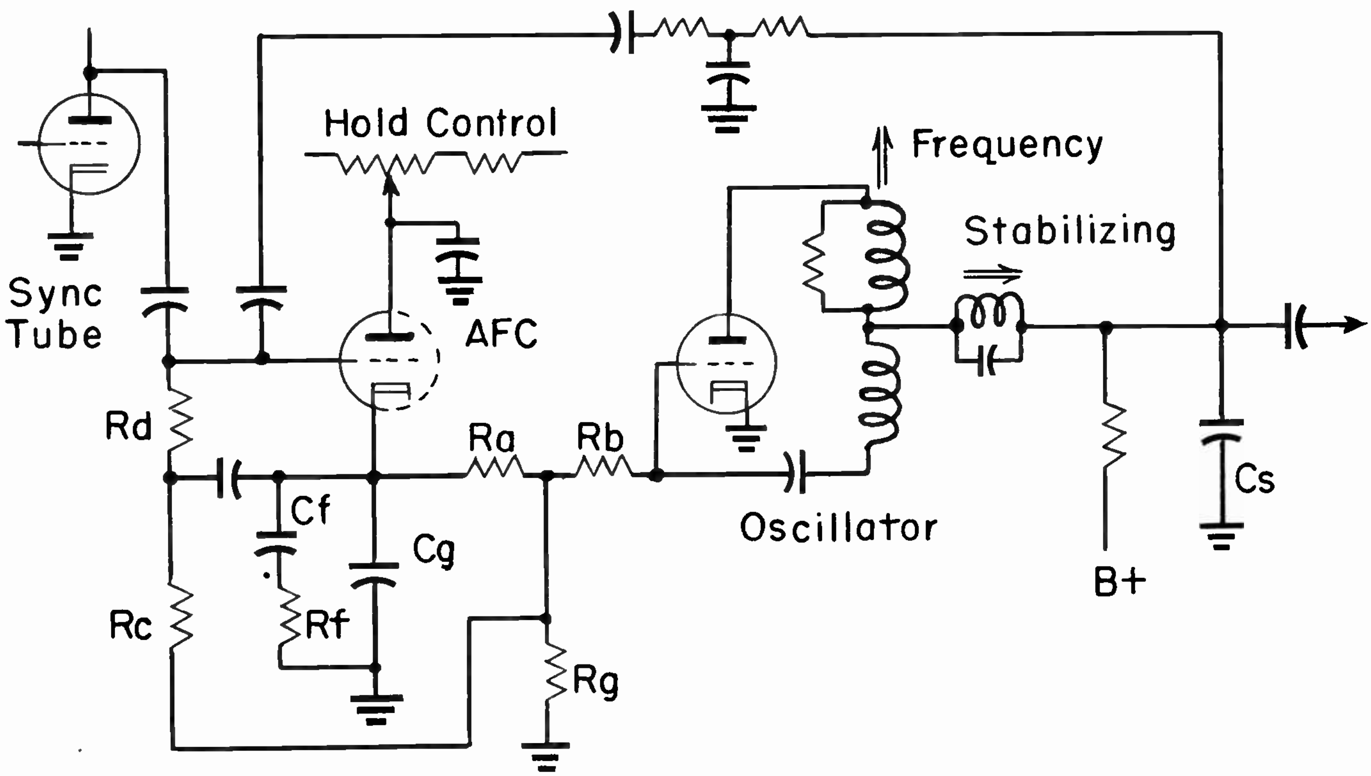

Fig. 14. A modification of the afc system in which sync pulse voltages are varied in duration or "width".

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lates oscillator grid bias and frequency by varying the width of sync pulse voltages. One is illustrated by Fig. 14. Here there is no lock-in capacitor. Grid bias voltage for the afc tube is obtained from the interconnection of resistors Ra, Rb, and Rg, and is taken to the grid through resistors Rc and Rd.

Most of the modifications represent efforts of designers to improve the waveform of voltage at the afc grid. It is desired to have a sawtooth rising at a steep slope toward its positive peaks, and falling sharply after the peak. You will find sawtooths taken from the oscillator grid instead of from a sawtooth capacitor connection. Pulse voltages, from which sawtooths are derived, may be taken from various points in circuits containing horizontal deflecting coils, output transformer secondaries, and damper tubes.

ADJUSTMENT OF AFC SYSTEMS WHICH VARY SYNC PULSE WIDTH. Service adjustments of afc systems which vary the width of sync pulse voltages are more numerous than for phase detector systems, consequently are more difficult. It may be advisable to make certain preliminary checks if there has been trouble with horizontal sync in the set being worked upon. These same checks may be worth-while when you encounter unusual difficulties with other horizontal afc systems.

There must be horizontal sync pulses of adequate strength. Probably the simplest check is to vary the vertical hold control and to switch from channel to channel to make sure that there is effective vertical synchronization. If vertical sync is poor, examine tubes and voltages in the sync section. Then make sure of correct alignment in the i-f section. If no faults are thus located, try new afc and horizontal oscillator tubes, or a new twin triode if such a tube performs both functions. With some tubes, it is almost impossible to make adjustments for satisfactory performance.

In making adjustments in afc system such as those of Figs. 10 and 14, follow this order.

1. Tune in a picture. Adjust contrast slightly lower than for normal viewing. Set the horizontal hold control at or near the position for maximum voltage on the afc plate, which means rotating the hold control clockwise in most receivers.

2. Adjust the frequency control. This is the slug for plate-grid windings of the oscillator transformer.

3. Adjust the lock-in capacitor if there is such an adjustment.

4. Stabilizing coil adjustment is not made unless satisfactory synchronization cannot be obtained otherwise. In such cases the stabilizer is the final adjustment.

Frequency Control. Turn the adjustment slug all the way out, which increases oscillator frequency, then back just far enough to sync the picture. Turn the selector to another channel, then back again. If the picture does not sync, turn the frequency control slug enough farther in to cause locking. Now try switching to all active channels. If pictures do not pull in promptly on all channels, turn the frequency slug still farther in.

Try operating the hold control on each channel. Pictures should remain synced with the hold control turned through most of its range. Keep the following facts in mind while readjusting the frequency control if necessary to obtain correct action of the hold control. Turning the frequency slug farther in lowers the oscillator frequency. Turning the hold control for less afc plate voltage, usually counter-clockwise, also lowers the oscillator frequency. Opposite adjustments of the frequency slug and hold control raise the oscillator frequency. From these facts you can determine which way to turn the frequency slug to compensate for sync failure at either end of the hold control adjustment.

Lock-in Capacitor. This adjustment is made so that pictures, after once synced, remain so with the hold control turned as far as possible each way from its mid-position. Check performance of the hold control on all active channels, and make final adjustment of the lock-in capacitor on the channel where there is least range of the hold control.

Stabilizing Coil. This adjustment can be made correctly only with an oscilloscope

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connected to the junction of the three windings in the oscillator transformer can. There is always an external terminal for this connection. If the terminal cannot be otherwise identified, it is the one that does not connect to the oscillator plate, does not connect through a capacitor to the oscillator grid, and does not connect to the sawtooth capacitor and the lead for the horizontal output amplifier. Use a frequency-compensating probe, or at least have about 50K ohms isolating resistance on the end of an ordinary probe.

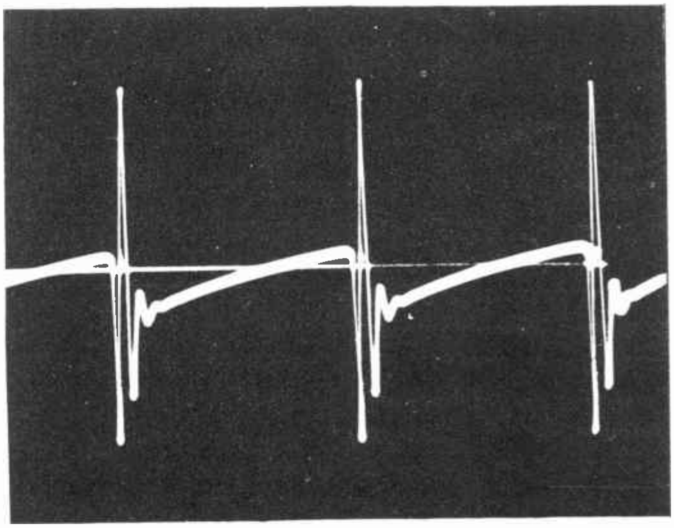

Fig. 15-A

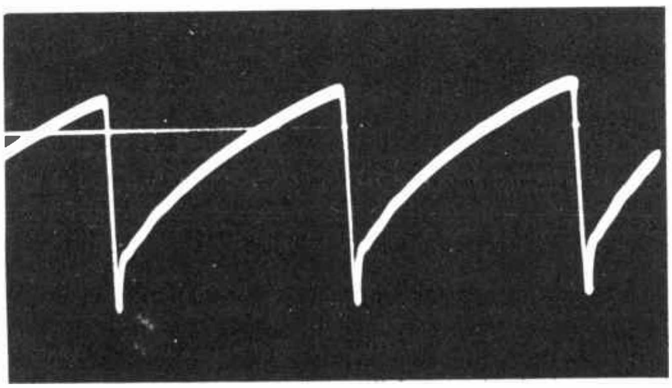

Fig. 15-B.

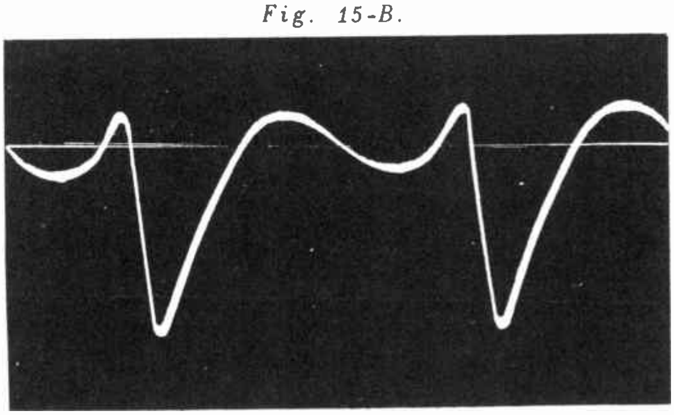

Fig. 15-C

Fig. 15. Waveforms observed at the transformer for the blocking oscillator.

A typical waveform at the plate of a blocking oscillator is shown at A of Fig. 15, and a sawtooth wave from the sawtooth capacitor at B. The waveform desired at the junction of the three windings is shown at C. It is a combination of the sawtooth output and the sine wave produced by the resonant stabilizing circuit.

Adjust the stabilizer slug to make the sharp peak from the sawtooth and the rounded peak from the sine wave of equal height, or so that the sawtooth peak is no more than 5 to 10 per cent higher than the sine wave. While making this adjustment keep a picture synced by changing, if necessary, the frequency slug in the transformer and the hold control.

If the sawtooth peak is too low the hold control will be lacking in adjustment range within which pictures remain synced. Horizontal frequency may double, with parts of several pictures distributed from left to right across the screen. If the sawtooth peak is too high the oscillator will fall out of sync when there are moderate noise voltages or other minor disturbances.

AFC WITH REACTANCE TUBE AND DISCRIMINATOR. The afc system used in the earliest television receivers employing horizontal sweep control, and still found in great numbers of sets, utilizes a reactance tube for regulating the frequency of a sine-wave oscillator. One of the many varieties of circuits based on this principle is shown by Fig. 16.

The manner in which a reactance tube regulates frequency of an oscillator is explained in the lesson on "Sweep Generators For Alignment". For the circuit described in that lesson, grid voltage on the reactance tube is varied by a 60-cycle a-c voltage. In afc systems the reactance grid receives a d-c correction voltage obtained from a twin diode usually called a discriminator. As will appear in following paragraphs, this afc discriminator does not operate just like the type of f-m sound demodulator which we call a discriminator.

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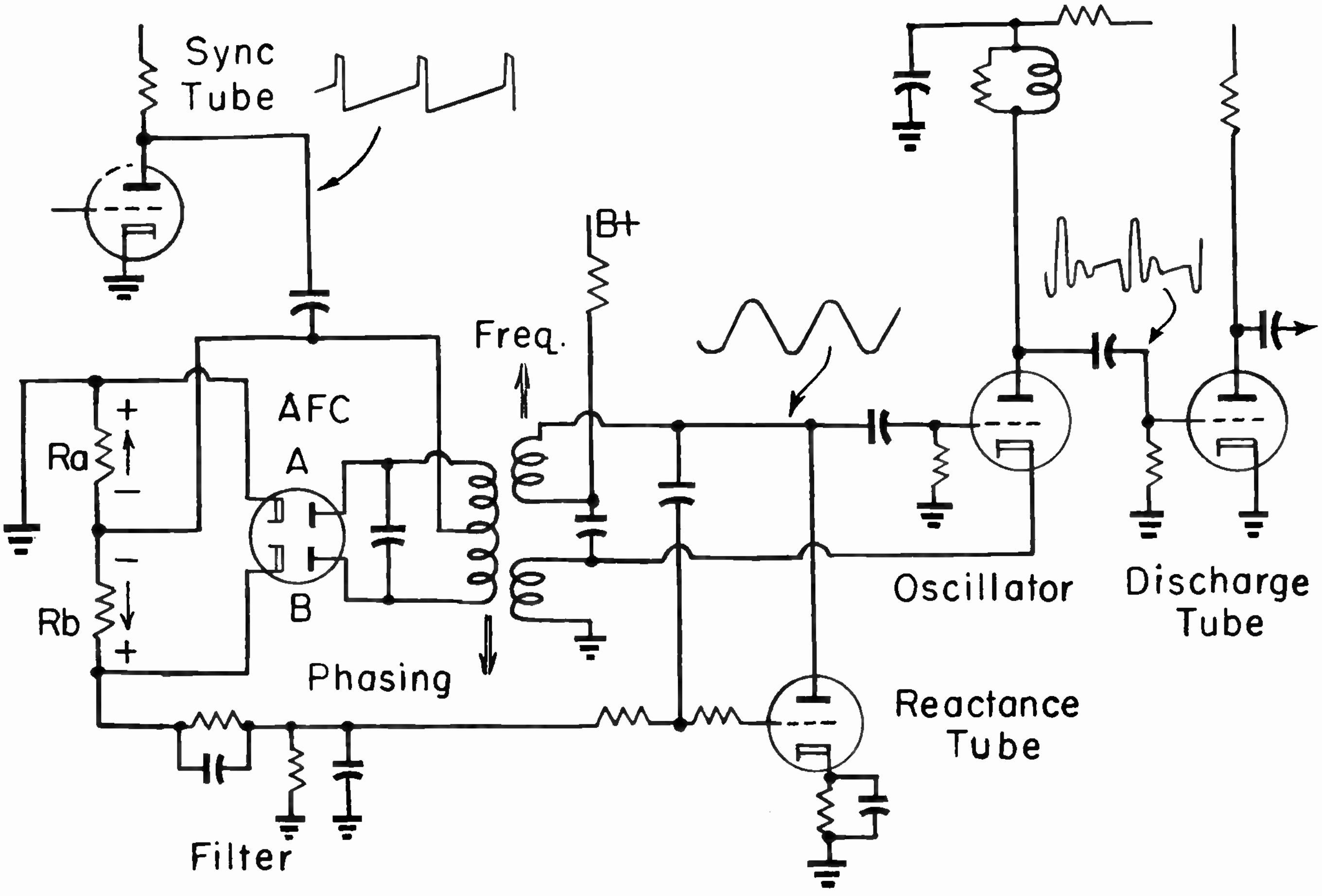

Fig. 16. An afc system employing a reactance tube and discriminator to control a sine-wave oscillator.

In afc systems which include a reactance tube the oscillator is neither a multivibrator nor a blocking type. It is a Hartley or modified Hartley oscillator whose sine-wave output is changed to a more sharply peaked waveform and applied to the grid of a discharge tube. On the output of the discharge tube, but not shown on the diagram, is the usual sawtooth capacitor and a lead to the horizontal output amplifier.

The feedback coils for the oscillator are shown as the right-hand windings of a transformer between the oscillator and the afc tube. Sine-wave oscillator current in these coils induces a sine-wave voltage in the left-hand winding, whose ends are connected to the plates of the afc diodes. Thus the actual operating frequency of the oscillator is applied to the afc tube in which a correction voltage is produced. The sine-wave voltage is of opposite polarity or phase at the opposite ends of the transformer winding, and accordingly is opposite at the plates of diodes A and B.

To the afc circuit are applied also positive sync pulses from a tube in the sync section of the receiver. These pulse voltages go to the center-tap of the transformer winding and to the mid-point between load resistors Ra and Rb. Consequently these pulse voltages appear at both diodes with polarity unchanged, still positive.

Fig. 17 shows how correction voltages are produced. When the oscillator is in time, correctly synchronized, the positive sync pulses occur at instants in which the sine wave voltages on both diodes are passing through their zero values. Pulses are of equal heights or equal voltages on both diodes and cause equal conductions in both diodes. Resulting currents and voltages are equal and opposite in load resistors Ra and Rb. These equal voltages cancel, and there is no correction voltage.

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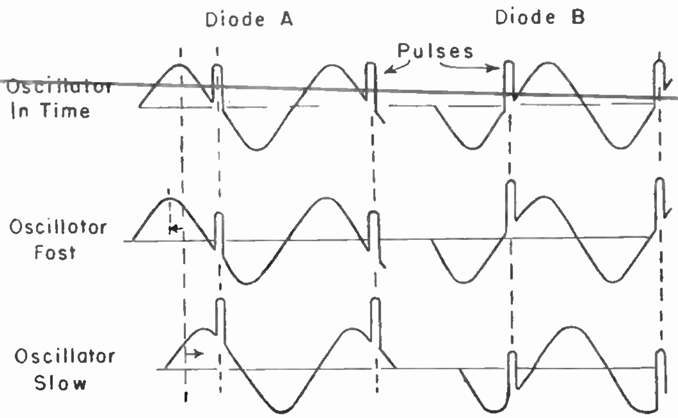

Fig. 17. As the sine-wave voltage shifts in time with changes of oscillator frequency, pulse voltages ride higher or lower.

When the oscillator tends to run fast, the sine-wave voltages occur earlier in relation to sync pulses. Pulse voltages drop on diode A and rise on diode B. Conduction is increased in diode B, decreased in A. More current and voltage drop appear on load resistor Rb, less on Ra. Since the positive end of Rb is toward the reactance grid, the reactance grid becomes more positive. Then the reactance circuit lowers the oscillator frequency, or slows the oscillator until it is again synchronized.

Should the oscillator tend to run fast, the pulse voltages rise on diode A and drop on diode B. There is more conduction in A, the reactance grid is made more negative, and the oscillator is caused to run faster until synchronized.

With some afc systems of this general type there is an adjustable hold control resistor on the oscillator grid. The range of oscillator frequency shift in which there is effective correction is so great in most applications of this method that a hold control resistor is not necessary.

There are two service adjustments on the afc transformer, frequency and phasing, as shown on Fig. 16. The frequency adjustment slug, for the oscillator coils, usually is accessible from the top of the transformer can. Set this slug so that pictures remain synced on all active channels, and pull in promptly when switching channels. If there is a hold control, make the frequency adjustment so that pictures remain synced with the hold control turned as far as possible each way from its mid-position.

Timing of sine-wave voltage is altered by a slug in the discriminator winding of the transformer, marked phasing on the diagram. Incorrect adjustment causes horizontal blanking to show as a vertical dark bar in pictures, or may cause pictures to appear as though folded on themselves. Turn contrast down and brightness up. If there is a hold control, set it at mid-position. Adjust the phasing slug to move the blanking bar just outside the picture area.

OTHER AFC SYSTEMS. We have examined in detail the afc systems which illustrate the most important principles and their applications found in the majority of receivers. There are many other combinations of these principles. For instance, you will find d-c amplifier tubes used between a phase detector and a multivibrator. In other cases a reactance tube may be used with a phase detector instead of with a discriminator. A discriminator instead of a phase detector may be used in connection with an amplifier and a blocking oscillator.

Service adjustments in these other afc systems conform, at least in a general way, to those which have been explained for similar or equivalent elements shown in this lesson. Assuming that the tubes are good, but that adjustments cannot be made satisfactorily, most troubles in afc systems are due to capacitors which have changed their values or which are leaky, shorted, or open. Next most common are incorrect voltages on tube elements, resulting from defective capacitors or sometimes from faulty resistors.

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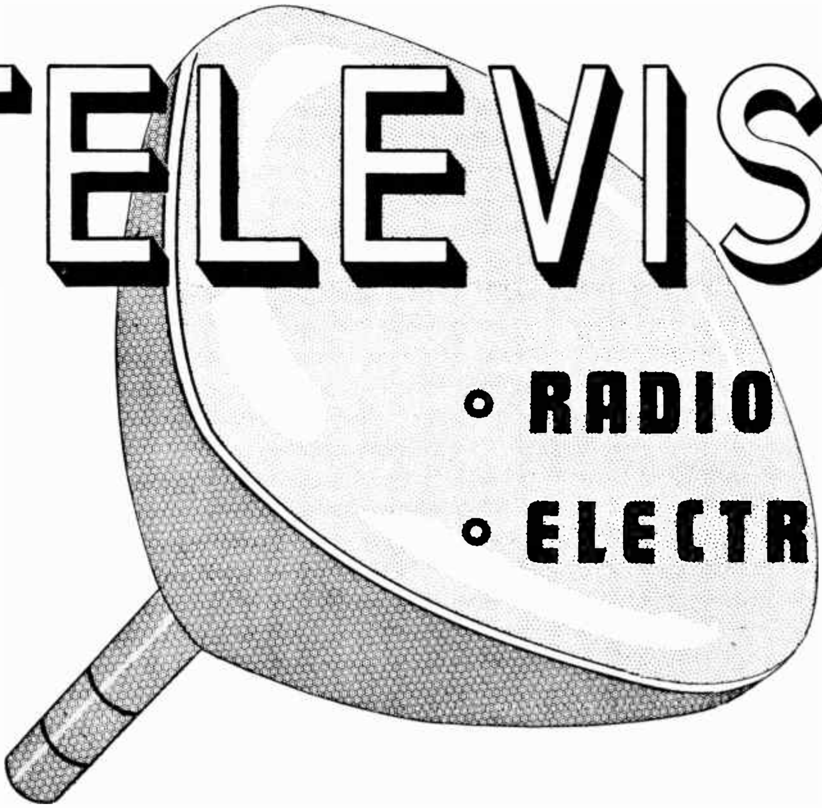

• RADIO
• ELECTRONICS

LESSON 68 — HORIZONTAL SWEEP CIRCUITS

Coyne School

practical home training

Chicago, Illinois

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Lesson 68

HORIZONTAL SWEEP CIRCUITS

Between the horizontal sweep oscillator and the deflecting coils in the picture tube yoke are three tubes, shown for one particular receiver by Fig. 1. At the right is the horizontal output amplifier. It is a beam power type operated with sawtooth voltage obtained from the sweep oscillator and furnishing a modified sawtooth current to the output transformer that can be seen back of the tubes in the photograph. This transformer provides a match between plate resistance or impedance of the amplifier and impedance of the deflecting coils, thus providing maximum power transfer.

Inductances of windings in output transformer and deflecting coils are resonant with distributed and stray capacitances in these circuits at frequencies much higher than the horizontal line frequency. Oscillating currents and voltages due to resonance must be stopped almost as soon as they begin. This is done by a heavy duty diode called the damper.

When sawtooth currents in deflecting coils go through retrace periods the sudden changes of current in coils and output transformer induce pulses of voltage in the transformer. These pulses are stepped up in an additional winding on the transformer, then are changed to direct voltage by the high-voltage rectifier tube. Pulsating direct voltage from the rectifier is filtered and fed to the high-voltage anode or ultor of the picture tube.

In the block diagram of Fig. 2 the horizontal output amplifier, the damper, and the high-voltage rectifier are represented by circles. Within rectangles on this diagram are names of service adjustments often associated with the three tubes and their circuits. The drive control is on the grid side of the horizontal amplifier. Controls for width and for linearity are on the deflecting coil side of the output transformer.

Any adjustable control which varies the strength or amplitude of sawtooth voltage applied to the grid of the horizontal output amplifier may be called a drive control. Such controls may be adjustable capacitors or adjustable resistors. Sometimes none of the service adjustments are called by the name drive control.

A width control or horizontal size control connected to a winding of the horizontal output transformer varies the strength or amplitude of sawtooth currents fed to the horizontal deflecting coils. Since the distance of electron beam deflection and consequent length of horizontal trace lines depend on amplitude of deflecting current, the width control varies the horizontal size of pictures in order that they may fill the opening of the mask in front of the picture tube.

The damper diode, connected to the circuit which includes deflecting coils and transformer secondary, passes current in one direction but not in the other. Oscillation due to inductances and capacitances in the coil and transformer circuit causes strong alternating current at the oscillation frequency. Conduction through the damper removes current alternations of one polarity and thus puts an almost immediate stop to the resonant oscillation. Alternations pass through the damper as pulses.

Energy withdrawn from the deflecting coil circuit through the damper is not wasted, rather it is made to produce useful voltage which is added to direct voltage obtained from the low-voltage B-supply of the receiver. Direct voltage obtained from the damper contains intermittent pulses. These pulses are partially smoothed in a low-pass filter circuit marked horizontal linearity in Fig. 2. The result is a direct voltage having an alternating component of approximately sine-wave form.

The combination or sum of direct voltage from the low-voltage B-supply and the direct voltage with an alternating component resulting from damper conduction is called

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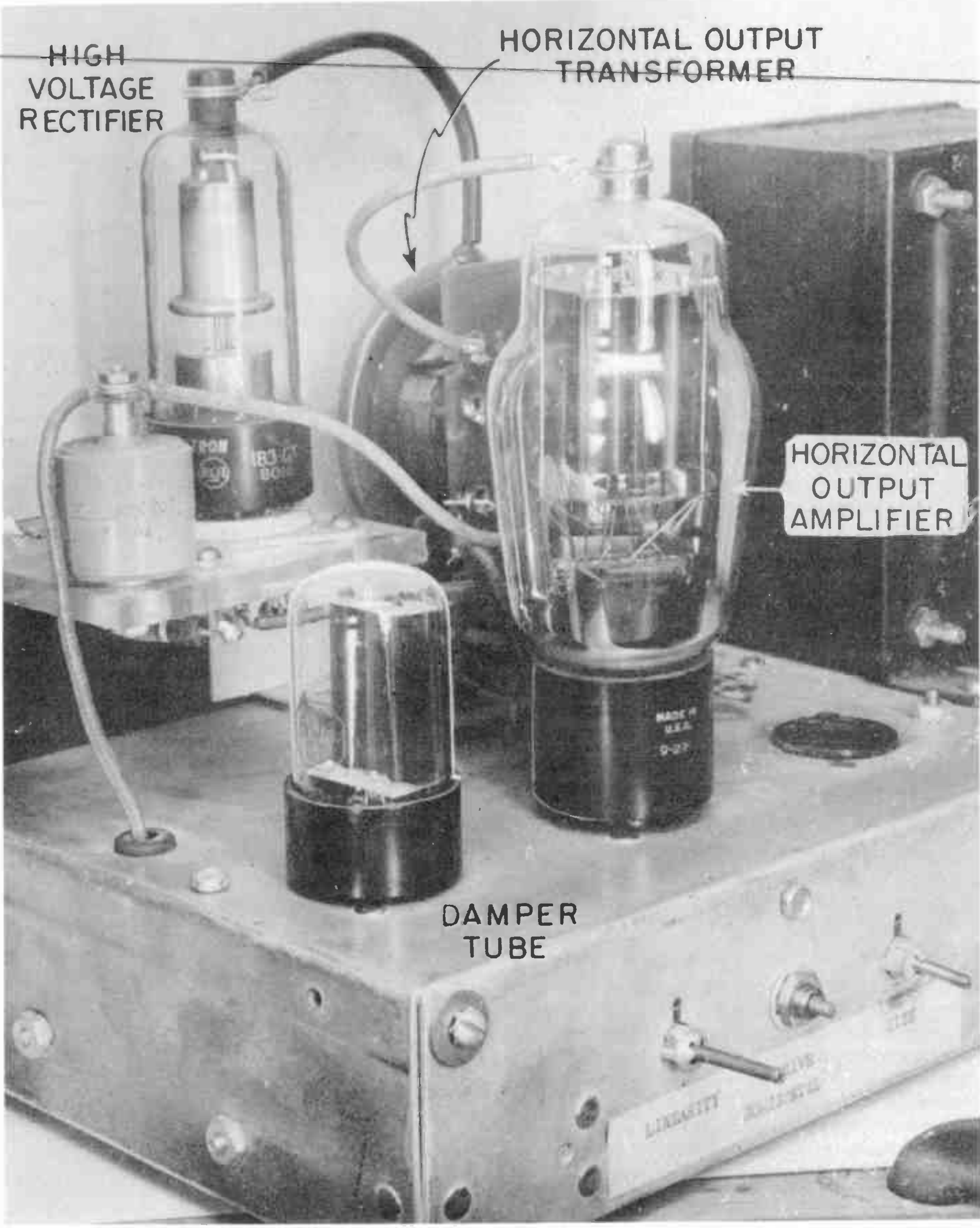

Fig. 1. The tubes and transformer of a horizontal deflection system and high-voltage power supply.

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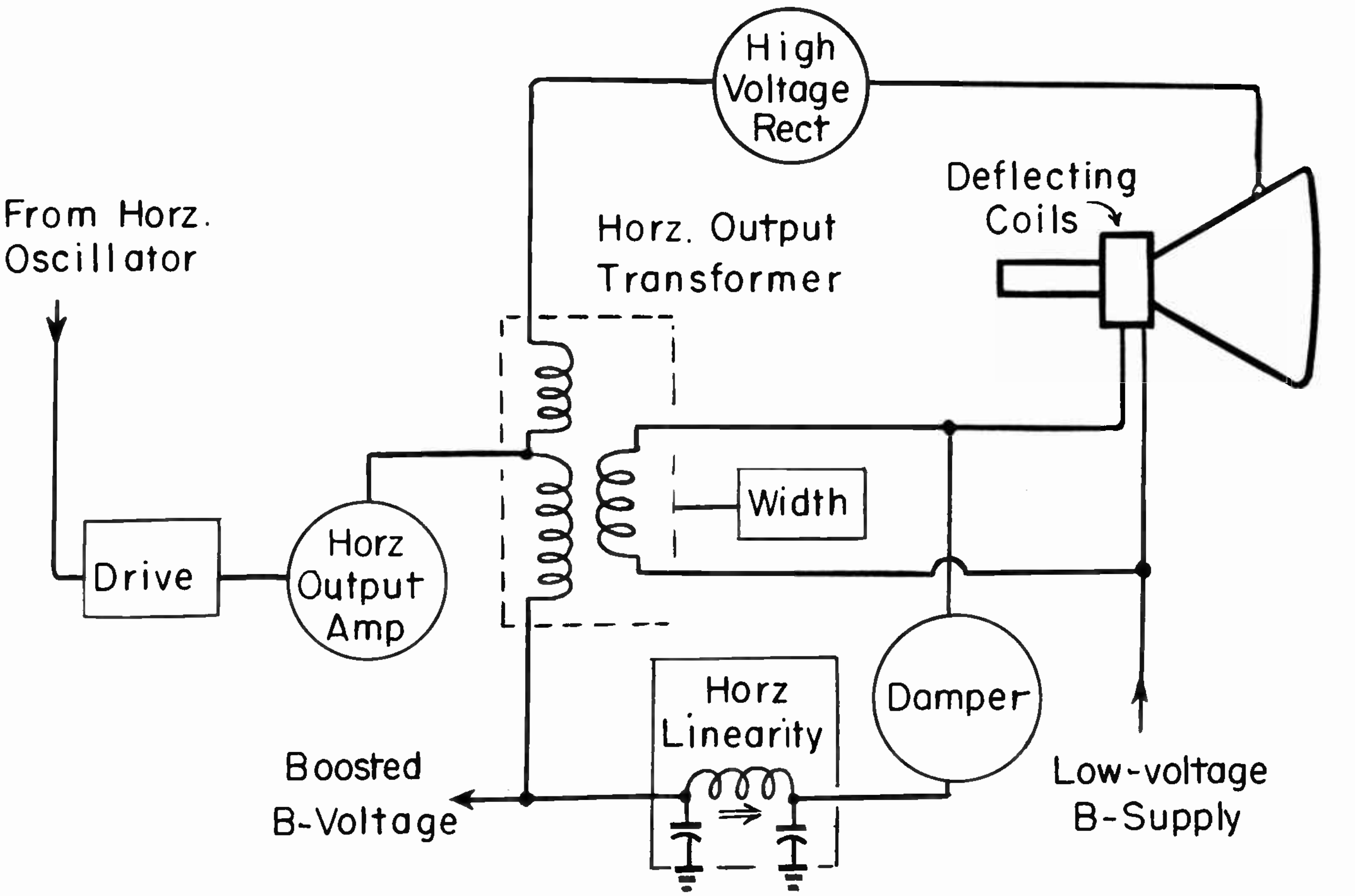

Fig. 2. Relations between principal parts in a common variety of horizontal deflection system and high-voltage power supply.

boosted B-voltage. This boosted B-voltage is applied to the primary of the output transformer and thereby to the plate of the output amplifier tube. After further filtering this boosted B-voltage may be used also for other circuits requiring higher potentials than available from the regular B-supply.

The low-pass filter which partially smooths voltage coming through the damper tube is called a horizontal linearity control for the following reason. The alternating component of boosted B-voltage which goes to the plate of the output amplifier causes alternations of amplifier plate current. Amplifier plate current is being varied at the same time by the sawtooth voltage applied to the amplifier grid. To produce plate current of waveform required for deflection purposes the sine-wave variations of boosted B voltage must have a definite phase relation to the sawtooth grid voltage. This phase relation is obtained by adjusting the value of inductance in the low-pass filter or linearity con-

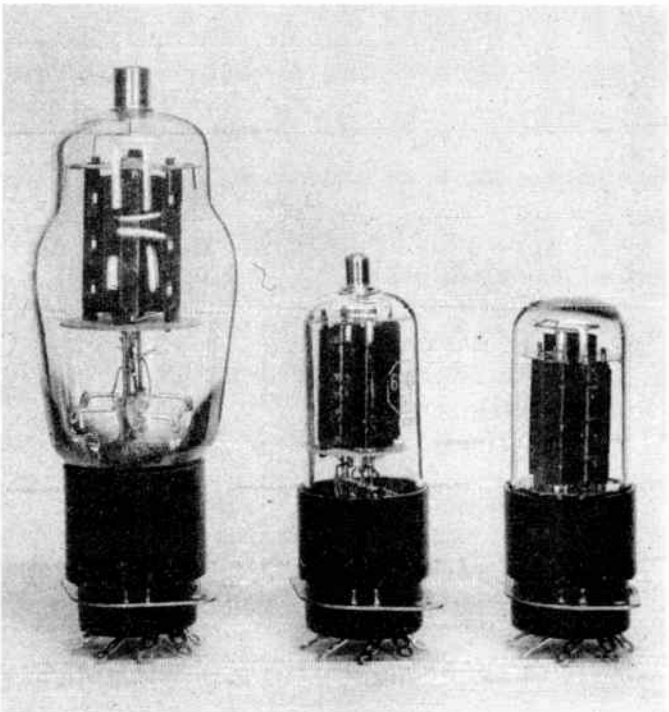

Fig. 3. Types and sizes of tubes used as horizontal output amplifiers.

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trol, thus preventing distortion or lack of "linearity" in the amplifier plate current.

HORIZONTAL OUTPUT AMPLIFIERS. In Fig. 3 you can see relative sizes and shapes of tubes commonly used as horizontal output amplifiers. Types 6BG6-G and 6CD6-G, pictured at the left, are of the same large size and both have top caps for plate connections. At the center is a 6BQ6-GT with the smaller glass envelope and with a top capfor its plate connection. Types 6AU5-GT and 6AV5-GT have no top caps, all elements being connected to base pins. These types are shown at the right.

Fig. 4 shows base pin and top cap connections for the horizontal amplifier tubes. All are beam power types. All have octal bases, some with six pins, others with seven. Heaters always are connected to pins 2 and 7.

Certain characteristics important in servicing and replacement are listed in the accompanying table. The 6BG6-G was the first tube especially designed for horizontal output amplifier service. The 6CD6-G will handle greater plate current than the 6BG6-G, but takes much greater heater current. The 6AV5-GT is essentially an improved version of the 6AU5-GT.

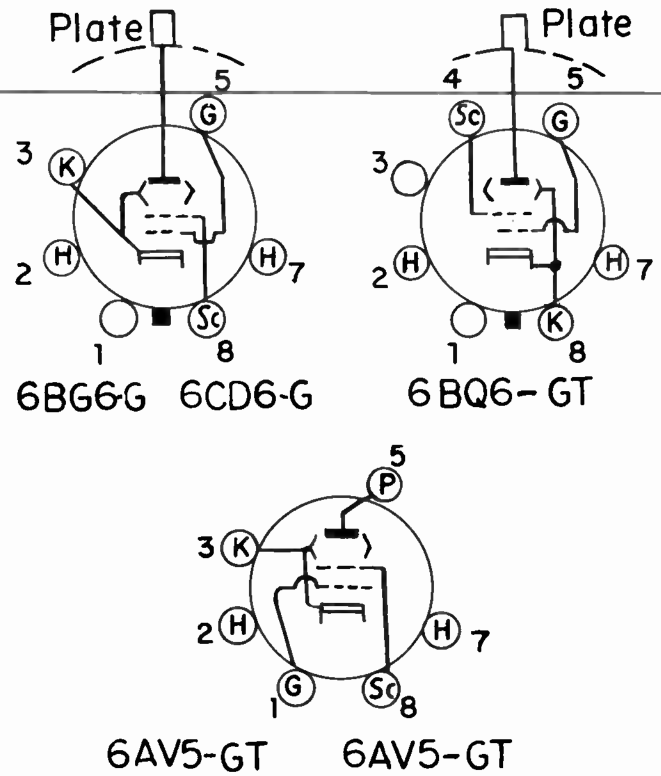

Fig. 4. Basing connections of tubes in general use as horizontal output amplifiers.

HORIZONTAL OUTPUT AMPLIFIERS					
RATINGS	6BG6-G	6CD6-G	6BQ6-GT	6AV5-GT	6AU5-GT
Heater Volts Current, amps	6.3 0.9	6.3 2.5	6.3 1.2	6.3 1.2	6.3 1.25
Plate, maximums Volts, d-c Milliamps, d-c Dissipation, watts	700 100 20	700 170 15	550 100 10	550 100 11	450 100 10
Screen, maximums Volts, d-c Dissipation, watts	350 3.2	175 3.0	200 2.5	200 2.5	200 2.5

As we learned when studying tubes in general, ratings such as listed are maximum permissible values for each factor considered by itself, and none of them may exceed the listed limits. For example, with a 6BQ6-GT, the combination of 550 plate volts and 100 plate milliamperes would result in power dissipation of 55 watts, which is $5\frac{1}{2}$ times the maximum permissible dissipation.

In some receiver designs, negative grid bias for the horizontal output amplifier is

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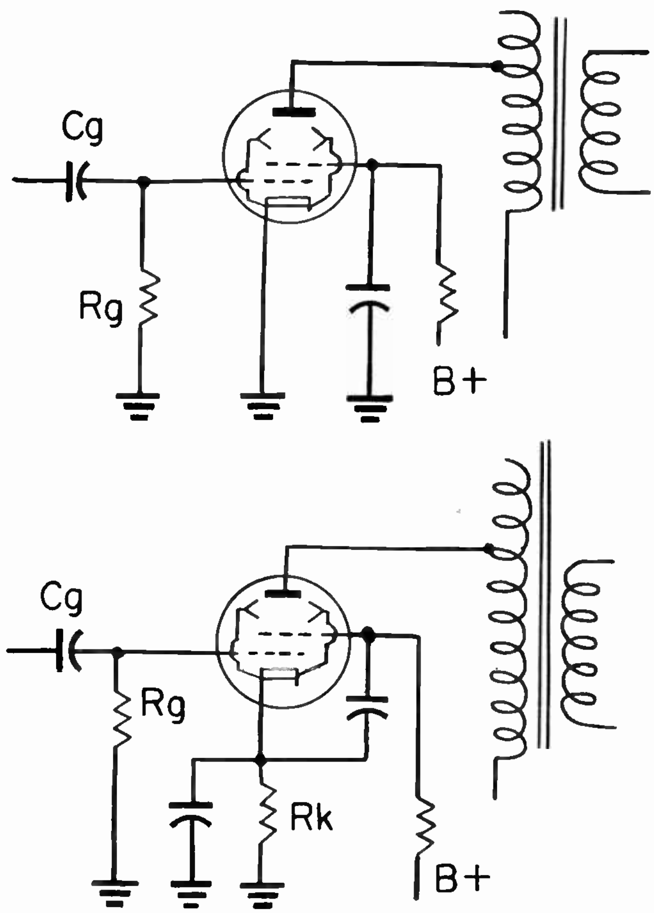

Fig. 5. Bias for the horizontal amplifier may be provided only by grid-leak action or by both grid-leak and cathode-bias methods.

provided solely by the grid leak method, as at the top of Fig. 5. Then the cathode is connected directly to ground or B-minus. In other cases, as in the bottom diagram, there is cathode bias in addition to grid leak bias.

Total negative grid bias is the voltage measured between grid and cathode. When this total is the result of both grid-leak and cathode biases, it will be equal to the sum of the drops across the grid resistor and the cathode resistor. The greater part of such a combined bias usually is obtained across the grid resistor, by means of grid-leak bias action. Total bias voltages usually are between 20 and 40 negative volts.

LINEARITY. One of the major troubles due to misadjustments and other faults in horizontal output amplifier and deflection circuits is poor linearity in reproduced pictures. Poor linearity means that pictures are not uniformly and correctly distributed on the screen or raster area of the picture tube. Objects in pictures may be unduly crowded together in some places and unduly spread or stretched in other places.

The dictionary says that linearity means the quality of extending along a straight line. To have good linearity and correct distribution of objects in pictures the waveform of current in horizontal deflecting coils must follow a straight line in the sawtooth portion between retraces, as in Fig. 6.

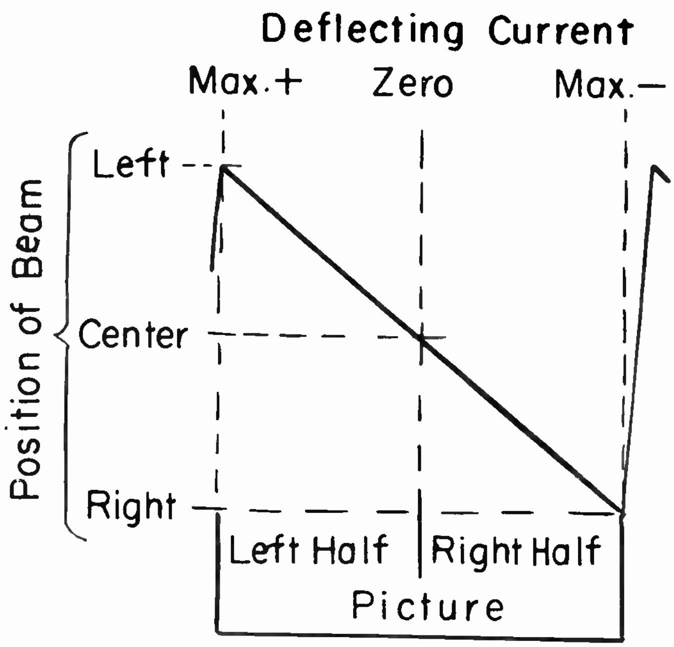

Fig. 6. When sawtooth current is linear, pictures will not be crowded or stretched but will be uniformly distributed across the screen.

As deflecting current changes from maximum in one polarity through zero and to maximum in the opposite polarity, it causes the electron beam to travel from left to right across the screen of the picture tube. We shall consider this current to be of maximum positive amplitude at the upper left on the diagram. With current of this value the electron beam is at the left side of the raster area, ready to commence tracing the left half of a picture.

As deflecting current decreases to zero at a uniform rate, or linearly, the beam travels at a constant rate to the center of the screen and traces everything which should appear in the left half of the picture being

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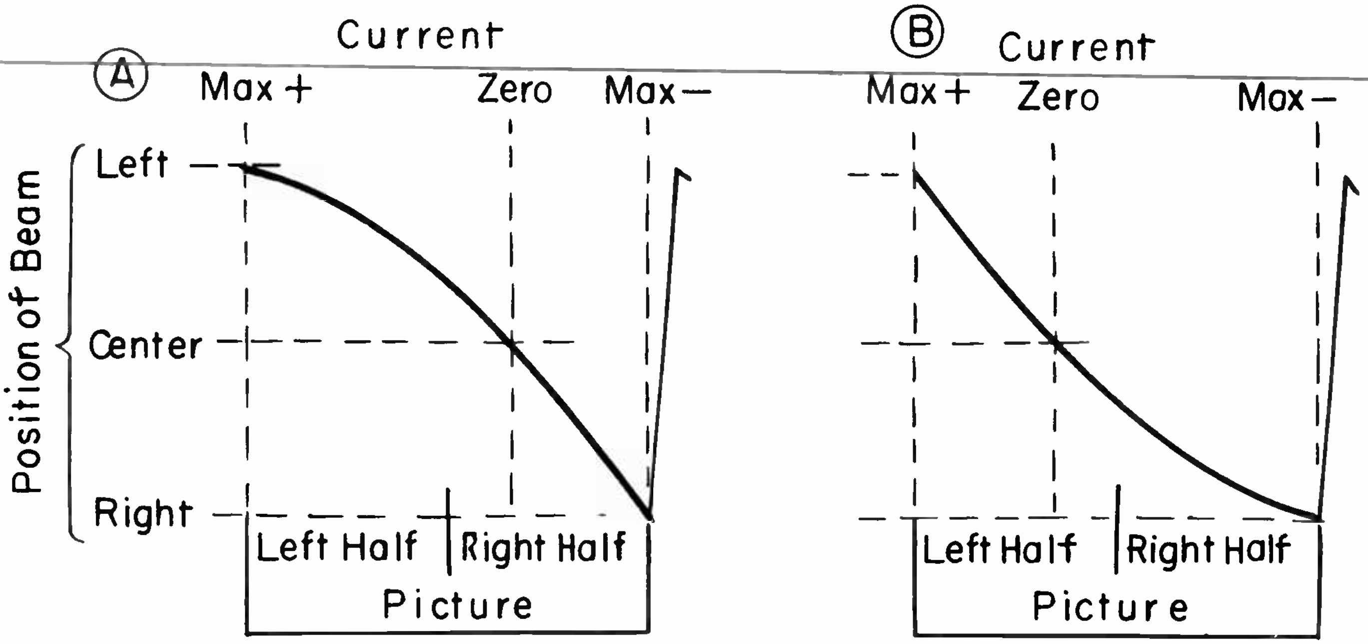

Fig. 7. When the sawtooth is non-linear, the beam does not travel across the screen at arate which corresponds to changes in the picture signals.

reproduced. Then, as current increases linearly to maximum in negative polarity the beam continues at the same constant rate to the right-hand side of the raster area, and traces the right half of the picture. At this instant the beam is blanked and deflecting current goes through its retrace back to maximum positive, ready to begin another horizontal line.

To understand the importance of good linearity we should know what happens when sawtooth deflecting current does not change at a constant rate or does not follow a straight line, and causes non-linearity. One such condition is illustrated at A on Fig. 7. Deflecting current decreases more slowly than normal from maximum positive to zero, and the beam takes longer than it should in traveling from the left side to the center of the screen.

During this slow travel of the beam, picture signals continue to come in at the regular rate. By the time the slow moving beam reaches the center of the screen the beam has been varied in intensity by video signals for all of the left half of the picture being reproduced and for part of the right half. Consequently, more than half of all the objects in the picture are crowded onto the left side of the screen area, while the remaining objects are spread out on the right side of the screen. This effect is shown by Fig. 8.

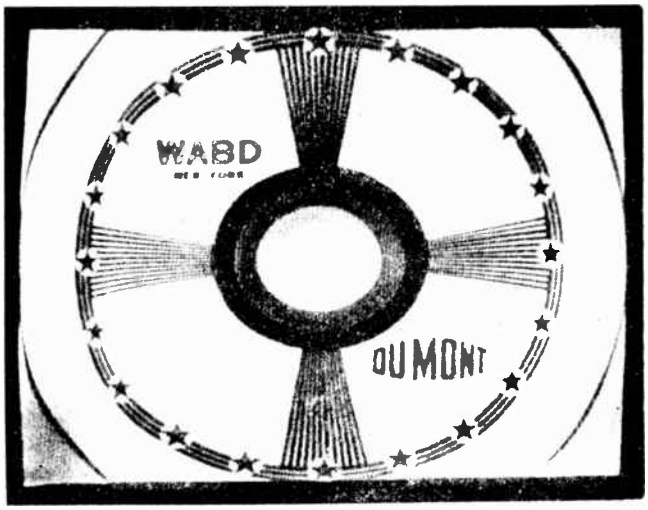

Fig. 8. The electron beam moves too slowly at the left, too rapidly at the right.

Another kind of non-linearity is illustrated at B of Fig. 7. Deflecting current here decreases too rapidly from maximum positive to zero, then goes too slowly from zero to maximum negative. Now the beam reaches the center of the screen during a time so short that only part of the left side of the picture has been received in the form of video signals. This relatively small portion of the picture is spread or stretched across the

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entire left half of the screen. The remainder of this first half of the picture, plus all of the right-hand half, is crowded onto the right-hand side of the screen. The result is shown by Fig. 9.

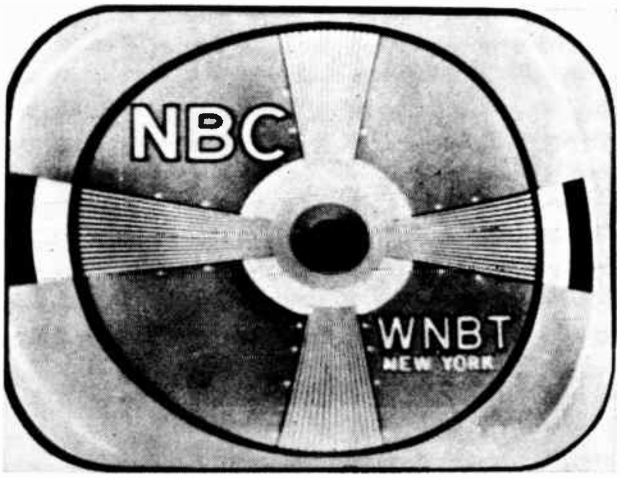

Fig. 9. The beam moves too rapidly at the left, too slowly at the right.

Non-linearity may have other forms than the two just discussed. We shall see examples in following pages. Non-linearity results not only from misadjustment of controls intended especially to correct this kind of trouble, but also from misadjustment of drive, width, and other controls not so directly associated with picture distortion. This is our reason for learning something about linearity and non-linearity before going ahead with study of sweep and deflection circuits.

DRIVE CONTROLS. As mentioned earlier, a drive control is any service adjustment capable of varying the strength or amplitude of sawtooth voltage applied to the grid of the horizontal output amplifier. Most drive controls consist of an adjustable capacitor in the grid circuit of the amplifier tube, as shown by Fig. 10.

The adjustable drive capacitor is in series with grid capacitor Cg between the sawtooth capacitor or sweep oscillator output and ground. When any alternating voltage is applied to capacitors in series with each other the voltage divides between the capacitors proportionately to their capacitive reactances. The arrangement is called a capacitance voltage divider.

The capacitance voltage divider acts just like a resistance voltage divider when we consider oppositions to current as consisting of capacitive reactances instead of resistances. Just as the greater voltage drop appears across the greater of two series resistors, so the greater drop appears across the greater of two capacitive reactances. We must keep in mind that capacitive reactance is inversely proportional to capacitance. The greater the capacitance in mmf the less is the reactance in ohms, and a lesser capacitance in mmf means more reactance in ohms.

The grid capacitor and the drive capacitor in series receive total sawtooth voltage from the sawtooth capacitor connected to the sweep oscillator. Part of this total voltage becomes a voltage drop across the grid capacitor, while the remainder becomes a voltage drop across the drive capacitor. Since the drive capacitor is connected between the amplifier grid and ground, the portion of the sawtooth voltage across the drive capacitor is applied to the amplifier grid.

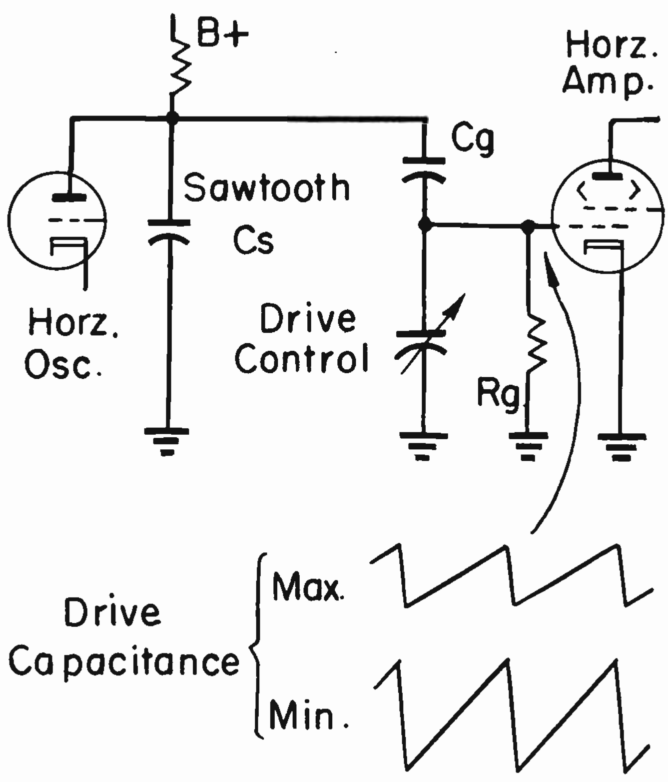

Fig. 10. A drive control most often is an adjustable capacitor in the amplifier grid circuit.

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In typical designs the grid capacitor, Cg of Fig. 10, may have some value between 250 and 600 mmf. Drive capacitors are adjustable between minimum of 20 to 40 mmf and maximums of 250 to 400 mmf. To illustrate the action we shall assume that sawtooth voltage from the oscillator circuit has peak-to-peak value of 120 volts, that the grid capacitor is a 400-mmf size, and that the drive capacitor is adjustable from 40 to 370 mmf.

At the horizontal frequency of 15,750 cycles per second, reactance of the grid capacitor is about 25,260 ohms. Reactance of the drive capacitor is adjustable from about 252,600 ohms when capacitance is at the minimum of 40 mmf, up to about 27,300 ohms when capacitance is at the maximum of 370 mmf.

With the drive capacitor set for maximum capacitance its reactance is roughly equal to reactance of the grid capacitor. Then the applied 120 sawtooth volts will divide roughly in equal amounts between the capacitors, and about half of the sawtooth voltage or approximately 60 volts will go to the amplifier grid.

When the drive capacitor is set for minimum capacitance its reactance is 10 times that of the grid capacitor. The 120 sawtooth volts will divide proportionately to 1 part across the grid capacitor and 10 parts across the drive capacitor. About 10.9 volts will be across the grid capacitor, and across the drive capacitor will be about 109 volts, which goes to the amplifier grid. Thus, with constant voltage from the sawtooth oscillator, adjustment of the drive control allows applying to the amplifier grid anything between 60 and 109 sawtooth volts.

A drive capacitor most often is a compression type mica capacitor or else an adjustable ceramic capacitor with adjustment by means of a screw driver slot or else a hexagon stud for a wrench. Depending on the construction, capacitance may be increased and capacitive reactance reduced by turning the adjuster either clockwise or counterclockwise. Adjustment for more grid voltage, less drive capacitance, is called increasing the drive. Adjustment for less grid voltage, more capacitance, is called reducing the drive. As soon as we learn the effects of drive adjustment you will have no trouble determining whether you are increasing or reducing the drive by turning the adjuster one way or the other.

Because the drive control alters the amplitude of sawtooth voltage on the grid of the horizontal output amplifier it alters the sawtooth plate current of this amplifier and also the sawtooth deflecting current in the yoke coils. Therefore, since amplitude of sawtooth deflecting current determines picture width, adjustment of the drive control will change the picture width. More drive (more amplifier grid voltage) will increase picture width, less drive will decrease the width.

Adjustment of a drive control varies the high voltage at the anode or ultor of the picture tube. Varying this ultor voltage affects brightness of pictures; more voltage causes brighter pictures, less voltage reduced the brightness. Drive adjustment varies high voltage for the picture tube in the following manner: More drive and proportionately greater amplitude of sawtooth deflecting current causes greater changes of current during retrace periods. This means stronger pulses of voltage induced in the output transformer, stronger pulses at the high-voltage rectifier, and greater voltage from this rectifier to picture tube.

Adjustment of a drive control from maximum to minimum capacitance may easily increase voltage at the picture tube ultor by 50 per cent, or from something like 8,000 volts to 12,000 volts. Many manufacturers advise adjusting the drive only while you have a voltmeter with a high-voltage probe connected to the picture tube ultor terminal. Exceeding the maximum high voltage recommended for a particular type of picture tube could very well overload the tube and cause rapid destruction of the screen materials.

When the drive is reduced, by increasing capacitance, and the picture is thereby made narrower, there is likely to be cramping or crowding on the left-hand side of the screen. That is, most of the narrowing effect occurs at the left. This is not always true; it depends on many details of circuit design.

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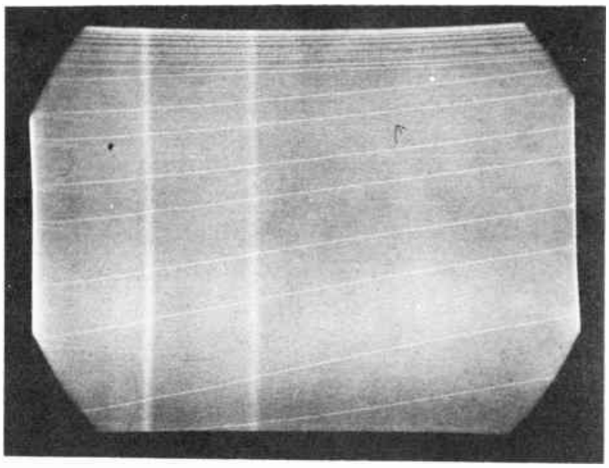

Fig. 11. Bright vertical lines on a raster or on pictures often indicate wrong adjustment of the drive control.

When excessive drive unduly increases high voltage to the picture tube and causes more than normal brightness, nearly always there will be one or more bright vertical lines or narrow bars on the left-hand side of the screen. These bright lines appear in pictures, but may be seen even more clearly with only a raster while the selector is set for a channel on which there is no transmission. Fig. 11 shows vertical lines of this kind as they appear on a raster.

DRIVE ADJUSTMENT. A drive control consisting of a variable capacitor connected as in Fig. 10 should be adjusted as follows.

1. Increase the drive, reduce the capacitance, as far as possible without causing appearance of vertical bright bars (Fig. 11) or undue crowding of part of pictures.

2. Adjust the width control or horizontal size control so that pictures are approximately of the same width as the mask opening.

3. Adjust any separate linearity control as may be necessary to prevent either crowding or stretching of pictures.

4. While adjusting width and linearity controls, reduce the drive should this be necessary in preventing appearance of bright vertical bars.

5. If pictures become excessively bright and cannot readily be made wide enough to fill the mask opening, it may be advisable to measure the high-voltage at the ultor or high-voltage anode of the picture tube by means of a voltmeter equipped with a high-voltage probe. If this voltage is as high or almost as high as the maximum rating for the particular type of picture tube, reduce the drive to bring voltage to or below 90 per cent of the maximum rating.

6. Final adjustment of the drive should be with minimum capacitance that allows satisfactory linearity, width, and brightness or ultor voltage. When adjustment is correct, slight changes should have relatively slight effect on width and brightness. If these characteristics change decidedly with small variations of drive control, it is probable that there is insufficient drive or that the control is adjusted for too much capacitance.

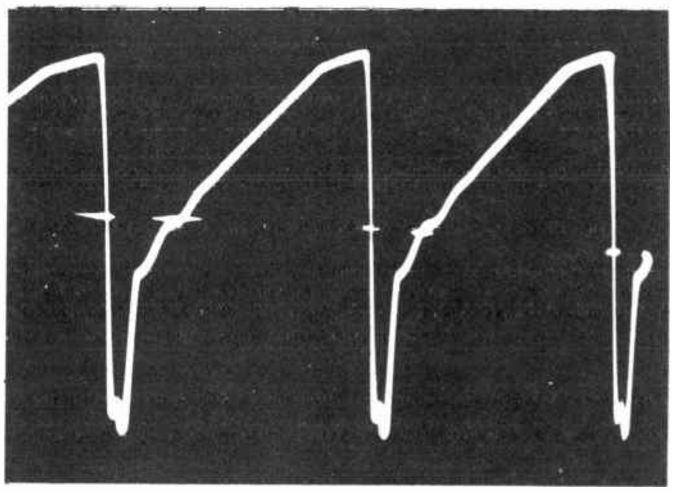

Fig. 12-A

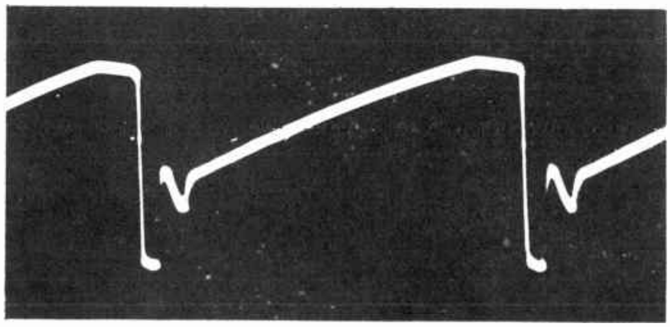

Fig. 12-B

Fig. 12. Negative peaking at the beginning of each sawtooth cycle or at each horizontal retrace.

NEGATIVE PEAKING. In order to produce a sawtooth current wave in the horizontal deflecting coils it is, of course, necessary to apply a sawtooth voltage to the grid of the

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horizontal output amplifier. In many receivers, but not in all, each sawtooth of grid voltage is preceded by a negative dip or negative peak such as those on the traces of Fig. 12. The chief purpose of this negative peak, when present, is to cause sudden cutoff of plate current in the output amplifier and thus to reduce the time required for horizontal retraces.

Sudden stoppage of plate current in the primary of the horizontal output transformer induces equally sudden reversal of voltage in the secondary and a fast reversal of current in the horizontal deflecting coils. It is this reversal of deflecting current that constitutes the horizontal retrace.

It might be mentioned that on the wave at A of Fig. 12 the sawtooth portion measured 53 volts while the added negative peak measured 37 volts. This made a total of 90 peak-to-peak volts for the combined waveform. Overall peak-to-peak values in most receivers are in the range of 70 to 130 volts.

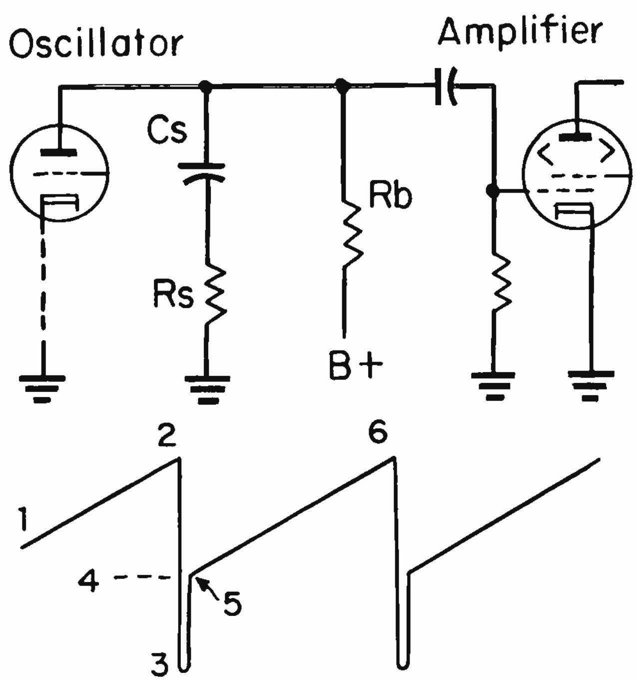

Fig. 13. Negative peaking results from delayed discharge of the sawtooth capacitor.

A negative peak may be added to the waveform from a sawtooth capacitor by means of a resistor in series with the capacitor, as in Fig. 13. The sawtooth capacitor usually is of a value between 300 and 700 mmf, with a series resistor of 4,000 to 10,000 ohms.

While the oscillator tube is non-conductive, sawtooth capacitor Cs is charged by current through the small series resistance at Rs and the much greater resistance at Rb, which is the resistor leading to the B-supply. This charging increases capacitor voltage from 1 to 2 on the waveform shown below the circuit diagram.

When conduction commences through the oscillator the tube becomes practically a short circuit, of negligible resistance, in parallel with Cs and Rs. Since there can be no appreciable potential difference where there is a short circuit, voltage measured from the plate to cathode of the oscillator and from the top of Cs to the bottom of Rs drops instantly from its maximum level at 2 to near zero at 3 on the voltage wave.

But capacitor Cs can discharge only through resistor Rs. Discharge cannot be instantaneous because the capacitor and resistor have a time constant of some small fraction of a second. Accordingly, although voltage across Cs and Rs together is near zero, the charge which has not had time to escape from Cs maintains a voltage across this capacitor equal to the level at 4 on the voltage wave.

As soon as the oscillator cuts off and becomes non-conductive, voltage applied from the receiver B-supply through resistor Rb causes almost instant rise of voltage from 3 to 5 as measured from the top of Cs to the bottom of Rs. However, when this rapidly rising voltage reaches the level at 5 it has become equal to the voltage remaining on the capacitor. Further rise of voltage then must proceed more slowly from 5 to 6 along the sawtooth wave, because now the capacitor is being recharged.

A different way of obtaining negative peaking is illustrated by Fig. 14. The sawtooth wave A results, as usual, from alternate charge and discharge of sawtooth capacitor connected to the oscillator plate and the B-plus line. From the secondary of the horizontal output transformer, to which are connected the deflecting coils, are taken

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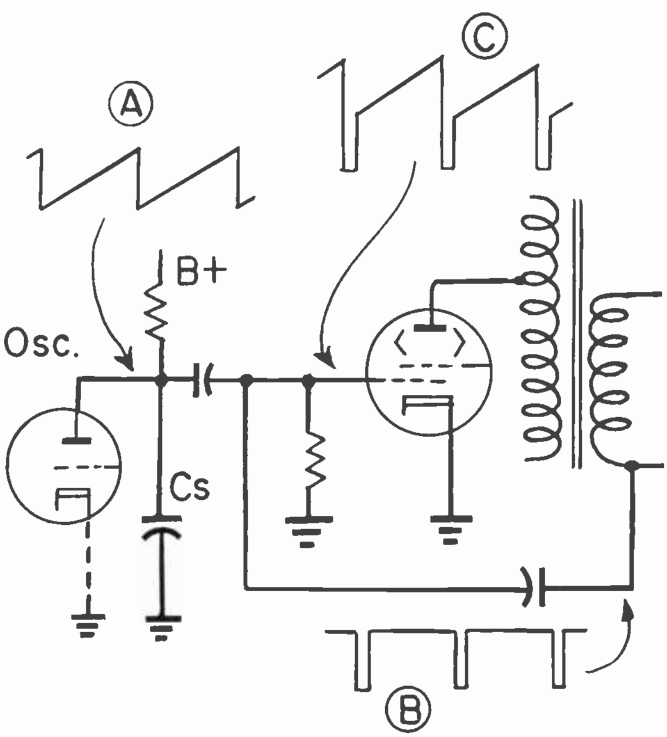

Fig. 14. A negative peak may be added to a sawtooth wave by feeding back a negative pulse from some point on the output side of the amplifier tube.

brief negative pulses B which occur at the instant of each retrace. The sawtooth with added negative pulses, C, are fed together to the grid of the horizontal output amplifier. Similar negative pulses may be taken from various other places in the deflecting circuits.

When sudden cutoff of plate current is not obtained by negative peaking at the amplifier grid it may be caused by sudden drops of amplifier screen voltage. Voltage for the amplifier screen may be taken wholly or in part from some point in the deflection circuits at which there are sharp negative drops during retrace periods.

Negative peaking affects the portion of each sawtooth cycle in which amplifier plate current remains cut off. More peaking, which means deeper negative peaks, increases the cutoff time. When we come to study action of the damper tube it will appear that formation of linear sawtooth deflecting current requires that the cutoff period be neither too long nor too short.

Peak-to-peak sawtooth voltage at the output amplifier grid tends to remain fairly constant regardless of peaking, as in Fig. 15. Then increased peaking, at A, leaves less of the overall voltage for the sawtooth portion of the wave, or reduces the amplitude of the sawtooth. It is this amplitude of sawtooth grid voltage, and resulting amplitude of sawtooth deflecting current that determine how far the electron beam in the picture tube is deflected from left to right. For this reason, more peaking and less sawtooth amplitude reduces picture width. Less peaking, as at B, increases sawtooth amplitude and picture width.

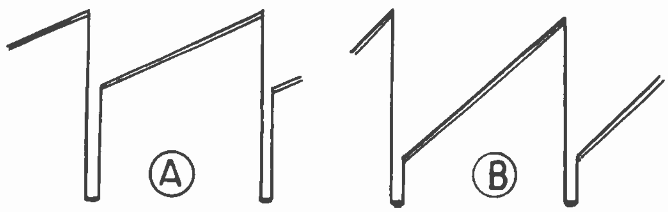

Fig. 15. Change of negative peak voltage alters the sawtooth voltage without affecting the peak-to-peak voltage.

Variations of peaking at the grid of the horizontal output amplifier do not affect the waveform of sawtooth current in the horizontal deflecting coils, although the amplitude is changed. That is, horizontal deflecting current remains of plain sawtooth waveform regardless of the degree of peaking at the amplifier grid. Peaking does not, or at least should not appear in the deflecting current.

Negative peaking of grid voltage at the grid of the horizontal output amplifier is not affected by adjustment of a drive control. Varying the drive changes the peak-to-peak grid voltage, but does not alter the relative proportions of sawtooth and peak portions of the wave.

ADJUSTABLE PEAKING (RESISTANCE DRIVE CONTROL). In a number of receivers, especially those of earlier design, the negative peaking resistor which is in series with the sawtooth capacitor is adjustable. As illustrated in Fig. 15, varying the amount of peaking varies the amplitude of the sawtooth portion of the combination wave. This variation of sawtooth amplitude applied to the grid of the horizontal output amplifier has much the same effect as variation of peak-to-peak voltage of the combination wave by

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means of a capacitor type drive control. Consequently, the variable peaking controls most often are called drive controls. When there is this type of drive control, consisting of an adjustable resistor, there will not be a capacitor type drive control.

Adjustment of a resistance type drive control which actually varies the peaking and indirectly the sawtooth amplitude, may be carried out in the same manner as that of a capacitor type drive control. In receivers employing peaking as the drive control, there seldom is danger of producing the bright vertical lines of Fig. 11. There may be considerable effect on horizontal linearity. In fact, the adjustable peaking control is called a linearity control or an auxiliary linearity control by several receiver manufacturers.

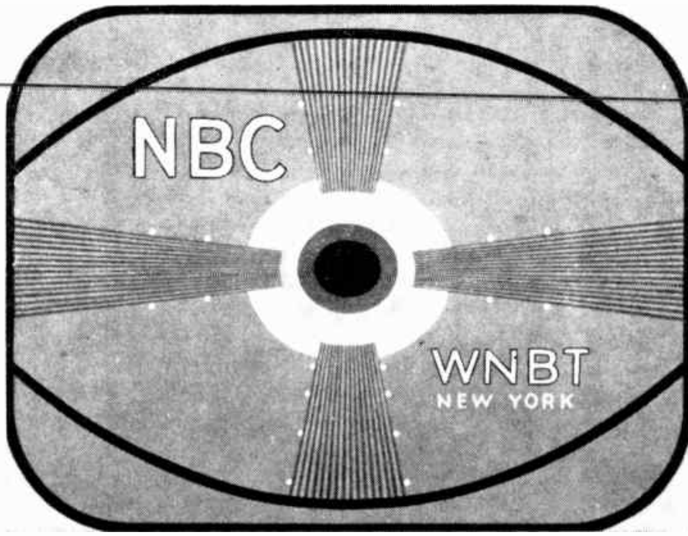

Fig. 17. Excessive sweep of the beam makes the pictures too wide.

Fig. 16. Pictures are too narrow when the electron beam has insufficient sweep.

PICTURE WIDTH. When the electron beam in the picture tube does not sweep far enough from left to right we have narrow pictures, as in Fig. 16. When the beam sweeps too far, the sides of pictures are cut off as in Fig. 17. Most receivers have a service adjustment for width or horizontal size. This adjustment should be set so that pictures extend a quarter-inch or somewhat more beyond the edges of the mask at both sides, when centering is correct.

Width adjustment should make pictures slightly wider than the mask opening in order that no dark or blank screen areas may be visible at the sides under any conditions of reception. Deflection is almost certain to be a little less on signals from some stations than from others. Also, there is likely to be some horizontal shift as the receiver warms up, and width will vary with fluctuations of power line voltage.

Service adjustments for width or horizontal size have sufficient range to make pictures of correct horizontal dimensions only when everything else which affects horizontal deflection is in good order. The number of these other things which affect width is astonishingly large. We shall consider them along with the many types of width adjustments.

Width is affected in some receivers by an adjustable resistor in the line furnishing B-voltage to the sawtooth capacitor and the plate of the horizontal sweep oscillator. Reducing this resistance increases charging voltage to the sawtooth capacitor, which means more sawtooth voltage. That is, sawtooth voltage rises to a greater value during periods of capacitor charge, which are the periods between discharges and horizontal retraces. The stronger sawtooth voltage goes to the grid of the horizontal output amplifier and increases picture width just as does an increase of drive. In fact, the adjustable resistor which alters sawtooth amplitude in this manner usually is called a drive control, not a width control.

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LESSON 68 – HORIZONTAL SWEEP CIRCUITS

Picture width will be increased by increasing the transconductance or gain of the horizontal output amplifier, since this will increase the sawtooth plate current for any given sawtooth voltage applied at the grid. The most effective way of increasing gain is to increase screen voltage. This is done in a number of receivers by a width control which is an adjustable resistor in the B-supply line to the screen of the output amplifier.

The principle of screen voltage variation often is of help when changes or substitutions of parts make it impossible to secure sufficient width by adjustment of width or drive controls. One method of increasing width in such cases is by reducing the value of a voltage dropping resistor in series with the screen of the output amplifier, thus increasing screen voltage and amplifier gain.

When changing the value of a screen resistor it is essential not to exceed the maximum rated plate current for the amplifier tube. To check plate current, connect a d-c milliammeter with a range of at least 200 ma in series with the output transformer terminal connected to the B-supply or boosted-B supply. Plate current goes through this terminal. Never connect any ordinary meter at the plate cap or plate pin of a horizontal amplifier tube, because pulses of several thousand volts occur at the plate. Do not reduce the screen dropping resistor below a value with which plate current is more than 90 per cent of rated maximum for the tube in use.

You will find that increasing screen voltage on the horizontal output amplifier increases the high voltage to the second anode or ultor of the picture tube. Increase of second anode voltage, considered alone, would tend to make pictures narrower. However, the widening effect of greater amplitude in sawtooth deflecting currect more than overcomes the narrowing effect of higher second anode voltage, and the net result of more amplifier screen voltage is more picture width.

There have been a few receivers in which an adjustable cathode bias resistor on the horizontal output amplifier has been used for width control. Because most of the total grid bias results from grid leak action, with a smaller fraction from cathode bias, increasing the cathode bias resistance may cause less rather than more total bias. However, decreasing the cathode bias resistor still makes the pictures wider.

Voltage applied to the second anode or ultor of the picture tube has a decided effect on picture size unless the effect is overbalanced by changes of amplitude in deflecting current. When studying the matter of deflection in general we learned that making the second anode highly positive with reference to the cathode gives electrons great velocity between electron gun and screen. The greater the voltage and resulting electron velocity the more difficult it is for deflecting magnetic fields to turn the electrons away from a straight path toward the screen. The deflecting fields cannot make pictures either so wide or so high as though there were less voltage on the second anode and less velocity of electrons.

Several receivers make use of variable second anode voltage as a width adjustment. The voltage is varied by changing the effective inductance, and thereby the inductive reactance, of the portion of the horizontal output transformer which is an auto-transformer extension for high voltage. This adjustment changes overall size, height as well as width, for the reason that greater or less electron velocity affects deflection in any or all directions. After picture width is satisfactorily adjusted by varying the second anode voltage, an independent adjustment in the vertical sweep circuit is used to alter picture height as may be necessary.

<u>WIDTH CONTROL ON OUTPUT TRANSFORMER.</u> The type of width control most often used consists of an adjustable inductor connected to one of the windings on the output transformer. Fig. 18 is a picture of several width control inductors or coils. All have movable cores with screw adjusters. These coils may be mounted through holes in the back or possibly in the top of a chassis, or they may be mounted on brackets attached to the output transformers or to some point near the transformers.

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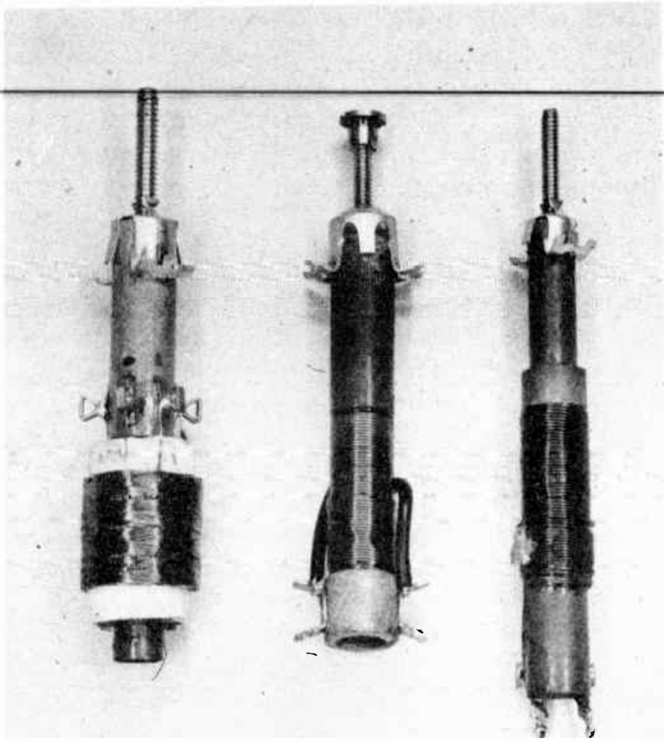

Fig. 18. Adjustable inductors such as connected to horizontal output transformers for width control.

In the circuit diagram of Fig. 19 a width control coil is connected across part of the turns of the output transformer winding. Width controls sometimes are at one end and again at another end of a winding which connects also to the deflecting coils and the damper tube. Oftentimes the width control is connected to a separate secondary winding of the output transformer. In this latter case one side of the width control and transformer winding usually are grounded.

A width control inductor on the horizontal output transformer is a load on the transformer and absorbs energy which otherwise would go to the horizontal deflecting coils in the yoke. This absorption of energy occurs no matter where the width control inductor is connected, whether to a separate winding or to a winding connected also to the yoke.

The greater the amount of energy absorbed by the width control, the less remains for the deflecting coils and the narrower are pictures. More energy is absorbed when the control is adjusted for less inductive reactance, which means adjustment for less inductance. Therefore, turning the width control slug farther out of its coil makes pictures narrower. Turning the slug farther in increases the control inductance, increases the inductive reactance, lessens the absorption of energy, and allows wider pictures.

You should think of the effects of inductance reactance, in ohms, as similar to those of resistance, in ohms. Were we to connect a high resistance to the output transformer this resistance would draw only small current, and because power is proportional to current squared there would be little dissipation of power and energy. This would leave more power and energy for the deflecting coils, and pictures would be wider. Less resistance (or less inductive reactance) would draw more current, take more power and energy away from the deflecting coils, and pictures would be narrower.

When the width control inductor is suited to the transformer, and properly connected, this type of control causes decided changes of picture width within the range of adjustment. The entire picture area expands and contracts uniformly unless the control unit is of too little inductance or is adjusted for too little inductance, whereupon there may be crowding at the right.

If parts have been changed or substituted it may be necessary also to substitute a new width control of greater inductance if pictures cannot be made wide enough, or a control of less inductance if pictures cannot be made narrow enough.

Disconnecting a width control inductor at one or both of its terminals prevents energy absorption from the output transformer. Pictures then will expand to maximum possible width, usually going well beyond the sides of the mask opening.

When a width control inductor is connected across more turns of a transformer winding, or to winding taps between which there are more turns, the inductor is subjected to greater voltage. Then the inductor will carry more current, will absorb more energy, and pictures will be narrower. Connecting the width inductor across fewer

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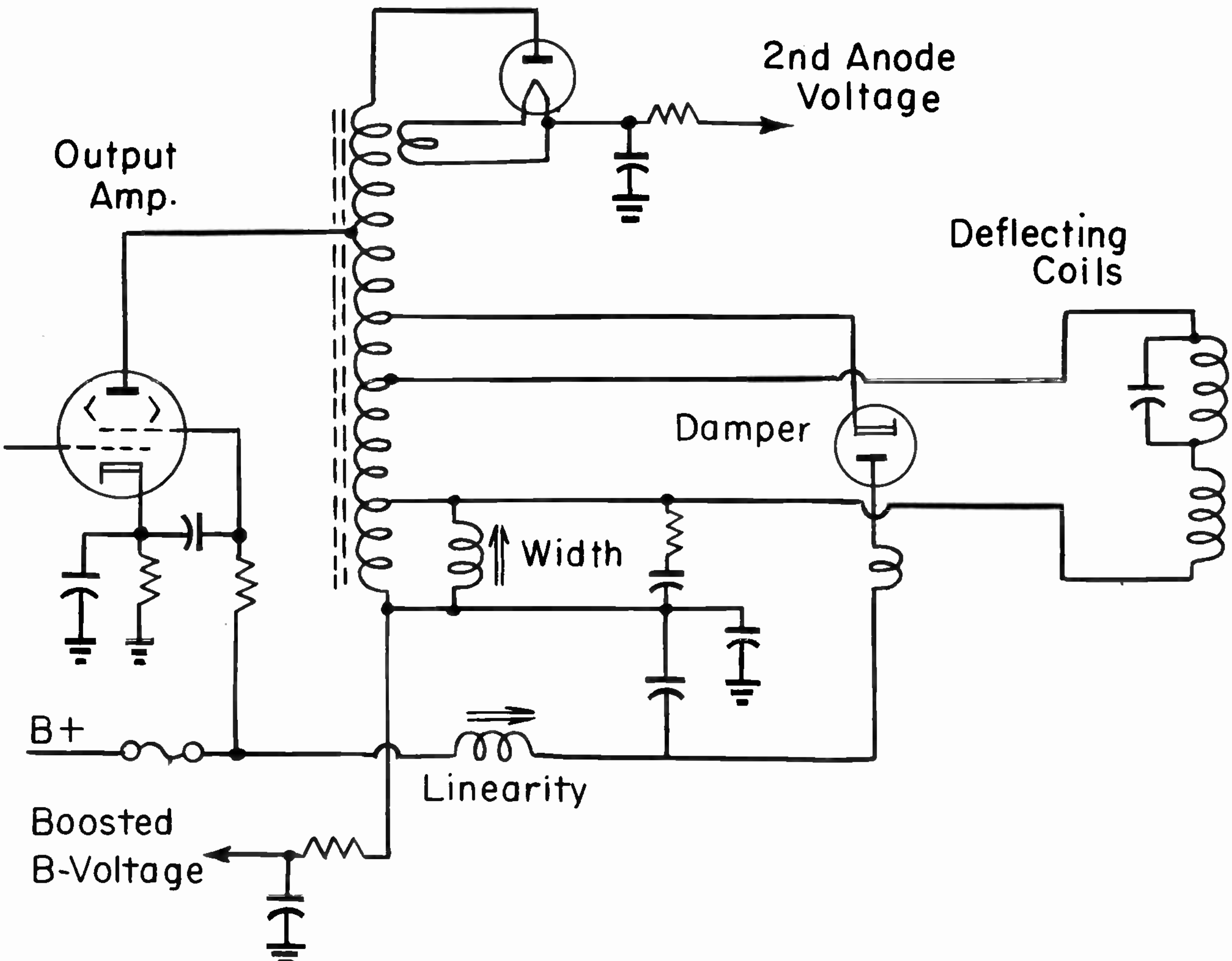

Fig. 19. A width control inductor is connected across turns at one end of the output transformer in this deflecting circuit.

transformer turns subjects it to less voltage, less power is absorbed, and pictures will be wider.

If changes or substitutions make it necessary to connect a width control across greater transformer voltage, more turns, than originally, it will be necessary to use a new inductor having greater inductance and inductive reactance. Should the alternations make it necessary to connect the width control across less transformer voltage, fewer turns, it may be necessary to use a control unit having less inductance and inductive reactance.

Adjustment of a width control inductor will alter the voltage at the second anode of the picture tube. Setting the control for more inductance, with the slug farther into the coil, will increase inductive reactance, lessen the absorption of power, and increase the second anode voltage. This increase of voltage tends to make a narrower picture, but the accompanying increase of deflecting current overcomes the effect of anode voltage, and pictures become wider.

From what has been said about performance of width control inductors it is apparent that the value of control inductance must be suited to the output transformer and to the transformer taps to which the control unit is connected. Unless you are willing to do a great deal of experimenting, use only a width control recommended for the type of output transformer in the receiver, and connect the control according to instructions.

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Width control coils of various types have a great variety of inductance ranges. Some are adjustable from 0.3 to 1.4 millihenrys and others for as much as 6.5 to 40.0 millihenrys, with many other ranges in between. A coil of too little inductance connected across too much voltage will prevent production of high voltage for the picture tube, and the control coil may burn out. Too much inductance may prevent variations of width great enough for service requirements.

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Lesson 69

HORIZONTAL DEFLECTION CIRCUITS

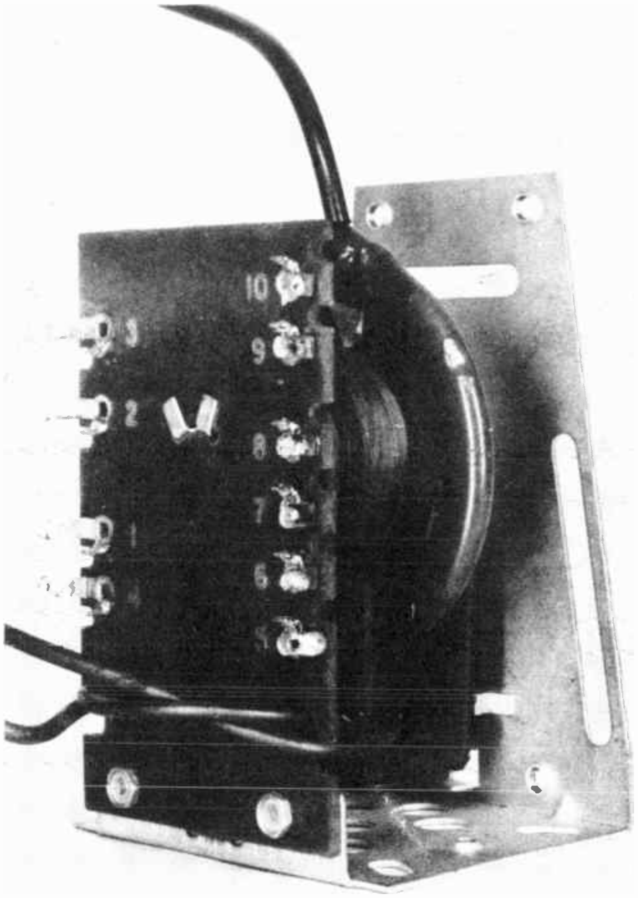

Fig. 1-A

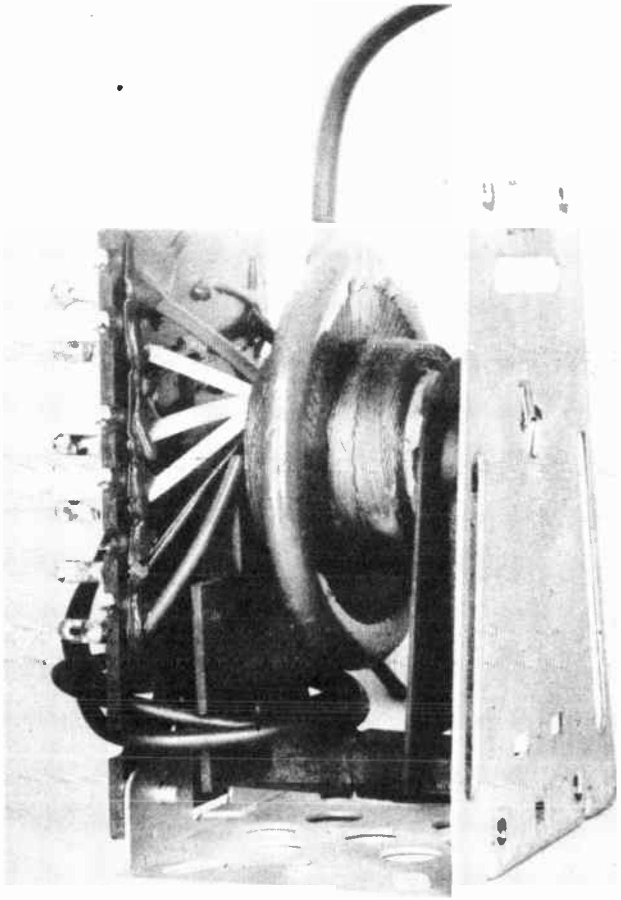

Fig. 1-B

Fig. 1. A horizontal output transformer viewed from one side to show the windings and from the front to show terminal and tap connections.

The external appearance of a common type of horizontal output transformer is pictured by Fig. 1. Considered with reference to the windings there are two common varieties of these output transformers, as shown in principle by Fig. 2.

At A in Fig. 2 there is a separate insulated secondary winding to which are connected the horizontal deflecting coils. To the primary winding is connected the plate-cathode circuit of the horizontal output amplifier. There is a step-down ratio of voltage and step-up of current between primary and secondary, or between the amplifier plate circuit and the deflecting coils. A continuation of the primary winding above the amplifier plate connection acts, in conjunction with the primary, as a step-up autotransformer winding providing high voltage for the rectifier-filter system which supplies the second anode or ultor of the picture tube.

At B is represented the type of horizontal output transformer usually referred to as an autotransformer. There is no separate insulated secondary winding. Instead, the deflecting coils are connected across only part of the principal winding. This portion serves as a secondary. The plate-cathode circuit of the horizontal output amplifier includes a greater part of the principal winding,

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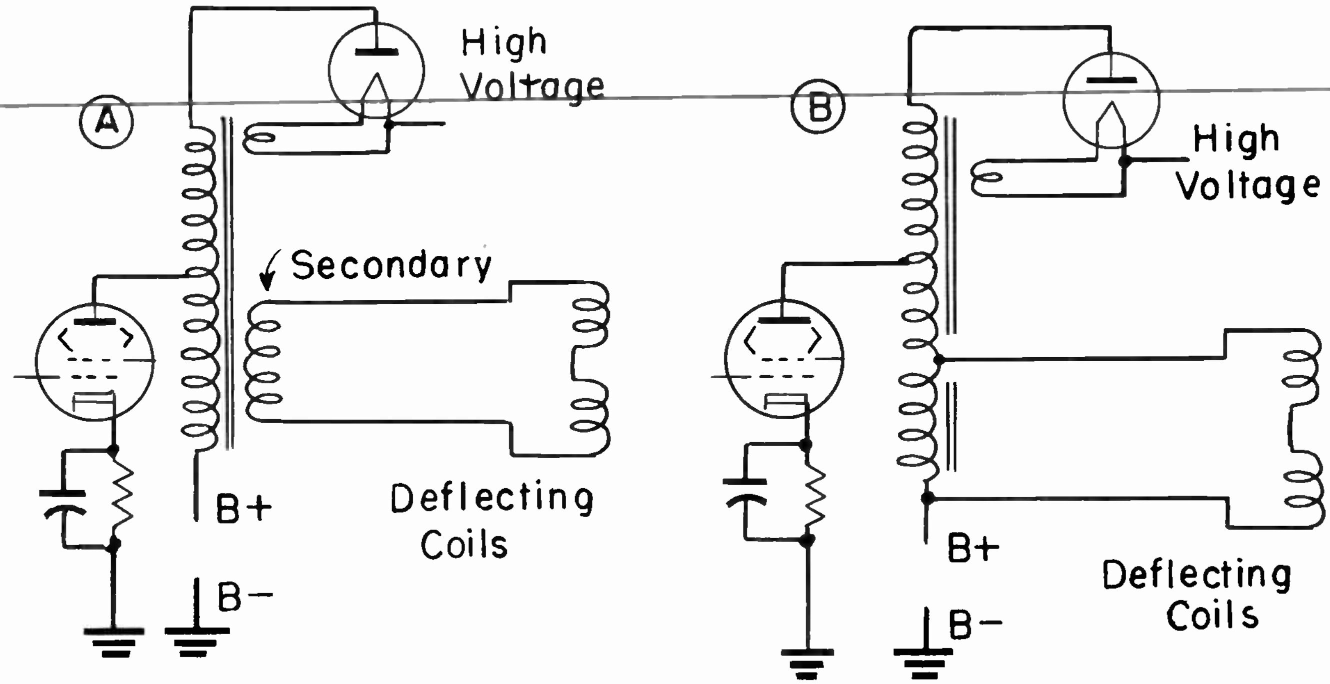

Fig. 2. An output transformer with insulated secondary (A) and one constructed as an auto-transformer (B)

with this portion serving as a primary. Between output amplifier and deflecting coils there is a step-down ratio of voltages and a step-up ratio of currents. This type of transformer has the same high-voltage extension as the type with insulated secondary.

On both types of output transformers there is an additional small secondary winding for the filament-cathode of the high-voltage rectifier tube. There may be other separate secondaries for connection of width control inductors, and for pulse feed-backs to horizontal afc systems and keyed agc systems.

An output transformer is needed because of the high plate resistance of the horizontal amplifier and the much lower impedance of the horizontal deflecting coils. Plate resistance and coil impedance must be matched through the transformer primary and secondary impedances. To permit selection of suitable turns ratios and impedance ratios, many transformers, especially those designed for replacement purposes, have taps on an autotransformer winding or on both primary and secondary of a two-winding transformer. Tap terminals may be seen on the transformer of Fig. 1.

In a few receivers the deflecting coils are of such great inductance and impedance as to match the plate resistance of the horizontal output amplifier, whereupon the tube plate is connected directly to the deflecting coils without a transformer. In other cases two output amplifiers of a type having rather small plate resistance are connected in parallel to further reduce the plate resistance. These amplifiers are directly connected to the horizontal deflecting coils, without a transformer.

A mismatch of tube plate resistance and deflecting coil impedance greatly lessens the power transferred into the coil circuit. The results include narrow pictures, lack of linearity, fluctuations of brightness, reduction of picture tube second anode voltage, fuzziness, and other troubles. Output transformers and deflecting yokes not designed to work together, and with the output amplifier tubes, cause some of the most puzzling problems in service work. Wrong connections between tubes, transformers, and yokes are just as bad.

Fig. 3 shows connections such as used in many deflection systems which include autotransformers. Connections fairly typical of

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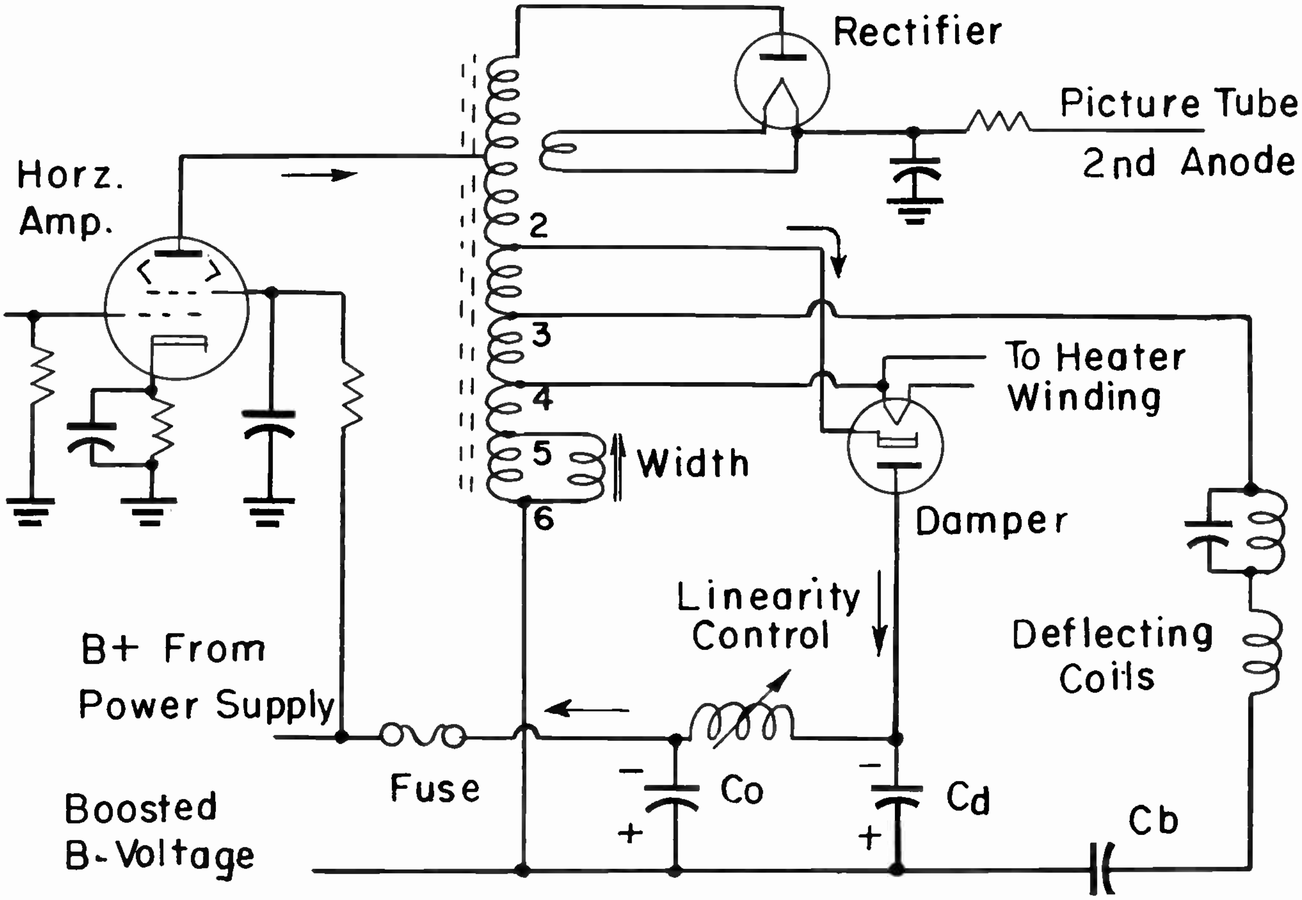

Fig. 3. A deflecting system employing an autotransformer for coupling the amplifier plate to the horizontal deflecting coils.

systems including transformers with insulated secondaries are shown by Fig. 4. We shall compare some of the more important features of the two systems to note similarities and differences which affect service operations.

A. Path of d-c plate current for the horizontal amplifier tube.

Autotransformers. Fig. 3. From amplifier plate through the transformer from 1 to 2 and to damper cathode. From damper plate through linearity inductor and the fuse to B+ of power supply. From B- of power supply through ground back to amplifier cathode.

Insulated Secondary. Fig. 4. From amplifier plate through transformer primary, the fuse, linearity inductor, and to damper cathode. From damper plate through transformer secondary to B+ of the power supply. From B- of power supply through ground to amplifier cathode.

B. Charging of capacitor Cd.

The potential difference developed by charging of this capacitor adds to the power supply voltage in order to provide boosted B-voltage.

Autotransformer. Fig. 3. Current through the damper tube is in such direction that capacitor Cd is charged in the marked polarity. The positive side of the capacitor is toward the boosted B-voltage, with the negative side toward B+ of the receiver power supply. Voltage across Cd thus adds to the regular B-voltage.

Insulated Secondary. Fig. 4. Damper current is in a direction to cause charging of capacitor Cd in the marked polarity. The positive side of Cd is toward the boosted B-voltage. The regular B+ voltage reaches the positive side of Cd through the damper, thus allowing the two voltages to add together. Of

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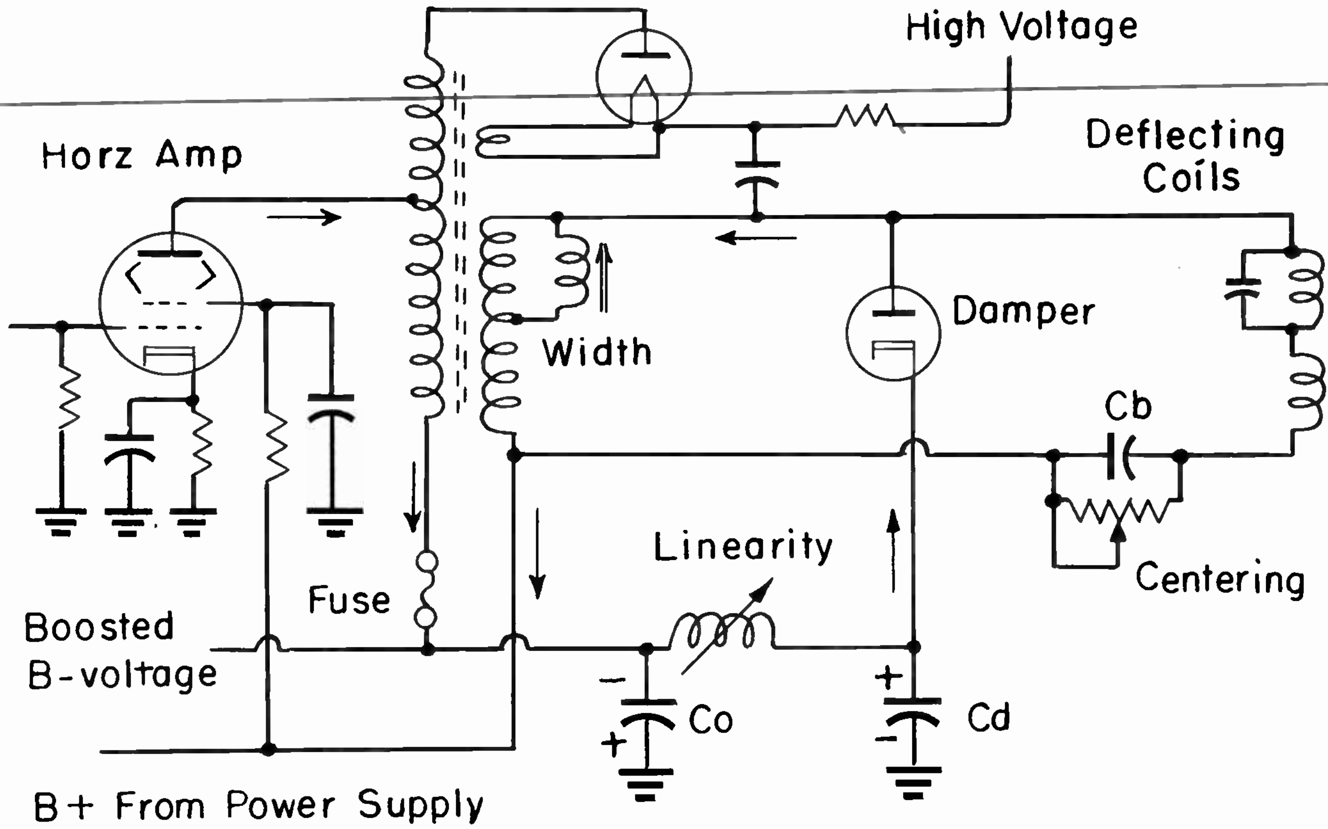

Fig. 4. A deflecting system in which the amplifier plate is coupled to the horizontal deflecting coils through a two-winding transformer.

course, it is not actually B+ voltage that reaches through the damper, it is capacitor charging current forced through the damper by this voltage. The effect, however, is the same.

C. Low-side connections of capacitors Cd and Co.

Regardless of the transformer type, the low side of both these capacitors may be connected either to ground or to the B+ line, or one may be connected to ground and the other to the B+ line. There is greater potential difference across the capacitors when connected to ground, and the units may require higher d-c voltage ratings.

D. Path of sawtooth (alternating deflecting current.

Autotransformer. Fig. 3. Voltage which causes deflecting current originates in the transformer winding between terminals 3 and 6. The high side of the deflecting coils is connected directly to terminal 3, with the low side connected through the small reactance of capacitor Cb to terminal 6. Capacitor Cb, thus connected, prevents flow of direct current in the deflecting coils while allowing flow of sawtooth deflecting current, which is alternating.

Insulated Secondary. Fig. 4. Deflecting current here originates in the entire secondary, but often is taken from taps between which is only part of the secondary. The high side of the deflecting coils is directly connected to the high side of the secondary, with the low side of the coils connected through low-reactance capacitor Cb to the low side of the secondary.

Across capacitor Cb in this diagram is an adjustable resistor which acts as a horizontal centering control by allowing a small direct current to flow in the deflecting coils. Such a width control is not always used, whereupon capacitor Cb blocks direct current from the coils.

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E. Fuse connections.

Peak voltages in deflecting circuits are high enough to cause danger of insulation breakdown. Resulting short circuits might damage costly parts. Also, circuit faults or misadjustments might allow excessive plate and screen circuit in the horizontal amplifier tube, which would ruin the tube. A fuse, usually of 1/4-ampere rating, may be used at any point which designers feel will provide adequate protection against overcurrent. This fuse is not found in all receivers.

F. Width control connections.

An adjustable inductor for width control may be connected between any transformer taps, on either primary or secondary sections, or it may be connected to a separate secondary. No matter where connected, this type of width control provides an adjustable load which diverts more or less energy away from the deflecting coils.

G. Damper heater connections.

Autotransformer. Fig. 3. The damper cathode is connected to a transformer tap at which are alternating voltage pulses that accompany sudden reversals (retraces) of deflecting current. These pulses usually reach values in excess of 2,000 volts.

When the pulses are negative they make the damper cathode negative. Then the tube conducts, and current flows through it from cathode to plate and to circuits carrying B+ and boosted-B voltages. The very low cathode-to-plate resistance during conduction practically short circuits the negative pulses into the relatively low-voltage circuits. Thus, during negative pulses, potential at the damper cathode can be little higher than that in the low-voltage circuits connected to the plate.

Positive voltage pulses make the damper cathode positive, and the tube cannot conduct because of exceedingly high cathode-to-plate resistance. Consequently, the full potential of positive pulses remains on the cathode, it is not shorted into the low-voltage circuits. Positive pulses at the plate of a horizontal output amplifier are shown at A of Fig. 5. Pulses from a lower tap on an autotransformer are shown at B. There is no change of polarity and but little change of waveform at various taps on an autotransformer.

The heater of the damper receives heating current from a winding on the power transformer of the receiver B-supply system, where normally there is practically zero voltage to ground, other than for capacitive effects. Then between heater and cathode in the damper there is full voltage of positive pulses in the deflecting coil circuit.

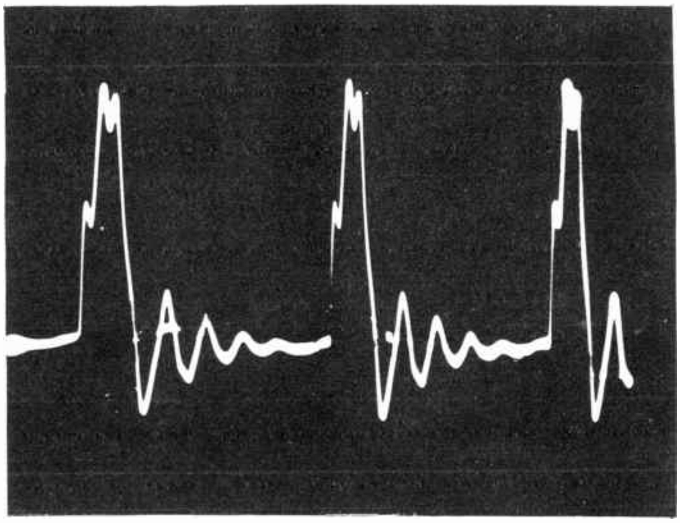

Fig. 5-A

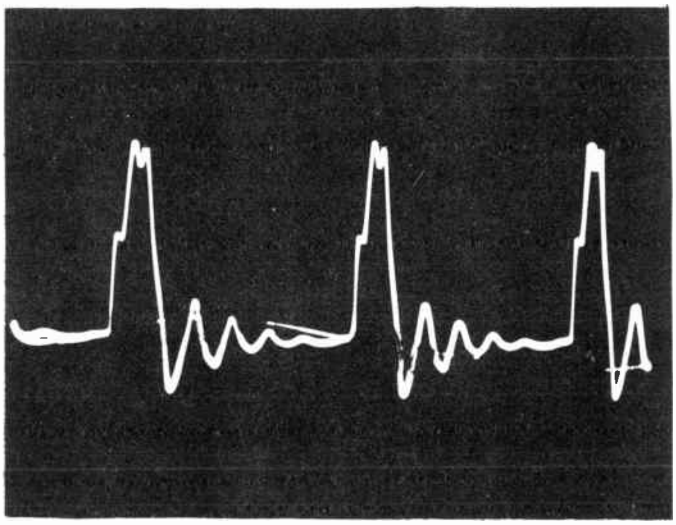

Fig. 5-B

Fig. 5. Positive pulses of voltage at the plate of an output amplifier appear as positive pulses at other taps on an autotransformer winding.

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Cathode-heater insulation in some tubes used as dampers is barely able to withstand the very high potential differences, and there is danger of breakdown. For example, the 6W4-GT damper diode is rated for 2,100 maximum peak volts between cathode and heater when the heater is negative with reference to the cathode. Should there be breakdown from cathode to heater the pulse voltage would reach the heater winding in the power transformer, and might puncture the insulation of this winding to allow a short circuit through the transformer to chassis ground.

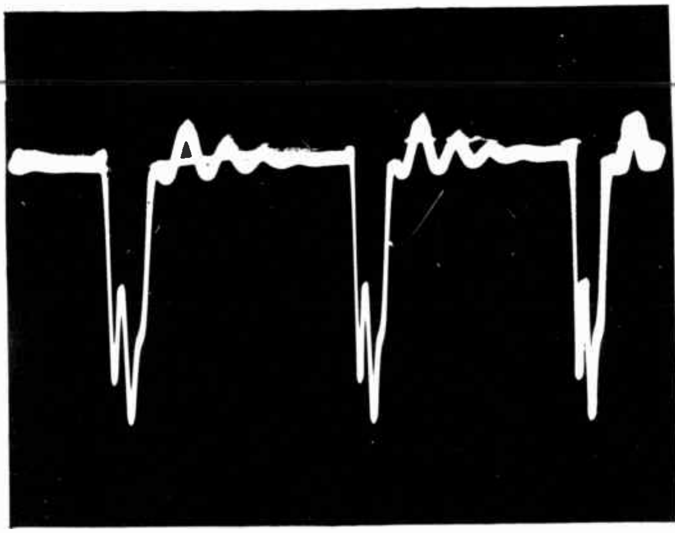

Fig. 6. Pulses at the high side of an insulated secondary are negative.

In many receivers the heater of the damper tube is connected to a tap on the output transformer which is negative with reference to the tap for the cathode, as to tap 4 in Fig. 3. Then voltage between cathode and heater cannot exceed that between transformer taps to which these tube elements are connected. Danger of insulation breakdown is greatly reduced.

Tubes more recently designed for damper service have cathode-heater insulation capable of withstanding higher voltages. The 6AX4-GT damper tube is rated for 4,000 maximum peak volts between cathode and heater. The 6V3 damper is similarly rated for 6,000 volts, always with heater negative. With these tubes it is not necessary to connect the heater to a tap on the output transformer.

Insulated Secondary. Fig. 4. The plate rather than the cathode of the damper is connected to the high sides of deflecting coils and transformer secondary. The damper becomes conductive by positive pulses or alternations of the high voltage which accompanies retrace of sawtooth current. Then negligible plate-cathode resistance through the tube practically short circuits the positive pulse voltage into the relatively low-voltage B+ and boosted-B circuits.

Negative pulses or alternations make the damper plate negative, and the tube becomes non-conductive. Full potential of the negative pulses remains at the damper plate, because these pulses are not shorted into the lower-voltage circuits connected to the damper cathode. Fig. 6 shows such pulses as observed at a damper plate connected to the high side of the insulated secondary on an output transformer. When voltage pulses are positive at the amplifier plate and at the high end of the primary to which the plate connects, voltage pulses will be negative at the high end of an insulated secondary on the same output transformer.

The high negative pulse voltage is acting between plate and cathode of the damper, not between cathode and heater, and is what we call a peak inverse voltage because it makes the plate negative. The 6W4-GT damper tube is rated for 3,500 peak inverse volts from plate to cathode, well in excess of any probable pulse peaks. Therefore, when used with an insulated-secondary transformer, this tube does not require a connection from its heater to a transformer tap. Such a tap is, however, used as an added precaution in some receivers. Peak inverse plate-cathode rating of the 6AX4-GT damper is 4,000 volts, and of the 6V3 it is 6,000 volts, so neither of these tubes requires a connection from its heater to the output transformer.

You will find wide variations in connection details of deflecting circuits which employ principles discussed with reference to Figs. 3 and 4. As one example, Fig. 7 shows an example of an autotransformer system in

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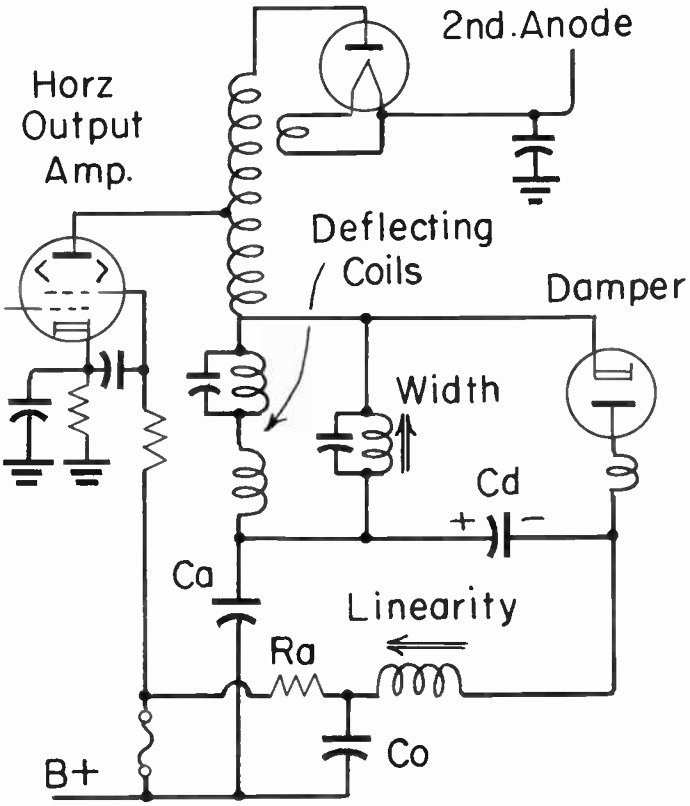

Fig. 7. The deflecting coils form the secondary section of the autotransformer winding.

which the deflecting coils themselves form the step-down secondary of the autotransformer. Service diagrams seldom place the deflecting coils so close to the remainder of the transformer as in our example, but by tracing the connections you will find that the circuit is essentially as shown here.

Across the deflecting coils is an adjustable inductor for width control. Shunted on the width inductor is a capacitor whose effect is to widen the pictures. This width control connection is equivalent to placing the control inductor across any part of any transformer winding so far as energy absorption is concerned.

Across the deflecting coils, or across the portion of the transformer represented by these coils, is also the damper tube. The damper cathode is toward the high side of the deflecting circuit, this being a damper connection which is typical of all autotransformer systems.

D-c plate current from the plate of the horizontal output amplifier flows through the portion of the transformer winding above the deflecting coils, thence to the damper cathode. Current from the damper plate flows through a radio-frequency choke which helps suppress oscillations at undesired high frequencies. D-c current flows from the choke through the linearity inductor, resistor Ra, the fuse, and to B+. From B- this plate current returns through ground to the amplifier cathode.

D-c current is kept out of the deflecting coils by capacitors Cd and Ca. Capacitor Cd is charged in the marked polarity, with its high positive charge voltage toward the deflecting coils and through them and part of the transformer winding to the amplifier plate. Sawtooth alternating current in the transformer-coil circuit completes its path through capacitor Ca.

DAMPER ACTION. When studying the performance of horizontal output amplifiers we learned that there is a negative bias which causes plate current cutoff during approximately the first half of each cycle of sawtooth voltage on the grid. This cutoff action may be seen at A of Fig. 8, which is an oscilloscope trace of cathode current, not voltage, in a horizontal output amplifier.

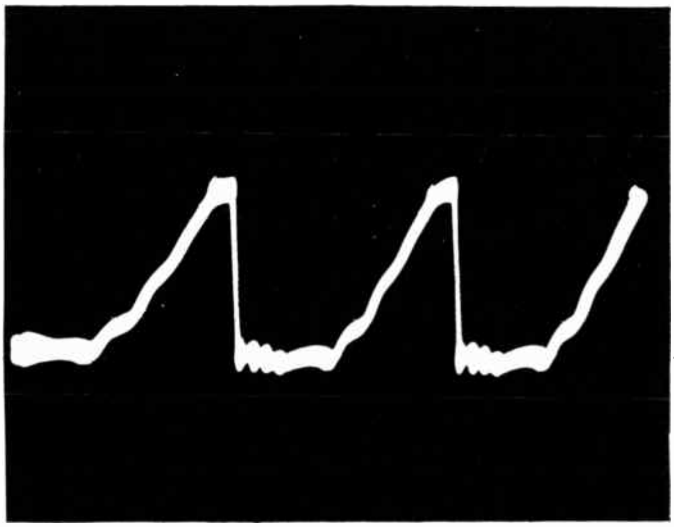

Fig. 8-A

The exact waveforms of amplifier cathode and plate currents vary with values of circuit components and with adjustments. In

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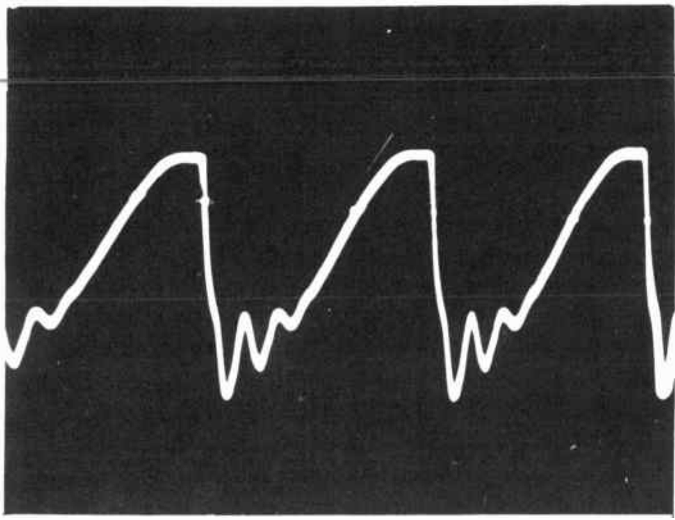

Fig. 8-B

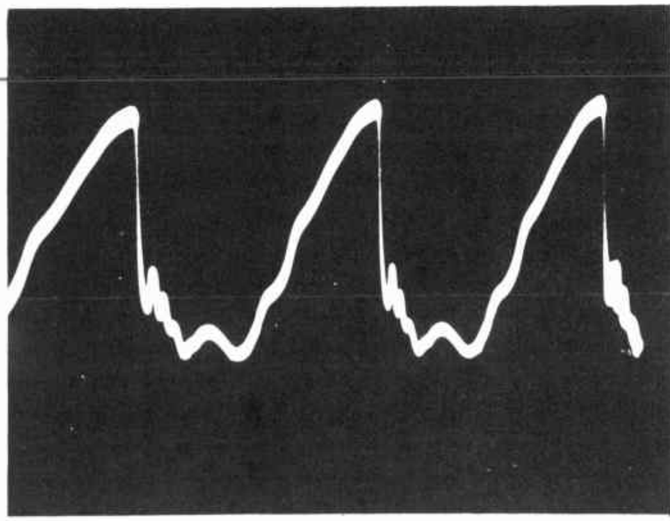

Fig. 8-C

Fig. 8. The effect of plate current cutoff in horizontal output amplifiers is shown by these traces of cathode currents and plate current.

a different receiver the trace of cathode current appeared as at B. A trace showing amplifier plate current, as at C, is generally similar to a trace of cathode current. In any case the cutoff action is quite apparent.

Plate current cutoff leaves only what would be the last half or the positive alternation of a complete sawtooth. This half of the sawtooth plate current can induce in the horizontal deflecting coils only a similar second half of sawtooth waveforms required for deflection. The first half of sawtooth current waveforms is produced by the damper, acting as follows.

The waveform of amplifier plate current, as cut off, is represented at 1 of Fig. 9. This is the same current shown by Fig. 8. At the completion of each gradual rise you can see that current drops very suddenly to zero. There is equally sudden drop of current which has been induced in the deflecting coil circuit. This causes a strong pulse of counter-emf. The pulse of counter-emf shocks the deflecting coil circuit into oscillation at the resonant frequency of inductances and capacitances in the circuit, usually at about 60 kilocycles per second.

Were nothing further done about it, the oscillating current in the deflecting coil circuit would appear as at 2 of Fig. 9. After each shock excitation the oscillations would die away because of energy losses in the circuit.

We are assuming that the first alternation of oscillating current in the deflecting coil circuit is negative, and that the high side of this circuit is connected to the damper plate. Reactance in this circuit is chiefly inductive, because of transformer and deflecting coil windings. Voltage in an inductive circuit leads the current by nearly 90 degrees, or a quarter-cycle. Accordingly, by the time oscillating current reaches its negative peak at A of diagram 2, the leading oscillating voltage has gone through its own negative peak and has returned to zero. Then, while current is changing from A to B, the leading voltage would be changing from zero to C, or would become positive.

The damper has been non-conductive while oscillating current changes from zero to A, because during this period the leading oscillating voltage has kept the damper plate negative. Consequently, there is no suppression or short circuiting of the oscillating current while this current changes from zero to A.

When the leading oscillating voltage becomes positive, with oscillating current maximum negative at A, this positive voltage on the damper plate makes the tube conductive. Energy which otherwise would have

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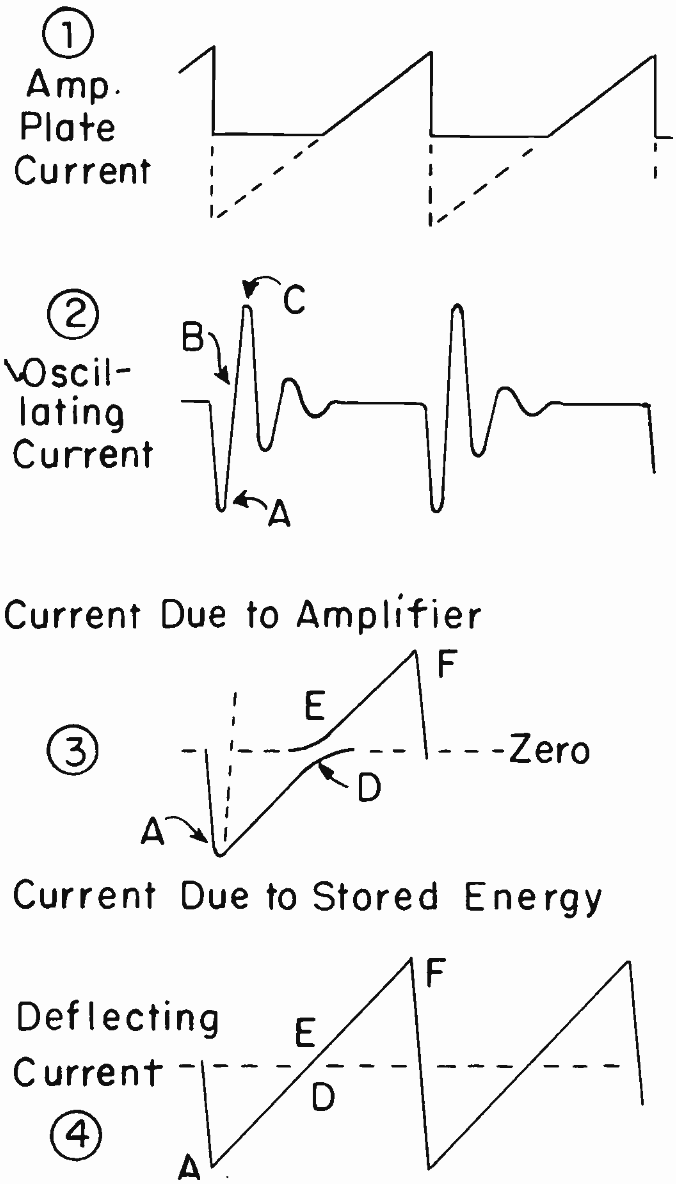

Fig. 9. How damper action and stored magnetic energy provide the first half of each sawtooth current wave.

maintained oscillating current from A through B, C, and so on, in diagram 2, is shorted through the damper to lower-voltage circuits. Consequently, the oscillation actually is stopped or damped when the first current alternation reaches its maximum negative peak at A.

Now we have the conditions of diagram 3. The rapid change of oscillating current from zero to A has caused strong magnetic fields to appear around the deflecting coils and transformer winding. Magnetic energy is stored in these fields. Due to the inductance-resistance time constant of the coil-transformer circuit, energy from the magnetic fields cannot return instantly to the circuit, which means that the fields do not instantly collapse. During the relatively slow collapse of the magnetic fields they return energy to the circuit at a rate which maintains current at the slowly diminishing rate from A to D.

When current due to energy from the magnetic fields approaches zero, at D of diagram 3, the output amplifier commences to conduct after its cutoff period, as in diagram 1 of Fig. 9. This new amplifier plate current induces deflection coil current which increases from E to F on diagram 3.

If everything about the sweep and deflection circuits is in good order, and if all adjustments are correct, coil current induced by amplifier plate current takes up at E of diagram 3, where current due to stored energy leaves off. Then we have the smooth sawtooth wave of deflecting current shown by diagram 4.

Had the first alternation of oscillating current in the deflecting circuit been positive instead of negative, the actions would have been as described except for reversals of all polarities. Then the damper cathode instead of plate would have been connected to the high side of the deflecting coil and transformer circuit. This would result in damping the oscillating current at its first positive peak, and current due to stored magnetic energy would have continued from there.

As you will realize from examining diagrams 2 and 3 of Fig. 9, the higher the resonant frequency of the deflecting coil and transformer circuit the less time will be consumed during retraces. This is because higher frequency means shorter periods of resonant oscillation and shorter times for change of current from zero to point A. Since fast retrace is highly desirable, we must take care to avoid excessive stray and distributed capacitances in the deflecting coil circuit, since more capacitance slows the oscillating frequency and the time of retrace.

A weak or defective damper tube may result in horizontal foldover as illustrated by Fig. 10. A whole series of foldovers with

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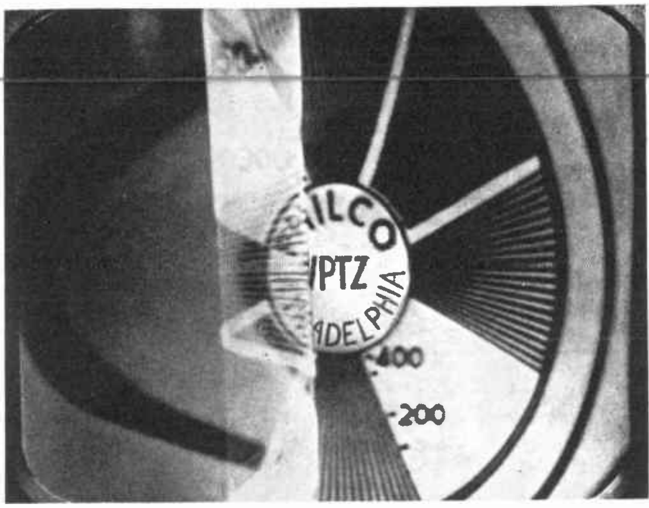

Fig. 10. A defective damper tube may cause this kind of horizontal foldover.

Fig. 11. Open or disconnected damper capacitors may cause this kind of foldover.

bright vertical lines or bars, as in Fig. 11 may mean an open or disconnected capacitor in position Cd of Figs. 3 and 4, or possibly, at position Co.

Successive foldovers, rippling, stretching, or the appearance of bright vertical bars on pictures may indicate insufficient voltage applied to the damper, to cause what is called underdamping. This is corrected by moving the connection of either damper element to a transformer tap which will include more transformer turns between damper plate and cathode.

Excessively high voltage on the damper, an unlikely condition, may cause crowding on the left sides of pictures. This would be overdamping. Correction is made by moving the connection of either or both damper elements to include fewer transformer turns between the elements.

DAMPER TUBES. The accompanying table lists ratings for diodes which are now used and which have been used in the past as dampers.

DAMPER TUBE RATINGS

TYPE	6V3	6AX4-GT	6W4-GT	5V4-G
Base	Miniature	Octal	Octal	Octal
Pins	Nine	Six	Six	Eight
HEATER Volts	6.3	6.3	6.3	5.0
Amps	1.75	1.2	1.2	2.0
MAXIMUM RATINGS				
Peak inverse plate volts	6000	4000	3500	1400
Current peaks, ma	600	600	600	525
Peak heater-cath volts*	6750	4000	2100	
D-c heater-cath volts*	750	900	450	

* Heater to be negative with respect to cathode.

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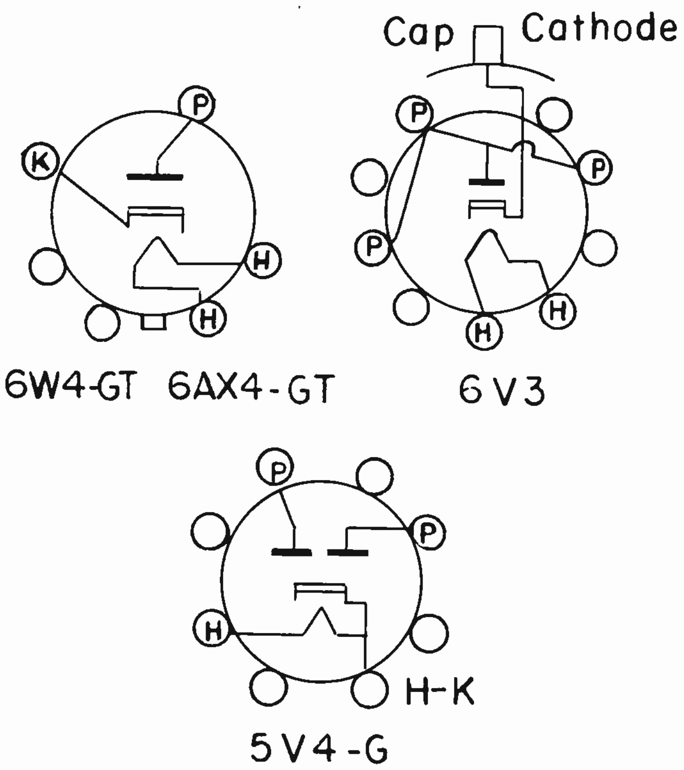

Fig. 12. Basing connections of damper tubes.

Basing connections for damper tubes are illustrated by Fig. 12.

The 6V3, a miniature nine-pin type, has its cathode connected to a top cap to avoid breakdown between base pins at high-voltage pulses. This also keeps the highest voltage connections on top of the chassis, where there is less chance of shorting to other conductors. Note that the single plate is connected to three of the base pins.

The 6AX4-GT and 6W4-GT have the same envelopes (GT style), the same pin connections, and the same ratings for heater volts and amperes. Therefore, the 6AX4-GT may be a replacement for the 6W4-GT. A 6W4-GT is not a replacement for the 6AX4-GT because of a lower peak heater-cathode voltage rating.

The 5V4-G, originally designed for a full-wave power rectifier, was used as a damper in many early receivers. There are no ratings for heater-cathode voltages because the two elements are connected together internally. There is always a separate heater winding for this tube on the power transformer. In a receiver rebuilt for larger picture tube with higher deflecting currents and voltages, a 5V4-GT should be replaced with one of the other types, which requires rewiring at the socket.

In a few receivers of early design the damper is a twin triode 6AS7-G. Plates are tied together, grids are tied together, and cathodes are tied together. Negative pulse peaks at the plates must not exceed 1,700 volts.

BOOSTED B-VOLTAGE. In the deflecting circuits of Figs. 3, 4, and 7 a capacitor marked Cd is connected to the lower-voltage element of the damper tube, which may be either the plate or the cathode. The other side of the capacitor is connected either to ground or a B+ line. Conduction current through the damper charges these capacitors in such polarity that their high positive charge voltage is toward the plate of the horizontal output amplifier, and often toward plate and screen leads for other tubes as well.

Peaks of charge voltage applied through the damper to the capacitor are nearly as great as voltage peaks applied from the high side of the deflecting circuit to the damper, since the damper has small internal resistance during conduction periods. The average of capacitor voltage due to rectification of deflection pulses by the damper is the boost voltage. Boost voltage alone may amount to almost anything from 40 volts to 200 volts or more. Connection of the damper capacitor to B+ voltage from the receiver d-c power supply, directly or indirectly adds the boost voltage to the regular B+ voltage. The sum of these voltages is the boosted B-voltage, which may be 400 to 500 volts or even more.

When there is a linearity control inductor the boosted voltage usually is taken through it to circuits operated from this voltage. The inductor, in combination with capacitors Cd and Co of our earlier diagrams, act somewhat similarly to a low-pass inductor-capacitor filter in a d-c power supply, to smooth the boosted B-voltage.

A linearity inductor in the damper cir-

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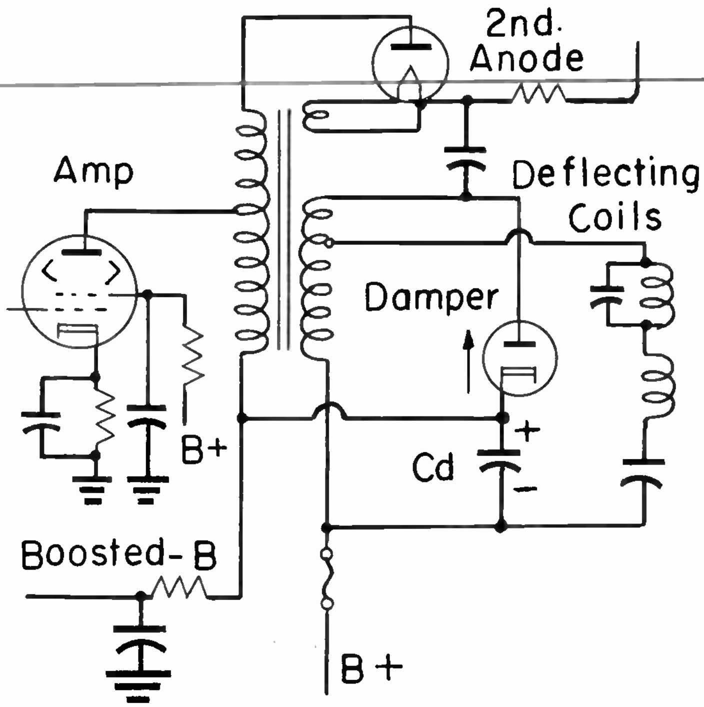

Fig. 13. Boosted B-voltage is produced in this insulated-transformer circuit, which does not contain a linearity inductor.

cuit is not at all necessary for production of boosted B-voltage. Fig. 13 is a deflecting circuit employing an output transformer with insulated secondary, and having no linearity inductor. Boost voltage is developed by charging of capacitor Cd through damper conduction. This capacitor is between the damper cathode and the B+ line from the receiver d-c power supply, with polarities such that capacitor boost voltage and B+ voltage add together.

Boosted B-voltage for the plate of the horizontal output amplifier is not filtered or smoothed other than by the choke effect of the transformer primary. Boosted B- voltage for other tube circuits is additionally filtered by the resistor and bypass capacitor shown on the diagram and by other capacitor-resistor combinations at various places in circuits supplied.

Fig. 14 shows two autotransformer deflecting circuits which furnish boosted B-voltage but which have no linearity control inductors. Positive voltage from the receiver d-c power supply is applied to the damper plates and thus to the side of the damper capacitor which is made negative so far as charging through the damper tube is concerned. This places receiver B+ voltage and capacitor charge voltage in series, because the positive side of the regular B-supply is connected to the negative side of the damper capacitor. This is the manner in which any two d-c voltage sources would be connected in order to add their voltages.

Boosted B-voltage always is furnished to the plate of the output amplifier, through the transformer. This high voltage causes greater plate current in the amplifier and results in greater sawtooth deflecting current than could be had with lower plate voltages. The stronger the voltage pulses from the deflecting circuit to the damper the stronger will be the boosted B-voltage and the greater the possible deflection of the electron beam.

Boost voltage is increased by connecting the damper to a higher tap on output transformers which have a number of taps. In most receivers the damper is connected to the highest tap on a secondary, even when the deflecting coils are connected lower down. A slight increase of boosted B-voltage sometimes can be obtained by using greater capacitance in the positions marked Cd on our circuit diagrams.

Boosted B-voltage often is supplied to plate circuits of both horizontal and vertical sweep oscillators, and may be used for plate or plate and screen of the vertical sweep amplifier. On many receivers the boosted B-voltage is applied also to the first anode of picture tubes, this being the anode connected to number 10 base pin on magnetically deflected tubes.

LINEARITY CONTROL INDUCTOR. It has been mentioned before that boosted B-voltage from the output of a linearity control inductor to the output transformer and amplifier plate is of waveform resembling a sine wave. Adjustment of linearity control inductance, by turning its slug one way or the other, varies the phase or the time relation of boosted B-voltage with reference to sawtooth voltage applied to the grid of the horizontal output amplifier.

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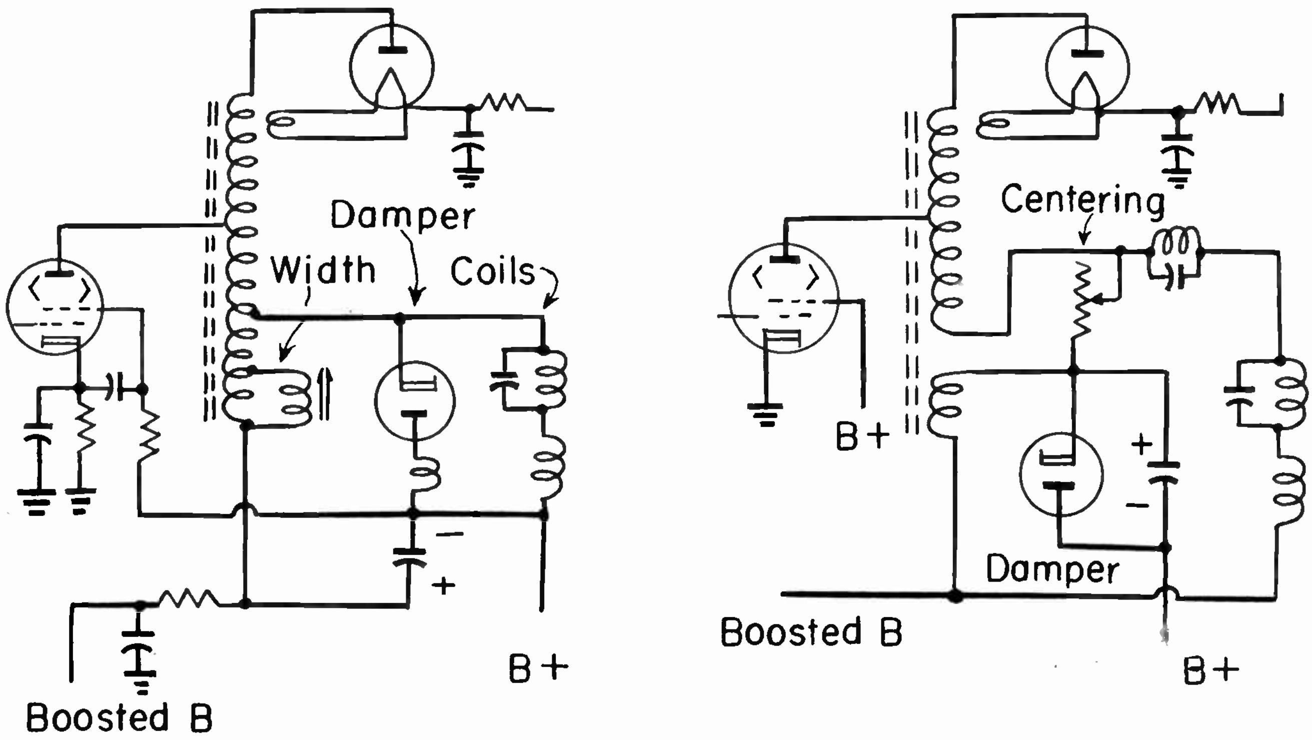

Fig. 14. Autotransformer deflecting circuits furnishing boosted B-voltages, but having no linearity inductors.

With sawtooth voltage acting on the amplifier grid, and boosted B-voltage on the amplifier plate, the effect of linearity inductor adjustment is to change the time during sawtooth cycles at which the amplifier resumes conduction after the cutoff period. As you will realize by looking back at Fig. 9, the point during sawtooth cycles at which amplifier conduction resumes determines whether or not the amplifier plate current takes over the deflection after dying away of deflecting current due to stored energy in magnetic fields.

During observations of deflecting current waveforms in a particular receiver while varying the adjustment of its linearity control inductor it was impossible to obtain the shapes illustrated by Fig. 15. Curvatures of the sawtooth slope are exaggerated in this drawing. The curves did not show so plainly on the oscilloscope trace, but their effects were plainly evident in pictures.

For diagram 1 the linearity slug was turned all the way out of its coil. Pictures were stretched just to the right of center, and crowded at the extreme right. Turning the slug in to the optimum point caused the linear sawtooth at 2, and undistorted pictures. Turning the slug farther in caused the waveform at 3, with stretching to the left of center and crowding at the center of pictures. With the slug almost centered in its coil the waveform appeared as at 4, with pictures crowded at the left and center while being stretched in the area between.

As a general rule, slight misadjustment of a linearity control inductor will affect pictures chiefly in an area midway between left and right sides, for it is here that deflecting current due to dying magnetic fields must be replaced by current due to the output amplifier. Fig. 16 illustrates center cramping with stretching at the left as caused by misadjustment of a linearity inductor. This would correspond roughly to the condition in diagram 3 of Fig. 15.

A somewhat similar effect is illustrated by Fig. 17. Here there is stretching toward the left, but most of the crowding is at the right. Actually the faulty picture here was caused by misadjustment of a drive control, not of a linearity control. This is an example

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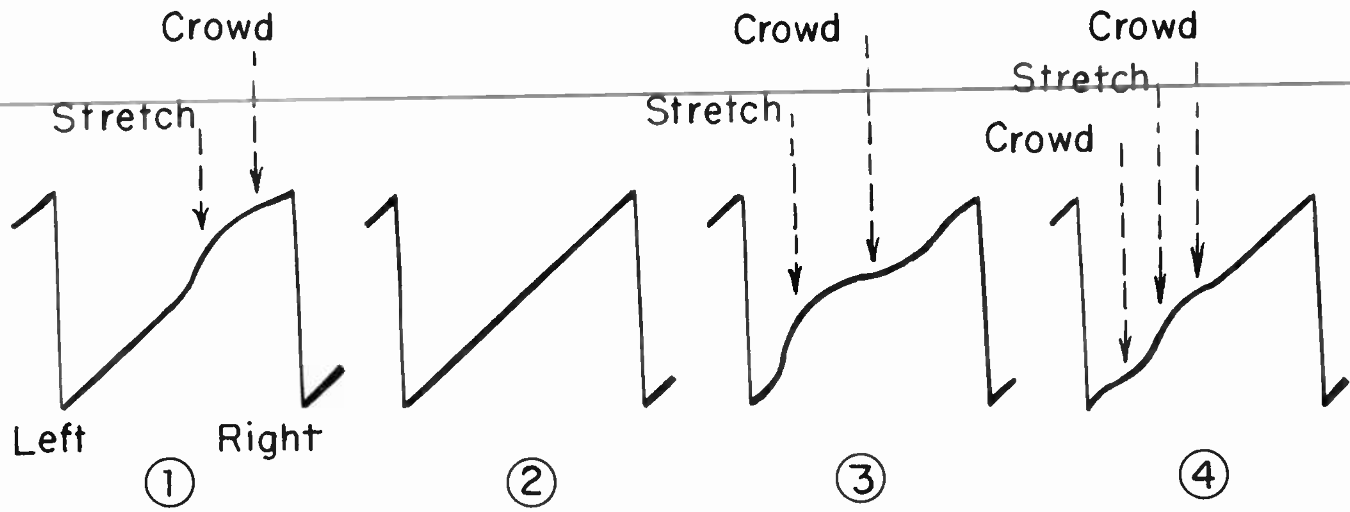

Fig 15. Horizontal deflecting current waveforms are varied by adjustment of the linearity control inductor.

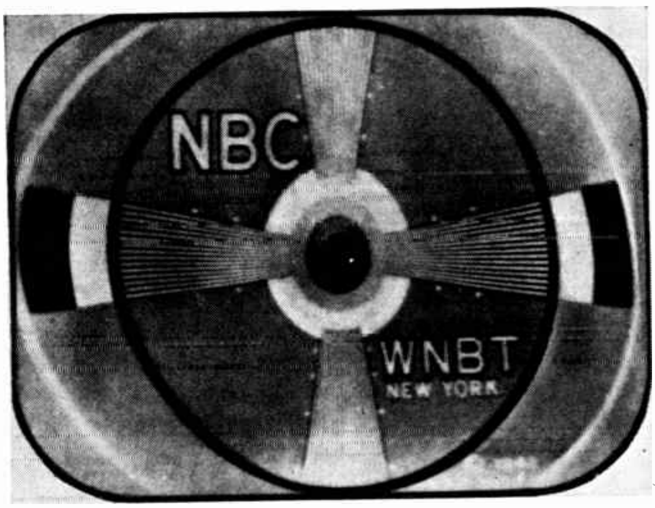

Fig. 16. Wrong adjustment of a linearity inductor often causes cramping at the center of pictures.

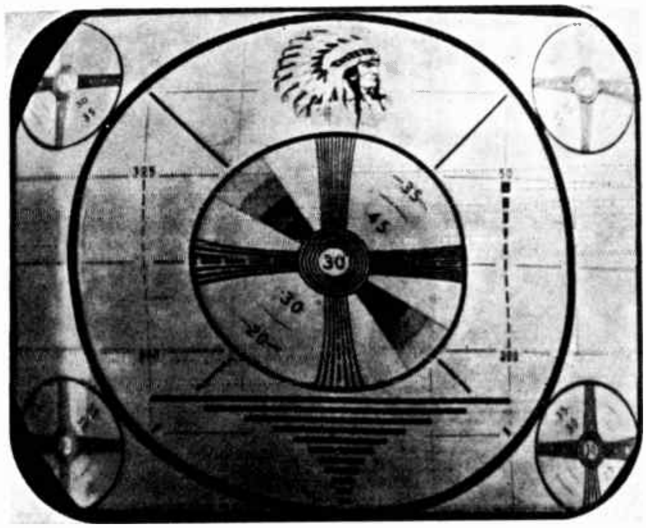

Fig. 17. Misadjustment of a drive control can cause non-linearity in pictures.

proving the general rule that controls for linearity, drive, and width practically always must be adjusted during the same operation. Good linearity ordinarily can be secured only by working back and forth between these three adjustments. Remember that a peaking adjustment acts much like a drive adjustment.

The value of a linearity inductor, in millihenrys, must be suited to the values of capacitors with which the inductor is used, and to some extent must suit the output transformer. Ranges of adjustment commonly found in linearity inductors may be such as 0.3 to 3.0 millihenrys, 0.6 to 2.4 millihenrys, 1.2 to 11 millihenrys, and 4 to 25 millihenrys. The appearance and mounting of linearity inductors are the same as of inductors used for width control. In fact, the same units often may be used for either purpose provided inductance values are suitable.

Capacitors used on the damper side of linearity inductors range from 0.01 to 0.50 mf, and sometimes are smaller than 0.01 mf. A value of 0.10 mf is quite common. On the output or transformer side of linearity inductors the capacitors usually are smaller

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than on the damper side. Values of 0.033 and of 0.05 are fairly common. Excessively small capacitance on the transformer side can decrease deflection current to the point of decided reduction of picture tube second anode current.

Whether capacitors at the ends of a linearity inductor are connected to ground or to the B+ line has little if any effect on linearity and on range of adjustment. Changing the value of a capacitor on the damper side of the inductor has little effect on linearity, but changing the capacitor toward the transformer usually has a decided effect on linearity and on range of adjustment.

DAMPER SHUNT RESISTOR FOR LINEARITY. Many receivers of fairly early design have, as a sort of auxiliary adjustment for linearity, an adjustable resistor shunted from plate to cathode of the damper tube, as shown by Fig. 18. These shunt resistors may be of values from as little as 4,000 to 5,000 ohms, and up to 50,000 ohms. As a rule the resistors are provided with several tap connections, although in a few receivers they are continuously adjustable with a clamp slider.

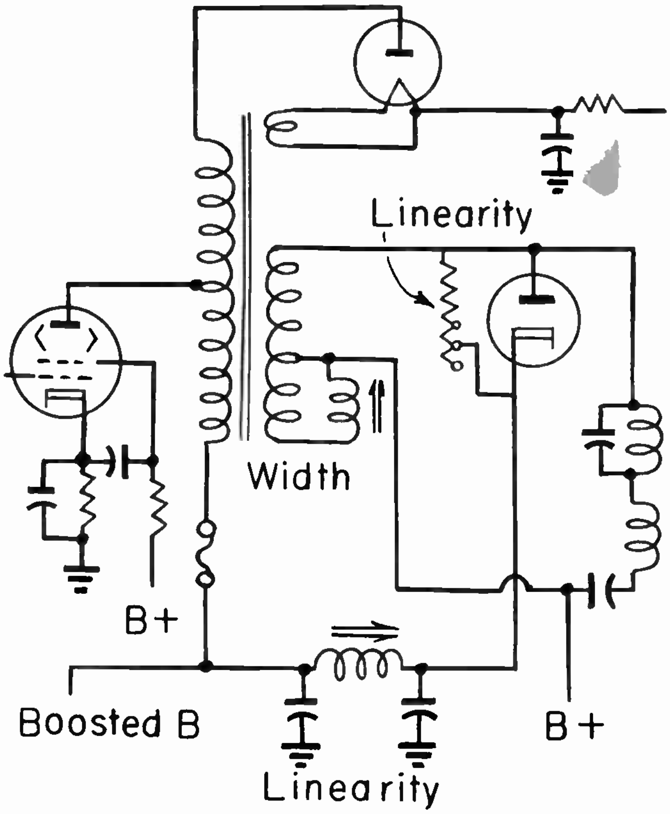

Fig. 18. The resistor shunted across the damper tube may be used as an auxiliary adjustment for linearity.

Damper shunts require adjustment only when it is impossible to obtain satisfactory linearity by adjustments of drive, width, and a linearity inductor. Any change of shunt resistance will require readjustment of these other controls. Pictures greatly stretched at the left, or appearance of a bright vertical line at the left, indicates the need for less shunt resistance. Flattening on the left side of pictures indicates that shunt resistance should be increased.

Shunt resistance lessens the pulse voltage applied to the damper, by carrying part of this voltage around the damper. Too little resistance thus reduces the boost voltage and sawtooth current from the output amplifier. This lowers second anode voltage at the picture tube, possibly enough to cause dim, fuzzy pictures and blooming of picture size when the brightness control is advanced.

LINEARITY ADJUSTMENTS. Service adjustments whose object is to obtain best possible linearity should be carried out as follows.

1. Try reducing the contrast control and adjusting brightness to suit the contrast. Excessive contrast will cause severe distortion of pictures.

2. Adjust the horizontal hold control midway between points at which there is drop out or pull in. A misadjusted hold control can cause distortion at the sides of pictures.

3. Tune to other channels. There may be a temporary fault in picture signals or temporary weakness of the received signals.

4. If there is actual need for linearity adjustment it is desirable to work while receiving a test pattern, not pictures in which there is motion. Test patterns are illustrated by Figs. 10, 16, and 17 of this lesson. Next best to a test pattern is a commercial in which objects or a display remain without

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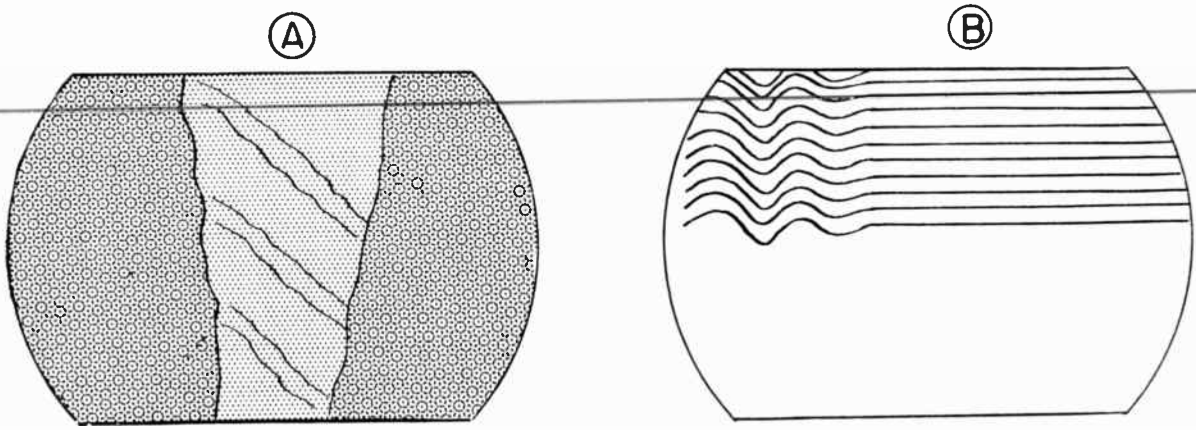

Fig. 19. Effects of shorted capacitors and of wrong capacitances across the horizontal deflecting coils.

motion for considerable periods. Linearity adjustments made when receiving moving pictures may not be satisfactory on other pictures.

5. Commence by making slight changes of adjustment for linearity, for width, and for drive or peaking. Note the effect of each adjustment on various parts of the picture or pattern before deciding how to proceed.

6. Linearity adjustments will affect width of pictures or patterns. Linearity may have to be sacrificed to some extent in order to obtain control of width.

7. Some receivers have no control intended especially for linearity correction. In this case adjust the drive or peaking control and the width control for best linearity.

CAPACITORS ON DEFLECTING COILS. Before leaving the subject of linearity we should note the effects of small capacitors connected across horizontal deflecting coils, as shown by circuit diagrams in this and other lessons. Usually there is a capacitor across only one of the two horizontal deflecting coils, but there may be capacitors of different values across the two coils, or a capacitor and resistor may be in series across one coil. Capacitors, and resistors when used, ordinarily are mounted inside the yoke structure and cannot be inspected or tested without dismounting the yoke.

The chief purpose of these capacitors is to compensate for differences between stray capacitances of the horizontal coils to ground and to the vertical coils, so that both horizontal coils may act alike when carrying the same deflecting current. Another purpose is to prevent high-frequency oscillation or ringing in the horizontal coils by changing the self-resonant frequency of one of them.

A capacitor which is shorted or very leaky reduces picture width to half or less than half the screen width, about as at A of Fig. 19, and at the same time causes extreme distortion. An open or disconnected capacitor may cause slight distortion at the left, but the effect or lack of effect depends on the type and design of yoke. Incorrect capacitance, usually too much, may cause horizontal waviness on the left side of pictures and on a raster, as shown much exaggerated at B.

The horizontal coil capacitors are ceramic or mica types, usually in a range of values from 36 to 68 mmf, depending on the individual yoke. D-c voltage ratings are either 1,500 or 2,000. Replacement always should be with the same capacitance and same physical size of unit. Some yokes are critical as to required capacitance, even to the extent that 5 per cent tolerance in a replacement may not be close enough. Then it is necessary to try several capacitors in order to have satisfactory performance. Other yokes are not at all critical, and work well with almost any capacitance within 10 per cent plus or minus of the original value.

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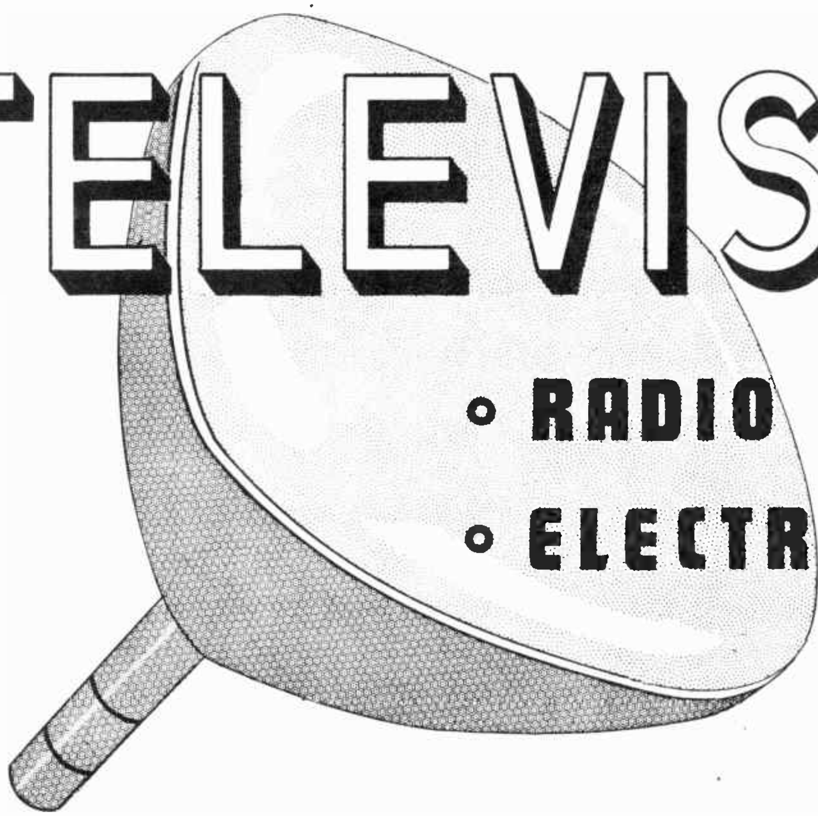

- RADIO
- ELECTRONICS

LESSON 70 — HIGH-VOLTAGE POWER SUPPLIES

Coyne School

practical home training

Chicago, Illinois

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Lesson 70

HIGH-VOLTAGE POWER SUPPLIES

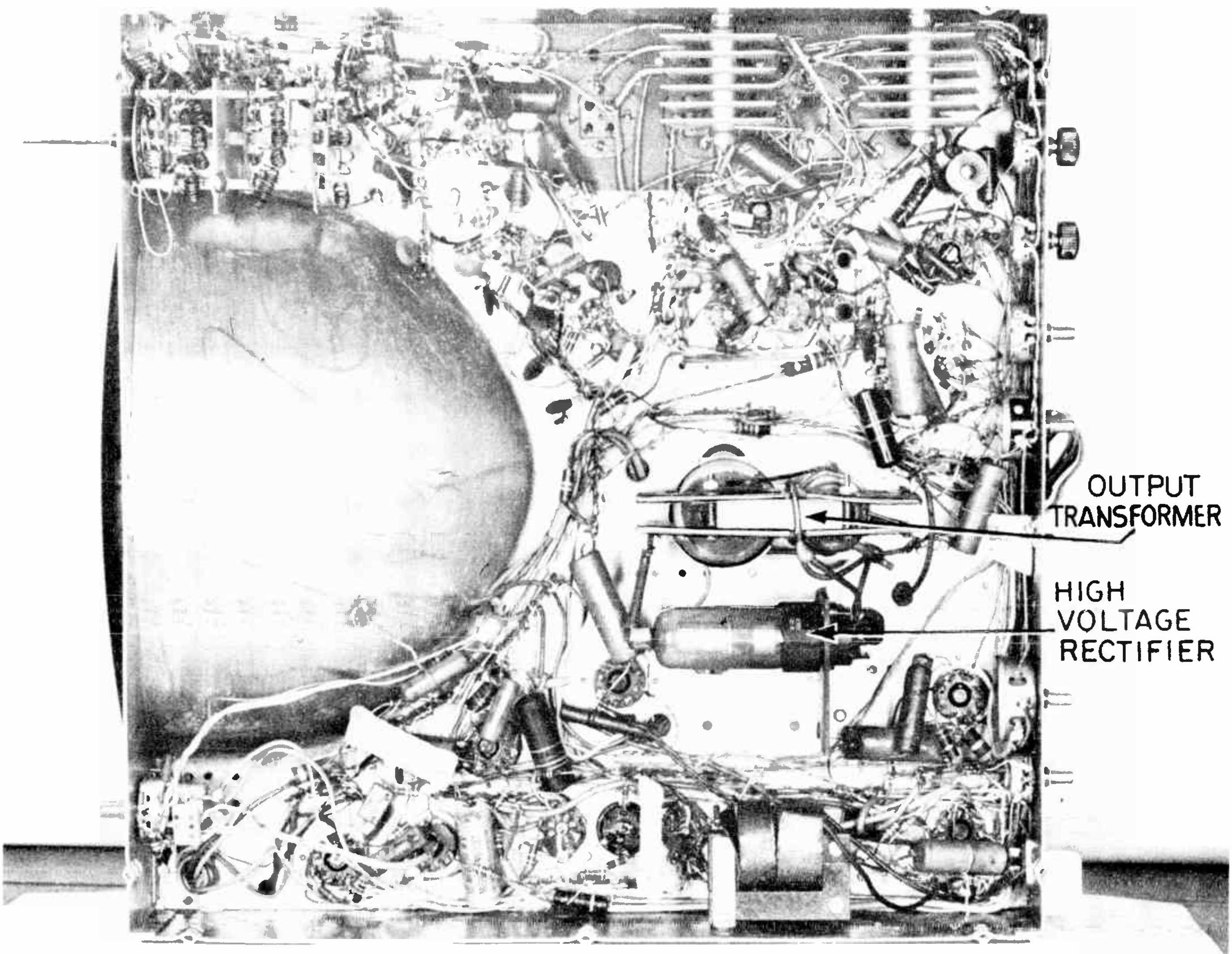

Fig. 1. Parts of the high-voltage power supply are mounted underneath this chassis.

In other lessons we have looked at circuits which furnish not only deflecting currents for yoke coils but also high voltages for the second anode or ultor element of picture tubes. High voltage is induced in these combination circuits only during retrace periods, or only while deflecting current is flying back from the end of one sawtooth rise to the beginning of another. For this reason we give these systems the name of flyback high-voltage power supplies. Later we shall look at other kinds of high-voltage supplies, because occasionally you will have to service them, but in almost every set of recent design the second anode voltage will come from a flyback power supply.

At the output side of filament-cathode of the high-voltage rectifier tube there is d-c potential to ground or B-minus of 8,000 to 16,000 volts. At the plate cap on top of the rectifier and in its lead to the flyback transformer are still higher peaks of alternating voltage. Chiefly as a matter of protection

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against these exceedingly high voltages the rectifier tube and flyback transformer are within a ventilated metal enclosure on top of the chassis or else are mounted underneath the chassis.

Fig. 1 shows a high-voltage rectifier and horizontal output or flyback transformer on the underside of a chassis. Because pulses of about 4,000 volts exist at the plate cap of horizontal output amplifiers, the amplifier, high-voltage rectifier, and flyback transformer quite often are mounted together inside a metal cage on top of the chassis. When the amplifier cap is not thus protected it is fitted with a well insulated connector.

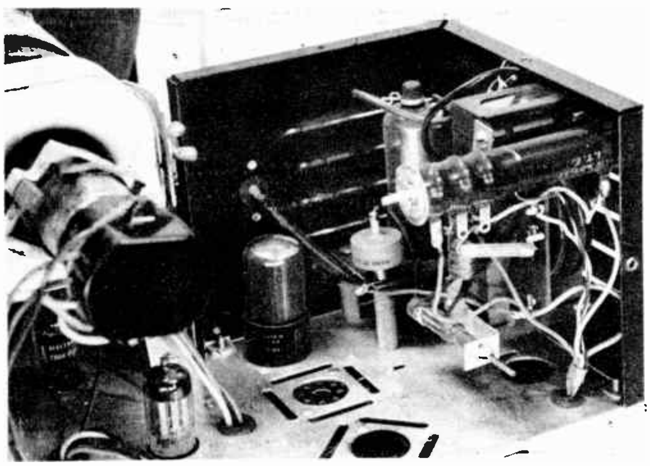

Fig. 2. The high-voltage power supply is within a metal housing on top of the chassis.

In still other receivers, a great many in fact, the rectifier, amplifier, damper, and transformer of the horizontal deflecting and flyback high-voltage system are enclosed within a fairly large ventilated metal cage on top of the chassis. Such construction is illustrated by Fig. 2, where part of the cage has been removed and two tubes have been taken from their sockets to expose other parts.

All receivers are so constructed that removal of the cabinet back, or opening of the high-voltage cage as in Fig. 2, will disconnect from the receiver the power cord that goes to a-c power lines in the building. In order that a-c power may be applied during service operations we use a service cord or "cheater" cord such as pictured in the lesson on "Television Alignment". This cord fits the chassis receptacle from which the regular power cord is disconnected.

It is not safe to work around the high-voltage power supply, the horizontal out-put amplifier, or the flyback transformer while line power is applied to the set. You should pull the service cord while making adjustments, alterations, and replacements, then reconnect the cord while checking on performance. Although this is the only safe way, technicians often rely on turning off the receiver power switch, with the service cord remaining connected. This is all right after you learn how to stay away from hot parts, but in the meanwhile you may get some painful burns.

Grounded metal enclosures around flyback high-voltage systems are not needed for shielding other parts of the set against the strong magnetic and electric fields produced during generation of high voltage. This is because high-voltage pulses occur only during horizontal retrace periods, while the picture tube beam is blanked. The shielding effect of grounded enclosures may help to protect near by radio sets from TV power supply radiation and consequent interference with a-m sound signals.

GENERATION OF HIGH VOLTAGE. Before talking about problems of replacement and other service operations in flyback systems it will be well to understand something about what happens during production of voltage for the picture tube second anode. Connections found in a number of receivers are illustrated by Fig. 3. So far as flyback generation of high voltage is concerned, explanations to follow would apply as well to any other horizontal deflection system wherein the output transformer has above the amplifier plate tap an extension connected to a high-voltage rectifier.

As you know, charging of a sawtooth capacitor eventually brings capacitor voltage up to a value at which the horizontal sweep oscillator becomes conductive, whereupon there is sudden discharge of the capacitor and a drop of voltage. The sawtooth voltage formed in this manner is applied to the grid of the horizontal output amplifier. As the

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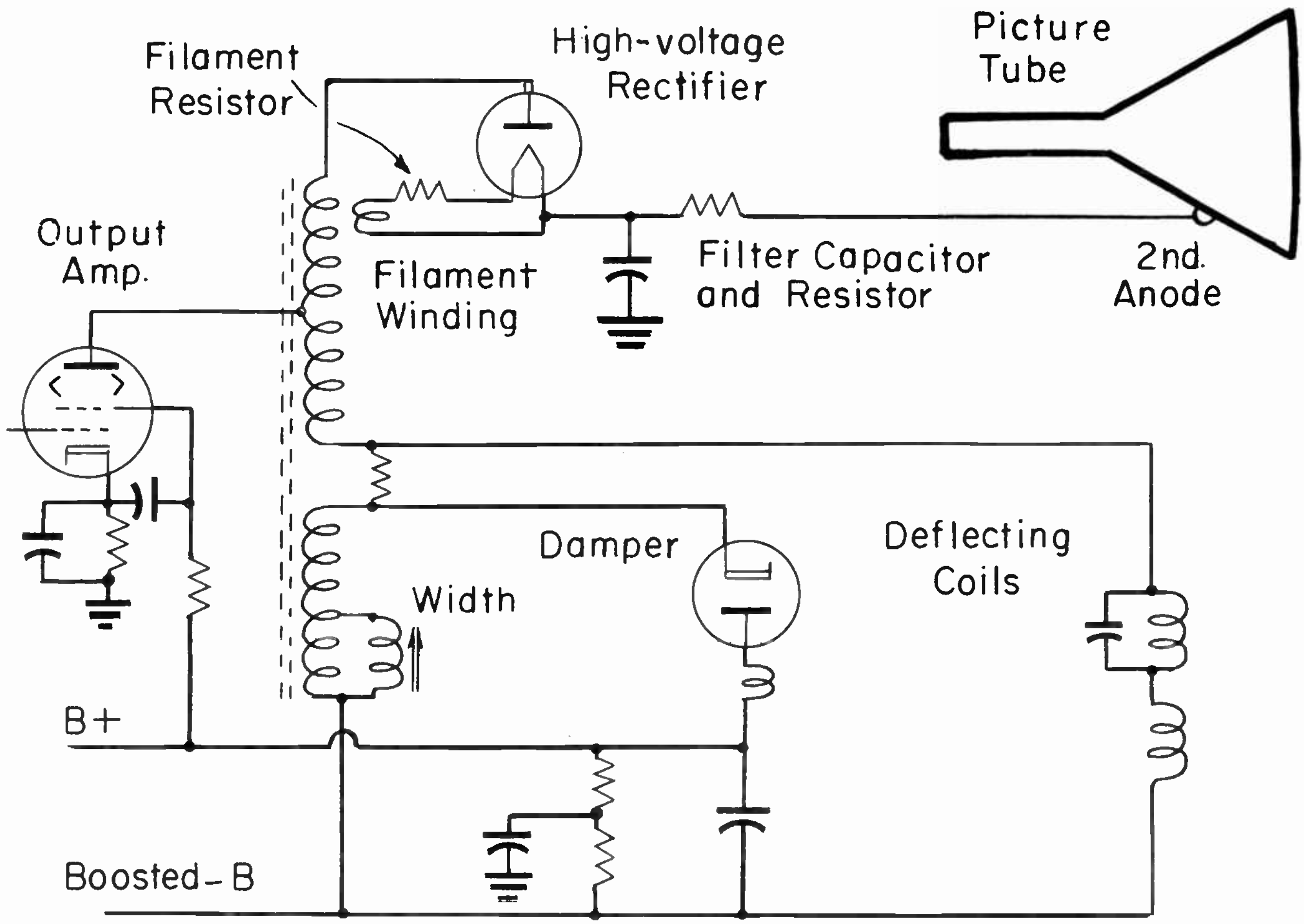

Fig. 3. Circuit connections of a flyback type high-voltage power system employing an auto-transformer.

amplifier is brought out of cutoff, at about the middle of the sawtooth cycle, plate current commences to flow and increases in sawtooth fashion until grid voltage makes its sudden drop. Then we again have cutoff, with plate current going rapidly to zero.

This sudden change of plate current shocks the circuits of transformer and deflecting coils into oscillation at their resonant frequency, with the result that current in these circuits goes through zero and reverses its direction. All this we learned when studying the action of dampers.

The change of plate current and transformer current from maximum in one polarity through zero and to maximum in the opposite polarity induces in the transformer winding an emf which may be called the inductive kick. Strength of any induced emf and of any inductive kick depends on the rate of current change. In the transformer winding we have a considerable variation of current, as measured in milliamperes, and have this change occuring within a very brief fraction of a second. Therefore, the rate of current change, in milliamperes per second, is so great that induced pulses reach a peak value usually on the order of 4,000 volts. Such pulses are shown at A of Fig. 4.

This high-voltage pulse is induced in the portion of the transformer winding between the amplifier plate and the low end of the winding. The extension of the winding, from amplifier plate to the lead for the high-voltage rectifier, ordinarily contains about twice as many turns as the part in which there is induction. Then the entire winding, from low side to rectifier lead, has about three times as many turns as the part in which we assume 4,000 volts to be induced. Autotransformer action steps up the ampli-

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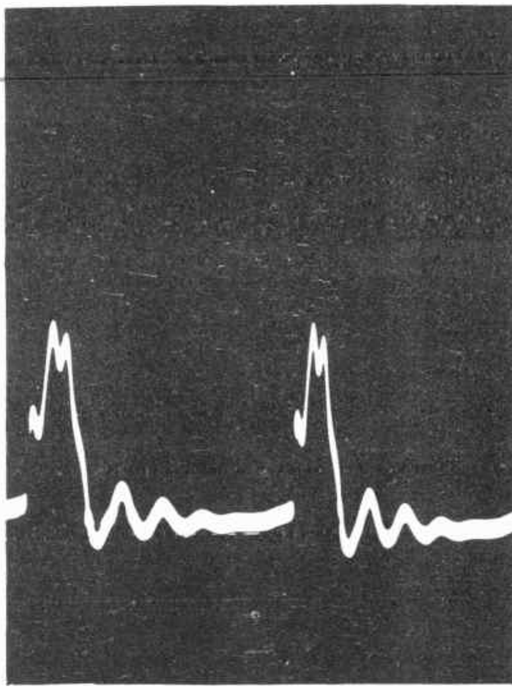

Fig. 4-A

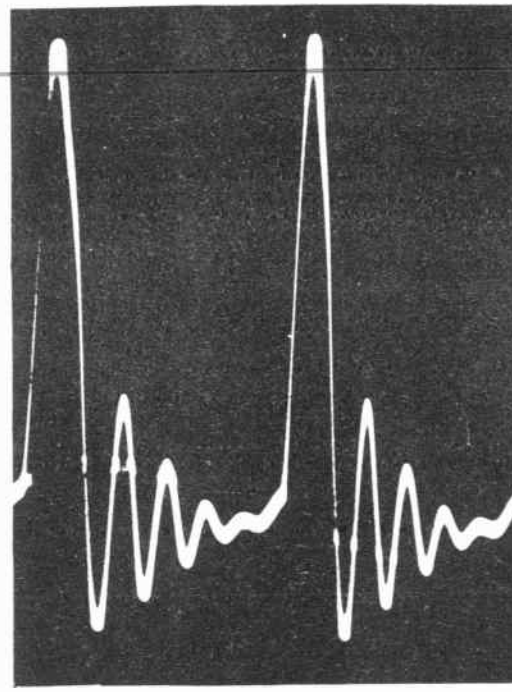

Fig. 4-B

Fig. 4. The strength of positive pulses at the plate connection for the horizontal amplifier is greatly increased at the plate of the high-voltage rectifier.

fier plate pulses about three times, and from the top of the transformer winding about 12,000 peak volts goes to the rectifier plate.

At B of Fig. 4 is a trace of voltage taken at the plate of a high-voltage rectifier when voltage at the amplifier plate was as at A. The two traces were made without altering vertical gain of the oscilloscope. Of course, these traces were made with a capacitance voltage divider capable of withstanding high potentials and of taking off fractional values safe for the vertical input of the scope. At the rectifier plate there is somewhat smoother or more regular waveform than at the amplifier plate, this being due to filtering effect of inductive reactance in the extension of the transformer winding.

Were we working with an output transformer having an insulated secondary, the positive pulses applied from amplifier plate to transformer primary would become negative on the high side of the secondary. Sudden reversal of current in the secondary and the deflecting coils would induce an emf back in the primary. In going back into the primary the induced pulse would change back to positive at the amplifier plate tap and the final result would be, in effect, the same as described.

An important advantage of the flyback system is this: Any failure in the horizontal sweep oscillator or its circuits cuts off sawtooth voltage to the output amplifier, thus stops generation of high-voltage pulses, cuts off second anode voltage to the picture tube, and thereby stops the electron beam. Were second anode voltage supplied in some other manner the beam would remain, but without horizontal deflection. The screen could be burned by the remaining bright vertical line due to vertical deflection.

Failure of the horizontal sweep amplifier itself would stop the flyback action and cut off the beam to protect the picture tube. Since horizontal amplifier plate voltage is practically always boosted B-voltage, and because boosted B-voltage results from damper action, failure of the damper tube would cut off the electron beam to leave the picture tube dark.

TRANSFORMERLESS RECEIVERS. On transformerless receivers with series heaters and hot chasses the horizontal output

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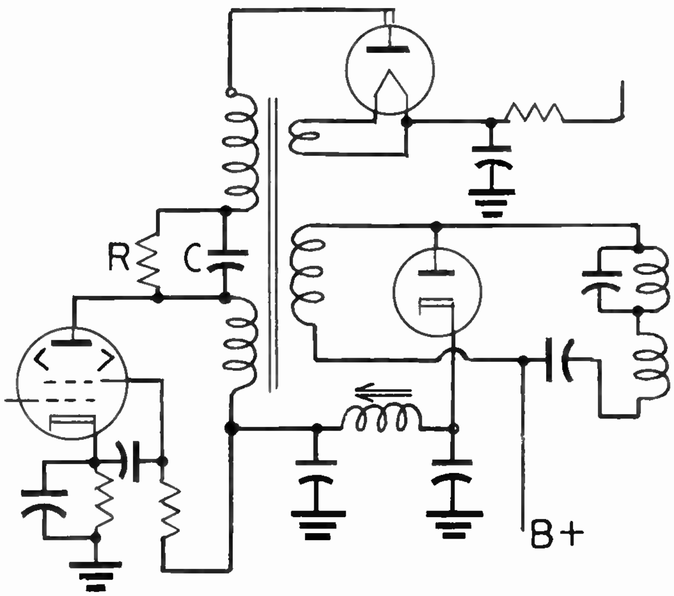

Fig. 5. Resistor and capacitor between sections of a flyback winding, as required for some "transformerless" receivers.

transformer may have a divided primary, as in Fig. 5, with a resistor and capacitor paralleled between the sections. Should the plate lead or cap of the high-voltage rectifier make accidental contact with chassis metal, power line voltage from the d-c B-supply through the damper could reach chassis metal only through the resistor and capacitor. Power line current could not be great enough to cause dangerous heating because the resistor usually is of about a half-megohm and the capacitor, of about 0.002 mf, has reactance in excess of a megohm at 60-cycle power line frequency.

Reactance of the capacitor between sections of the primary is only about 5,000 ohms at the horizontal frequency of 15,750 cycles. The small average current flowing to the high-voltage rectifier and picture tube second anode causes little voltage drop in this small reactance, consequently production of second anode voltage is affected hardly at all. The capacitor-resistor combination is a requirement of the Fire Insurance Underwriters' for certain constructions.

HIGH-VOLTAGE RECTIFIERS. All the high-voltage rectifier tubes used in second-anode voltage supplies are of the half-wave type, with a cathode and only a single plate. The cathodes in all these tubes are filament types, there are no heater cathodes.

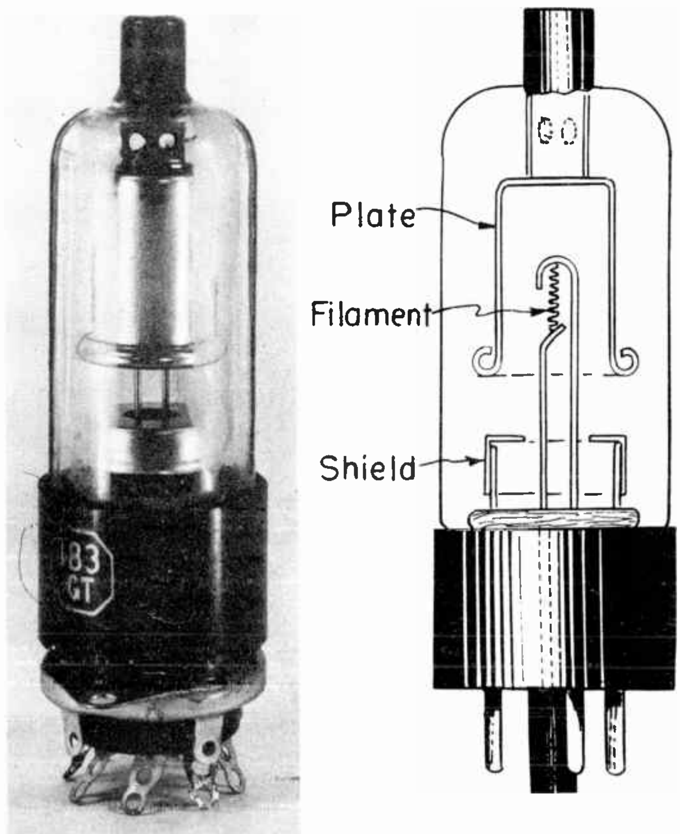

Fig. 6. Appearance and internal construction of a 1B3-GT high-voltage rectifier.

More commonly used than any other tube is the 1B3-GT, shown by Fig. 6. The plate is an inverted cup of rather large diameter compared to the glass envelope. Up inside the plate is the filament-cathode, a small spiral of coated wire attached to two supports which extend down through the glass press to base pins. Above the glass press is a cup-like shield connected through its own supports to the filament leads.

Some ratings of the 1B3-GT and other tubes less often employed as high-voltage rectifiers are listed in the accompanying table. Peak inverse voltages of the 1B3-GT and 1X2-A are high enough to allow using a single tube for rectification of the full second-anode voltage. Inverse voltage ratings of the other tubes are relatively low, allowing these types to be used only in voltage multiplier systems where the total sec-

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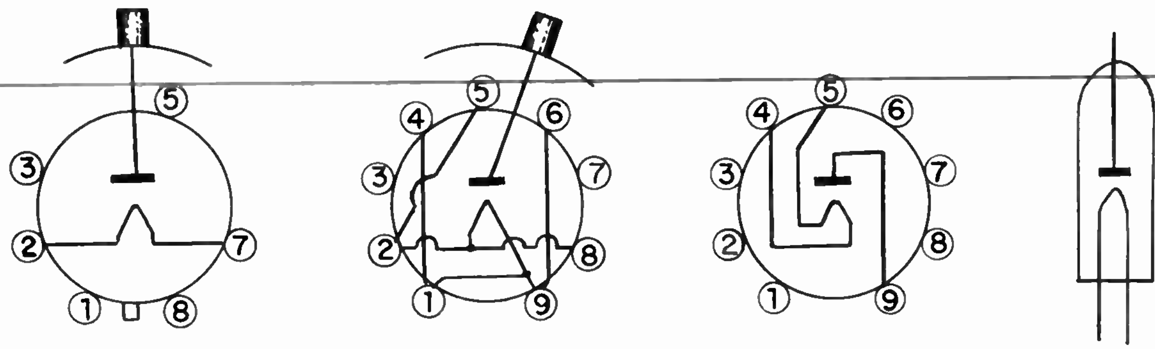

Fig. 7. Base pin and cap connections of high-voltage rectifier tubes.

ond anode voltage is distributed between two rectifiers.

Base pin and cap connections of the high-voltage rectifier tubes are shown by Fig. 7. The 1B3-GT is an octal-base type with six pins. The 1X2-A and 1V2 are nine-pin miniature types. Internal construction of plate, filament, and shield is like that in the 1B3-GT, but on a smaller scale. The 5642 rectifier is a subminiature type about 3/8 inch in diameter and approximately 2-1/6 inches long. There is no base on this tube. Plate and filament connections are in the form of semi-flexible wire leads extending from top and bottom of the glass envelope. This tube usually is soldered in place.

Although some of the base pins on these high-voltage rectifiers are shown as having no internal connections, socket lugs for these pin positions never should be used as tie points for rectifier circuit wires or any other wires. Using these socket lugs as tie points might result and probably would result in high-voltage short circuits. Another reason for leaving the lugs unconnected is that all rectifiers of a given type number are not connected internally in the same manner so far as the blank pins are concerned. Socket lugs for positions 4 and 6 on the 1B3-GT, where there are no base pins, often are used as tie points for resistors connected in series with the tube filament.

Rectifier filament voltages listed in the table are effective voltages. Actually they are d-c voltages which would cause rated filament currents and correct emission temperatures. Since the rectifier filament is connected to a winding on the horizontal output transformer the real filament voltage

HIGH-VOLTAGE RECTIFIER TUBES				
Type No.	1B3-GT	1X2-A	1V2	5642
Style Base pins	Octal 6	Miniature 9	Miniature 9	Subminiature wire leads, 3
Filament Volts Amperes	 1.25 0.2	 1.25 0.2	 0.625 0.3	 1.25
Maximum ratings Peak inverse volts Peak plate current Average plate current	 30,000 17 ma 2 ma	 18,000 10 ma 1 ma	 7,500 10 ma 0.05 ma	 10,000 5 ma 0.25 ma

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is pulsating at the horizontal line frequency of 15,750 cycles per second. The filaments are of fairly large wire formed so compactly as to hold their heat and temperature very nearly constant in spite of the voltage pulsating so rapidly.

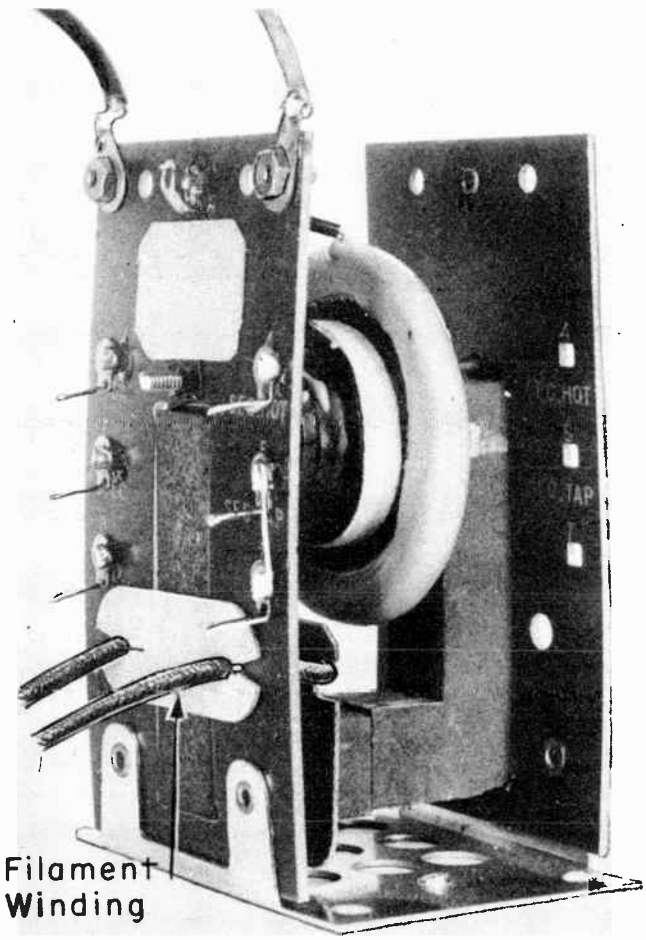

Fig. 8 Transformer windings for filaments of high-voltage rectifiers consist of one or two turns around the core.

Rectifier filament windings consist of one or two turns placed rather loosely around the core of the output transformer, sometimes close to other windings and again far away. A single-turn filament winding of this kind may be seen on the transformer of Fig. 8. The winding and leads to the rectifier socket or element terminals are a single unbroken and unspliced length of heavily insulated conductor. High-voltage insulation is necessary because the rectifier filament is at the same or a slightly higher voltage than the second anode of the picture tube.

In the circuit diagram of Fig. 3 a resistor is shown in series with the filament winding on the transformer and the filament-cathode in the rectifier tube. This resistor is not always used. You will find it only where effective voltage from the filament winding might overheat the tube filament with a direct connection. This depends on the number of turns and positioning of the filament winding and on the particular transformer. Filament series resistors, when used, may be of almost any value between 0.56 and 6.8 ohms, with values around 3 ohms most common. The size or power rating almost always is one watt.

Only slight overheating may damage the filament-cathode of a high-voltage rectifier enough to prevent necessary emission, even though the filament is not burned out and still "lights". It is impossible or at least impracticable to make direct measurement of filament voltage without a thermal meter insulated for 15 to 20 thousand kilovolts and guarded against capacitance to ground - something few service shops would possess.

You judge whether filament heating is correct or incorrect by watching the color or redness of the filament and comparing it with the color of other rectifier filaments which are known to be operating correctly. It is impossible to look directly at the filament, because it is too far inside the plate. Fortunately the flat top surface of the internal shield shown in Fig. 6 is shiny enough to act as a good reflector. By looking down toward the top of the shield at an angle of about 45 degrees you can see light reflected from the glowing filament.

If a red glow is barely visible in a room almost wholly dark the rectifier filament is hot enough for ample emission. If the glow is plainly visible in a lighted room the filament is much too hot, and may already have been damaged. The best way of reducing temperature is by using more series filament resistance or inserting a resistor where none is used originally. The filament may be checked for burnout with an ohmmeter connected to the filament pins or leads.

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HIGH-VOLTAGE FILTERING. Again looking back at Fig. 3 you will see between the rectifier filament-cathode and the second anode of the picture tube a series resistor and a capacitor to ground. These two units form a low-pass filter to smooth the pulsating d-c output from the rectifier in the same manner that filter units in the low-voltage d-c power supply smooth the output of the power rectifier.

When a filter capacitor is used in this position its value nearly always is 500 mmf. Rated working voltage may be 15,000, 20,000, or 30,000, but most often is 20,000 volts. The most commonly employed filter resistance is 1 megohm. Once in a while you will find filter resistance of more than a megohm, and quite often the value will be from 500K ohms down to as little as 100K ohms.

Second anode current flowing from the filter through the rectifier hardly ever would be as great as 100 microamperes, and with pictures of normal brightness this current is more likely to be from 10 to possibly 40 microamperes. This small current, combined with the high pulse frequency of 15,750 cycles per second, makes filtering effective with small capacitance in spite of the fact that we have half-wave rectification.

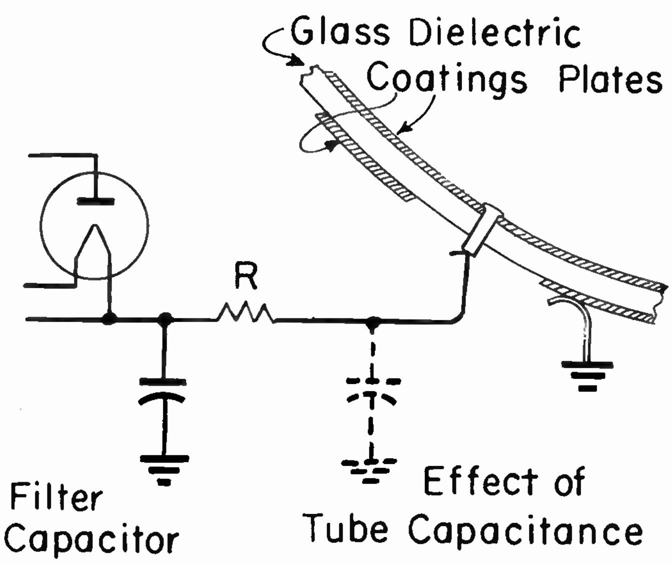

Fig. 9. Capacitance of an external coating on a glass picture tube adds to the high-voltage filter system.

When the picture tube has a glass envelope with external conductive coating, connected to ground, capacitance between the external coating and internal coating forms a second filter capacitor, as you can see from Fig. 9. The internal conductive coating, which is part of the second anode, acts as one plate of a capacitor. The glass envelope forms the dielectric. The outer conductive coating, which is grounded, acts as the second plate of a capacitor.

Capacitance of coatings on glass picture tubes ranges from about 500 mmf to as much as 4,000 mmf. This tube capacitance provides enough filtering action that many receivers have no additional external filter capacitor such as shown on our circuit diagrams. With no external filter capacitor there is no reason for a filter resistor, because, we learned when studying power supply filters, the function of a resistor is to allow fairly independent action of two capacitors or capacitances. Then we have a direct connection from rectifier filament to picture tube second anode terminal.

There are some receivers employing glass pictures tubes with conductive coatings which have an external filter capacitor but no filter resistance. Picture tubes with metal cones or shells have no external coating which can form a filter capacitance. Consequently, we always find an external filter capacitor, either with or without a filter resistor, when the picture tube is a metal type.

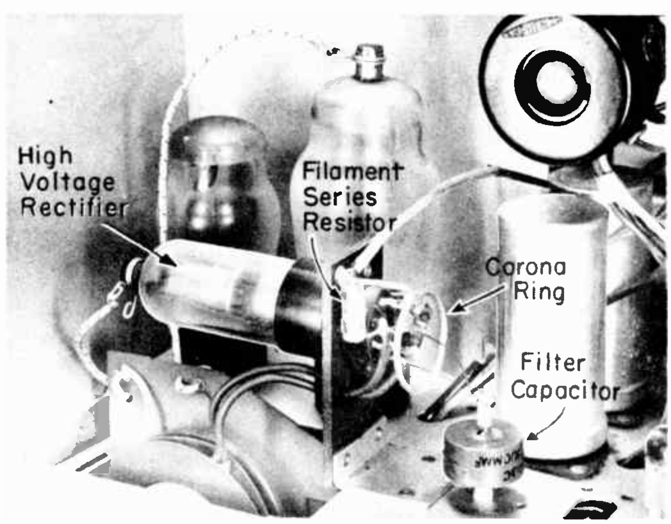

Fig. 10. Some details of a flyback high-voltage power supply. The transformer is below the rectifier tube.

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In Fig. 10 you can see a 500-mmf filter capacitor mounted on the chassis near the socket for the high-voltage rectifier. Most filter capacitors are of the cylindrical form illustrated, with the two terminals in the form of studs extending from opposite ends of the phenolic housing. The terminal studs may be plain, slotted, or threaded, depending on how they are mounted and on the connections desired. The bottom stud of the capacitor in the picture is threaded, passed through a hold in the chassis, and held by a nut and lock washer for support and for a chassis ground connection.

Close around the lugs of the socket for the high-voltage rectifier, but not touching the lugs, is a metal corona ring. This ring is connected to the filament lug from which a lead goes to the second anode of the picture tube. The purpose of the ring is to confine high-voltage corona discharges so that they will not cause interference lines on pictures and possible hissing noise from the speaker.

A corona discharge occurs to a greater or less extent around all uninsulated conductors which operate at very high potentials. In a darkened room you can see corona discharges as a faint blow glow near the conductors.

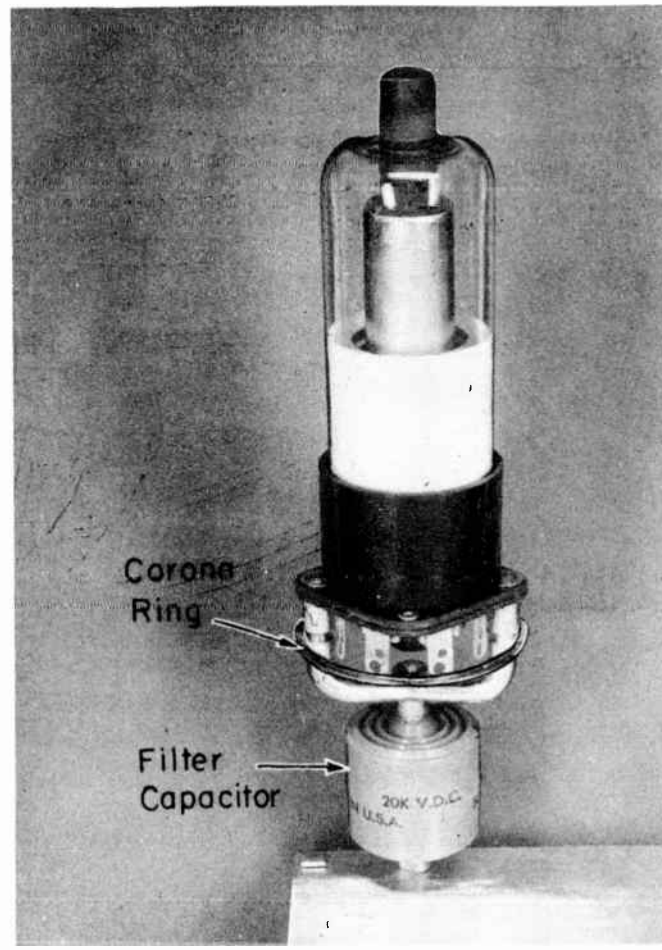

Fig. 11. A high-voltage rectifier supported by a filter capacitor.

Fig. 11 shows a fairly common method of mounting the high-voltage rectifier tube. The socket is supported by metal of approximate U-shape which itself is supported on a threaded stud extending upward from the cylindrical filter capacitor. Around the metal support and in contact with it is a corona ring. The socket lug which provides connection from the rectifier filament to the picture tube second anode is connected to the socket support bracket, and thereby to the filter capacitor and to the corona ring. The bottom terminal stud of the capacitor passes through a hole in the chassis, where it makes a chassis ground connection.

If you look back through all our circuit diagrams for horizontal deflection systems which include second-anode power supplies you will find that the low side of the filter capacitor is not always connected to ground. Sometimes this capacitor is connected to the high side of the deflecting coil circuit or to the transformer lead going to the damper tube. The capacitor connection to the deflecting coil or damper lead is made only when the transformer has an insulated secondary, not when it is an autotransformer.

Doubtless you recall that voltage pulses are negative at the high side of an insulated secondary, and are positive at the high side of an autotransformer. The negative pulses on the insulated secondary occur at retrace periods, just when positive pulses appear at the plate of the horizontal output amplifier and at the plate of the high-voltage rectifier. By connecting the bottom of the high-voltage filter capacitor to the source of strong negative pulses, and its top to the rectifier which is made conductive by strong positive pulses, the pulses of opposite polarities add their effects on the filter capacitor. Charge and charge voltage of the filter capacitor thus are increased, and we have a corresponding

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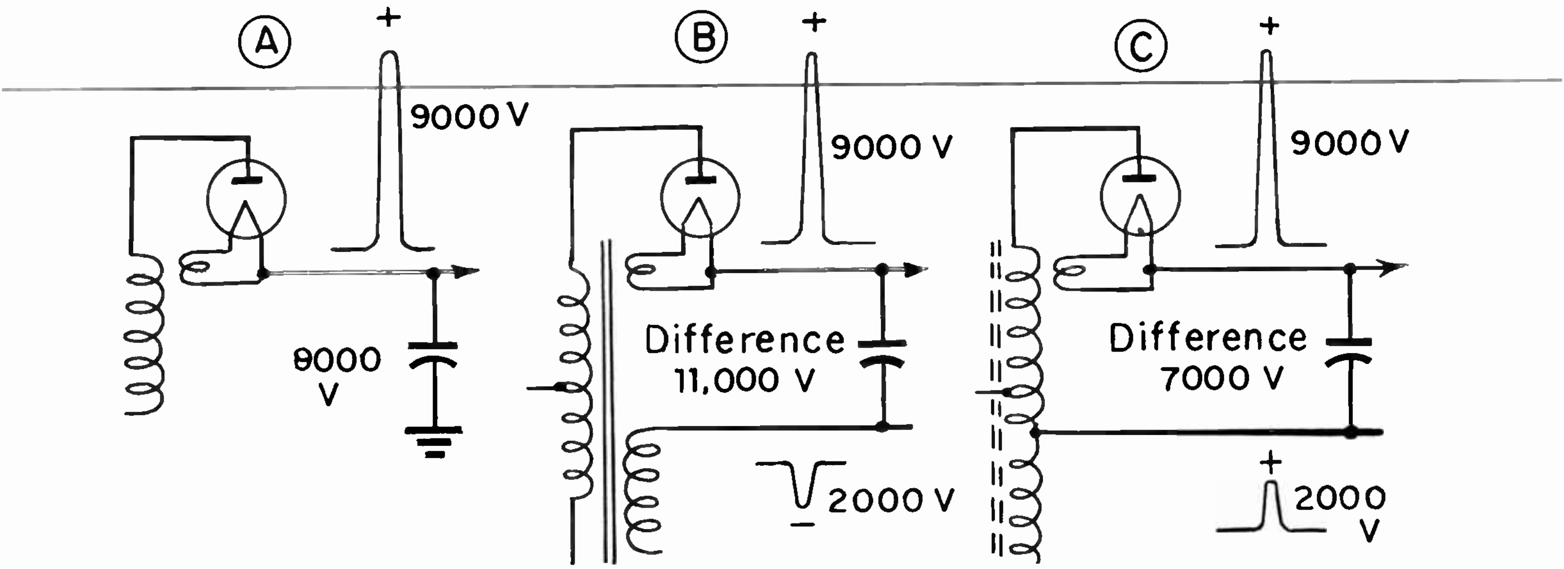

Fig. 12. Connections for the low side of a filter capacitor, and how they affect second-anode voltage.

increase of average d-c voltage for the second anode of the picture tube.

This method of raising the second anode voltage cannot be employed with an autotransformer for the horizontal output. At taps for the damper or deflecting coils on an autotransformer, and at any other taps above the low end of the winding, the voltage pulses are positive. These positive pulses would subtract from filter capacitor voltage and charge were the low side of the capacitor connected to receive them.

How all this works out is illustrated by Fig. 12. At A we have a filter capacitor connected from the rectifier filament (and picture tube second anode) to ground. No matter whether the flyback transformer has an insulated secondary or is an autotransformer, there are positive pulses going to the rectifier plate. These positive pulses make the rectifier conductive, they pass through, and charge the filter capacitor. Assuming that the positive pulses have 9,000-volt peaks with reference to ground, the peak charges on the capacitor will be 9,000 volts to ground.

At B the low side of the filter capacitor is connected to the high side of the secondary on a transformer with insulated secondary. We may assume that negative pulses on the secondary winding and on the low side of the capacitor have 2,000-volt peaks. Then the high side of the capacitor is subjected to 9,000 positive volts while the low side is subjected to 2,000 negative volts, and potential difference across the capacitor is the sum of the opposite potentials or is 11,000 volts.

At C we have an autotransformer, with the low side of the filter capacitor connected to a tap on this transformer. Pulse voltages at this or any other tap are positive, and we shall assume a peak of 2,000 volts. Now the high side of the capacitor is subjected to 9,000-volt positive pulses while the low side is subjected to 2,000-volt positive pulses. The potential difference across the capacitor is the difference, or is 7,000 volts. We might better have connected the low side of the capacitor to ground, as at A, for the ground connection would give higher charge voltage and higher voltage for the second anode of the picture tube.

SECOND ANODE VOLTAGE. On Fig. 13 are marked ten things which can either raise or lower the voltage furnished to the second anode of the picture tube when the high-voltage supply is a flyback type. The output transformer is shown as an insulated secondary type only because this allows changing the connection of a high-voltage filter capacitor, and because damper shunts seldom if

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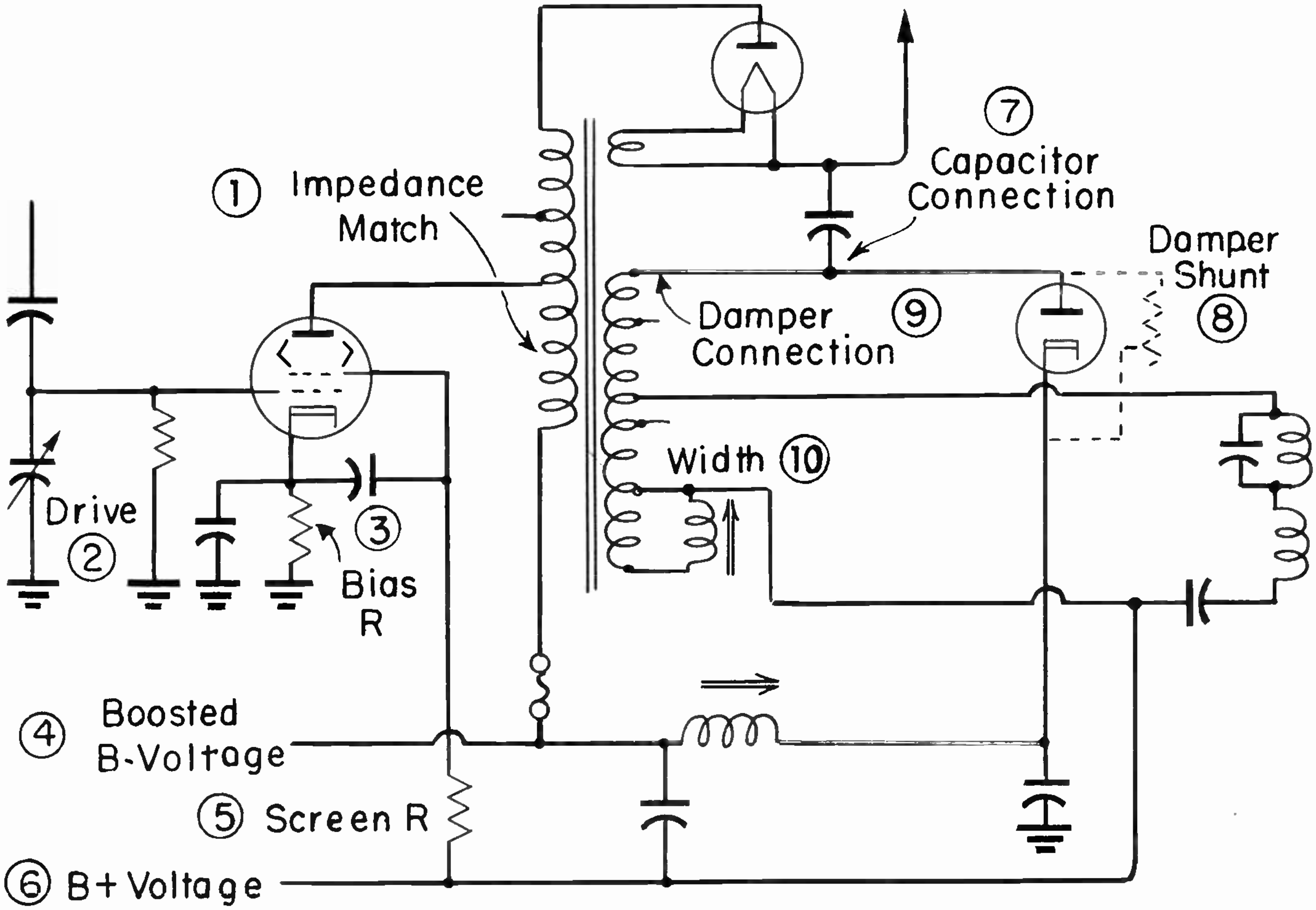

Fig. 13. Factors which affect picture tube second anode voltage when the high-voltage supply is a flyback type.

ever are found on the newer autotransformers. Everything else on the figure applies to any kind of flyback transformer. We shall follow the various items downward and from left to right on the diagram, without regard to their relative importances.

1. Impedance Matching. Output transformers and deflecting yokes used as original equipment provide correct matching of primary impedance to the plate resistance or impedance of the original type of output amplifier, and provide correct matching of secondary impedance to impedance of the horizontal deflecting coils. Then there is maximum power transfer through the transformer, there is correct voltage for the second anode, and all around good performance. Exact replacements for transformer, yoke, or both will provide the same satisfactory performance when correctly connected.

Universal replacement transformers have a number of taps on their winding or windings. If the plate of the horizontal amplifier is connected to the right primary tap, and if the horizontal coils of the yoke are across the right secondary taps, there will be a good impedance match, good power transfer, and satisfactory performance. If connections to the primary are not suitable for both the amplifier tube and the deflecting coils, or if secondary connections are not suitable for the deflecting coils, nothing you can do will allow both a necessary second anode voltage and trouble-free deflection of the electron beam.

Transformer manufacturers furnish instructions for connecting each type of replacement transformer to certain tubes and to yoke coils of certain inductances or certain type numbers. When you use a transformer and a yoke so designed that they can

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work well together, and make connections according to instructions, results will be satisfactory. Otherwise you face difficulties which may require hours of experimenting for solution unless you have necessary measuring instruments and experience in using them.

2. Drive Adjustment. Increasing the drive, which means increasing the amplitude of sawtooth voltage on the amplifier grid, will increase second anode voltage. Less drive drops this voltage.

3. Amplifier Cathode Bias. More bias resistance usually lowers the second anode voltage, but will have other effects such as reducing picture width. Total grid-cathode bias may change oppositely to cathode bias considered alone, resulting in linearity difficulties. Changing the value of a cathode-resistor bypass capacitor usually has little effect on second anode voltage.

4. Boosted B-voltage. Increase of boosted B-voltage increases plate voltage on the horizontal output amplifier and increases picture tube second anode voltage. Boosted B-voltage is increased slightly by greater capacitance of the damper capacitor which is connected from the low side of the damper (plate or cathode) to ground or to a B+ line.

Boosted B-voltage is increased by reducing the load on the boosted-B circuit, by connecting plate and screen circuits of tubes other than the horizontal output amplifier to other sources of B-voltage (the regular B+ lines) when these tubes originally are supplied from the boosted-B line.

Boosted-B voltage is affected also by damper connections, as noted later.

5. Amplifier Screen Voltage. Increase of screen voltage on the horizontal output amplifier, by reducing the voltage dropping resistance to the screen, will increase picture tube second anode voltage. This one of the more effective methods of raising second anode voltage, also one most likely to overload the horizontal amplifier tube.

6. B-voltage To Deflection System. Increasing the B+ voltage from the receiver d-c power supply to the deflection increases the boosted-B voltage and thereby increases picture tube second anode voltage. This may cause troublesome reduction of B-voltage to other tubes and circuits in the receiver.

7. High-voltage Filter Capacitor. As explained earlier, connecting the low side of this capacitor to the high side of the insulated secondary of a two-winding output transformer will raise the second anode voltage by large amounts, as compared with voltage secured with the filter capacitor to ground.

The higher the secondary tap to which this capacitor is connected, the greater will be the increase of second anode voltage. The capacitor need not be connected to the same tap as the yoke nor to the same tap as the damper.

8. Damper Shunt Resistance. When there is an adjustable resistance shunt from damper plate to cathode, more resistance will raise the picture tube second anode voltage.

9. Damper Connection. The higher the transformer tap to which the damper plate or cathode is connected, the greater will be the boosted B-voltage to the amplifier plate and the higher will be picture tube second anode voltage. This is the damper plate connection with an insulated-secondary transformer, or the damper cathode connection with an autotransformer.

Most often it is desirable to have maximum boosted B-voltage, especially with large picture tubes, so it is common to connect the damper to the highest secondary tap on any kind of transformer. Horizontal deflecting coils may be connected to some other tap in order to have correct impedance matching.

10. Width Control Inductor. Adjusting this inductor for more reactance by turning the slug farther into the coil will increase second anode voltage because of less absorption of deflecting energy. Connecting the width control inductor across more transformer turns increases its effectiveness as a width control, and also increases the effect of adjustment on second anode voltage.

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Should you wish to reduce second anode voltage, make changes which are the opposite of those mentioned for increasing this voltage.

Increase of second anode voltage always increases the brilliance and sharpness of definition in pictures and patterns. This voltage increase, considered by itself, tends to make pictures narrower and of less height for any given amplitude of sawtooth deflecting current in the yoke coils. However, the second anode voltage may be increased by adjustments or alterations which increase deflecting current amplitude at the same time. The change of amplitude may overbalance the effect of more second anode voltage to make pictures larger and more brilliant at the same time.

After gaining some experience you will be able to judge from appearance of pictures whether second anode voltage is satisfactory or too low. Your judgment will be helped by the manner in which controls for width and brightness affect pictures. But the right and proper way is to keep a high-voltage meter or probe on the second anode terminal or connection while making any changes that may affect the voltage.

All of the changes shown on Fig. 13 can have some effect on plate current in the horizontal output amplifier. The changes for increasing second anode voltage which are numbered 3, 4, 5, 6, and 9 in preceding instructions may raise plate current enough to seriously overload the amplifier. Such changes should be made only with a milliammeter in series with the amplifier cathode, using a range of at least 300 ma. Disconnect the cathode resistor from ground or B-minus. Connect the resistor to the positive terminal of the meter, and the negative of the meter to ground or B-minus.

Under no conditions allow total cathode current to exceed rated maximum plate current for the kind of amplifier in use. Since cathode current includes both plate and screen current, this method of measurement provides a fair safety factor.

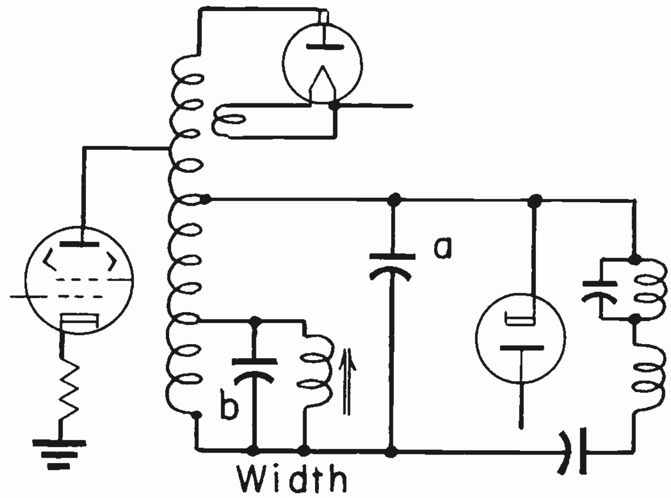

Fig. 14. Capacitors across parts of the deflection circuit increase width and height by dropping second anode voltage.

CAPACITOR ON DEFLECTING CIRCUIT. Picture width sometimes is increased by connecting a capacitor across part of the output transformer secondary or across the horizontal deflecting coils, as at a in Fig. 14, or by connecting a capacitor across a width control inductor as at b. Capacitors in these positions increase width, and at the same time increase height, because they lower the second anode voltage for the picture tube. As mentioned many times, less second anode voltage allows any given yoke currents to cause greater deflections or swings of the electron beam.

A capacitor connected across the entire yoke or across transformer taps leading to the yoke usually must be of a value considerably less than 500 mmf to avoid getting second anode voltage so low as to make pictures decidedly fuzzy and rather dim. The d-c voltage rating must be at least 1,500 volts for a capacitor in this position. Ceramic or mica units are satisfactory.

The fewer the transformer turns across which the capacitor is connected, the greater must be the capacitance for a given widening of pictures, and the lower may be the capacitor voltage rating. When connected only across a width control, and thus across relatively few transformer turns, capacitance may be as large as 0.01 mf for any worthwhile widening effect. Wherever the capacitor is connected, its value for the desired effect is a matter of trial and error.

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Capacitors in these positions lower the frequency at which the yoke-transformer circuit is resonant, because capacitance is added to this circuit. The effect is to cause slower retraces. Excessive capacitance will make retrace so slow as to cause foldover at either side of pictures or patterns.

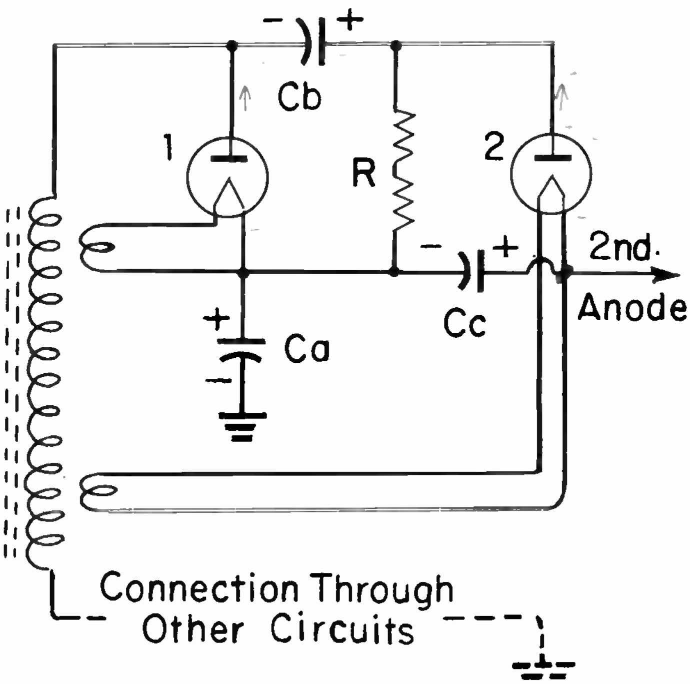

Fig. 15. A doubler circuit used with flyback high-voltage supplies.

FLYBACK VOLTAGE DOUBLING. When large screen picture tubes first came into general use the necessary high voltages for second anodes were not available from horizontal output transformers of constructions then commonly available. In those earlier sets and in a few current models we may find two rectifiers in a voltage doubling circuit of the kind illustrated by Fig. 15. Efficiency of flyback output transformers has been so improved in recent years that almost any required second anode voltage may be obtained, and only a single high-voltage rectifier is needed.

You will note that the flyback doubler circuit is not like the type used in low-voltage d-c power supply systems. This is because the voltage to be rectified in low-voltage power supplies is of approximate sine-wave form, while in the flyback system this voltage consists of strong positive peaks and only weak negative amplitudes. Flyback voltage doublers are used both on autotransformers and on insulated-secondary transformers. The only change necessary on the transformer is provision for an extra filament winding for the added rectifier tube.

The flyback voltage doubler performs as follows: Positive pulses from the top of the transformer winding go to the plate of rectifier 1 and make this tube conductive. Current from cathode to plate inside the rectifier must come through capacitor Ca. This capacitor is charged in the marked polarity to a voltage nearly as great as the positive pulse peaks.

Then negative amplitude from the top of the transformer makes rectifier 1 nonconductive. The strong charge voltage remaining on capacitor Ca forces current through ground connections, the transformer winding, capacitor Cb, and resistance at R. This current charges capacitor Cb as marked.

During positive pulses rectifier 2 is made conductive because of the combined effects of pulse voltage and of voltage across capacitor Cb, which is positive toward the plate of rectifier 2. Conduction current from cathode to plate in rectifier 2 must come through capacitor Cc, charging this capacitor as marked.

Now we find capacitors Ca and ~~Cb~~ CC in series with each other between ground and the second anode of the picture tube, and find positive charges and voltages on both capacitors are toward the second anode. Consequently, the two charge voltages add together. Since each is almost as strong as positive peak voltage from the transformer, second anode voltage is almost double that which could be had through a single rectifier from the same transformer.

Because each rectifier is acted upon only by transformer pulse voltage, these tubes require only moderately high inverse peak voltages, and often are type 5642 or type 1V2. Naturally, the 1B3-GT or the 1X2-A rectifier could be used, since they have still higher inverse voltage ratings.

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All three capacitors in the doubler circuit are of the same value, usually 500 mmf. Their ratings are 5,000 to 10,000 d-c volts, as required to withstand transformer pulse voltage to which the capacitors are subjected. Capacitor Ca sometimes is connected on its low side to some point in the deflection circuit where B+ or boosted B-voltage is available, instead of to ground. Such a connection increases second anode voltage.

Resistance at R usually consists of two or more series resistors, to withstand the overall voltage which might break down a single resistor. The total power rating of all the resistors usually is 4 watts or more. Total resistance at R is 2 to 3 megohms in most receivers.

ELECTRONIC MAGNIFIERS. Several makes and models of television receivers have included auxiliary controls which allow enlargement of pictures produced on 10-inch and 12-inch tubes. Enlargement results from increased deflection of the electron beam both horizontally and vertically. This places top, bottom, and both edges of complete transmitted pictures outside the screen area. Images and details of the remaining central portion of pictures are as large as they would appear on picture tubes of greater size. Although these magnifiers are not in current production, thousands still are in use.

Enlarged pictures are produced by operation of a multi-contact switch that changes the connections of width and height controls, or else shifts from a set of controls adjusted for normal picture size over to another set adjusted for enlarged pictures. Inasmuch as variations which alter width and height often affect such things as linearity, hold, and even centering, the magnifier switch may also change the controls for these other characteristics.

Variation of some types of width control will alter second anode voltage and thus change brightness and focus. Then the magnifier switch may make compensating changes to maintain second anode voltage or to restore brightness and focus.

Fig. 16 illustrates typical methods of obtaining enlarged pictures. At A there are two sawtooth capacitors, Cs, of different values. On each capacitor is an adjustable peaking resistor. You will recall that adjustable negative peaking is a type of drive control, and that varying any type of drive alters picture width because it changes the amplitude of sawtooth voltage applied to the grid of the output amplifier. The switch connects either one or the other of the peaking resistors to ground. One resistor is adjusted for normal picture size, the other for enlarged pictures.

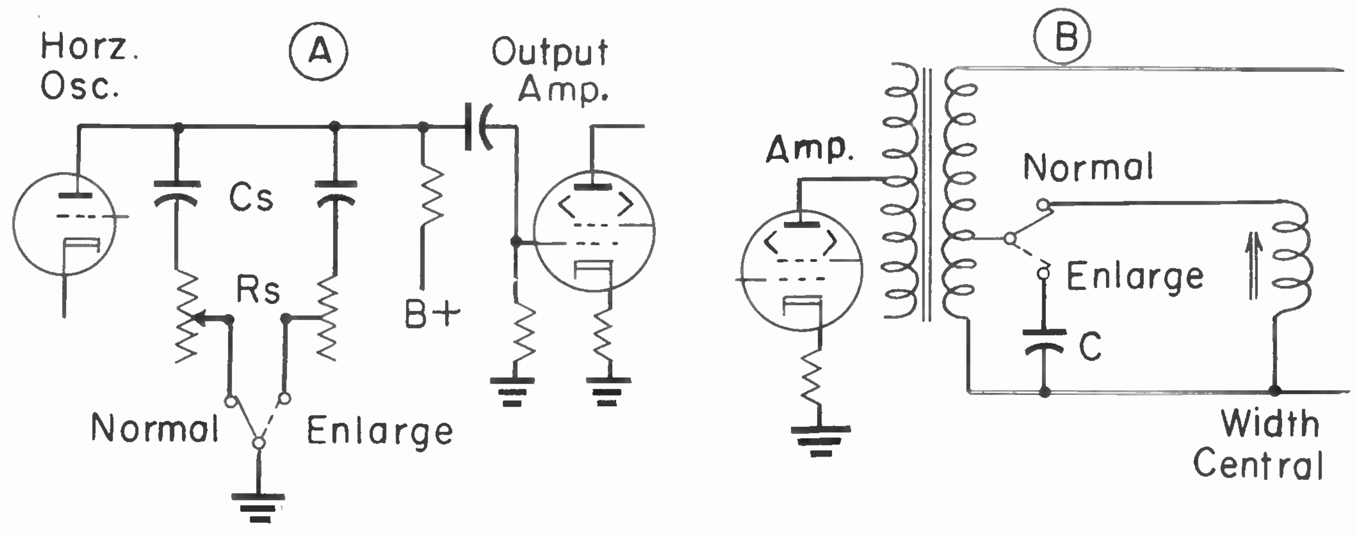

Fig. 16. Methods of circuit switching which alter drive and width controls for obtaining enlarged pictures.

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At B is a width control inductor on part of the output transformer secondary. For normal pictures the switch closes the inductor circuit. For enlarged pictures one end of the inductor is disconnected from the transformer, thus increasing the width. At the same time the switch connects capacitor C across the transformer turns from which the inductor is removed. This increases width still more.

At A of Fig. 17 are dual size controls which may be used for either width or height. Adjustable resistors are in the B+ line through which sawtooth capacitor Cs is charged. More resistance, for normal pictures, slows the charge rate and lessens the sawtooth amplitude applied to the grid of the following sweep amplifier. The resistors are separately adjustable for each picture size.

At B is a dual control for vertical linearity. This characteristic usually is corrected by means of an adjustable cathode bias resistor on the vertical sweep amplifier. The two cathode resistors, one for each picture size, are individually adjustable.

At A and B of Fig. 17 either one or the other of two resistors are brought into action by the magnifier switch. At C are connections whereby only one adjustable resistor is in circuit when the switch is set for normal picture size. Closing the switch, for enlarged pictures, parallels the first resistor with another one, thus lessening total resistance or effective resistance. This scheme may be used also for dual size control instead of the resistor connections in diagram A.

Service adjustments on receivers which provide enlarged pictures are no more difficult than on other sets, but there are more adjustments. You will find all the usual service adjustments or controls for width, height, linearity, and all the others which we have examined. In addition there will be controls for picture characteristics which must be changed when size is altered. These additional controls will be identified by some marking such as "magnify" or "enlarge", or by an abbreviation. The additional controls may be on the front of the chassis, with regular controls on the back. On other receivers

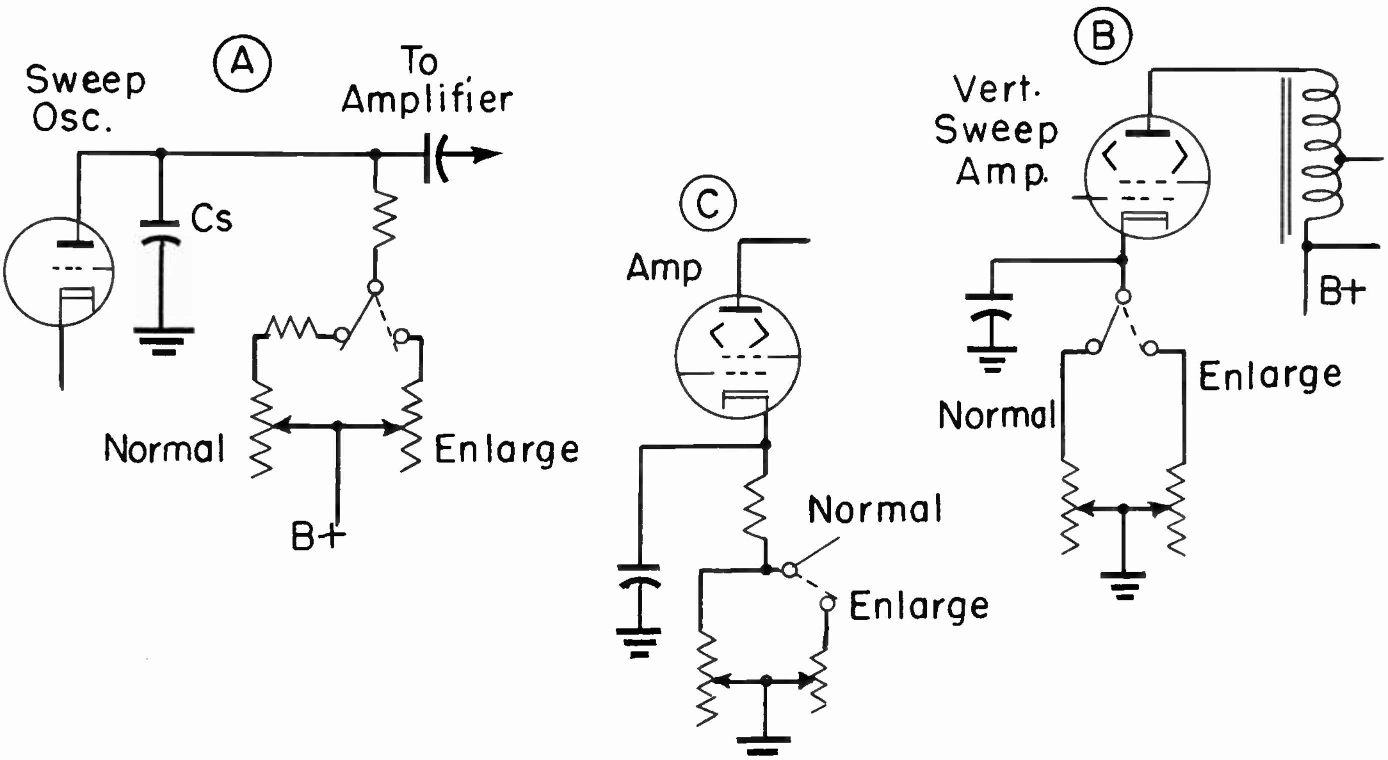

Fig. 17. Switching of size and vertical linearity controls for enlarged pictures.

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all the controls may be together on either the front or back of the chassis.

Usually it is advisable to adjust all the regular controls while the magnifier switch is set for pictures of normal size, then set the switch for enlarged pictures and adjust all the auxiliary controls. Adjustments are likely to be more critical for enlarged pictures than for those of normal size. For example, hold controls adjusted for normal pictures may fail to synchronize on enlargements. But when these controls are readjusted on enlarged pictures they usually hold synchronization when you switch back to normal picture size. There may be an auxiliary hold adjustment for enlarged pictures.

The switch for producing enlarged pictures may be hand operated, and located with other front panel controls. On several types of receivers the enlarging switch is actuated by a magnetic relay located in the chassis. The relay circuit is closed or opened, for enlarged or normal pictures, by a push button switch at the end of an extension cord.

Shutters located between the screen of the picture tube and the mask in the cabinet usually are operated by the magnifier switch. These shutters expose the complete circle of the screen for enlarged pictures, and move to conceal small portions of top, bottom, and possibly the sides for viewing pictures of normal size.

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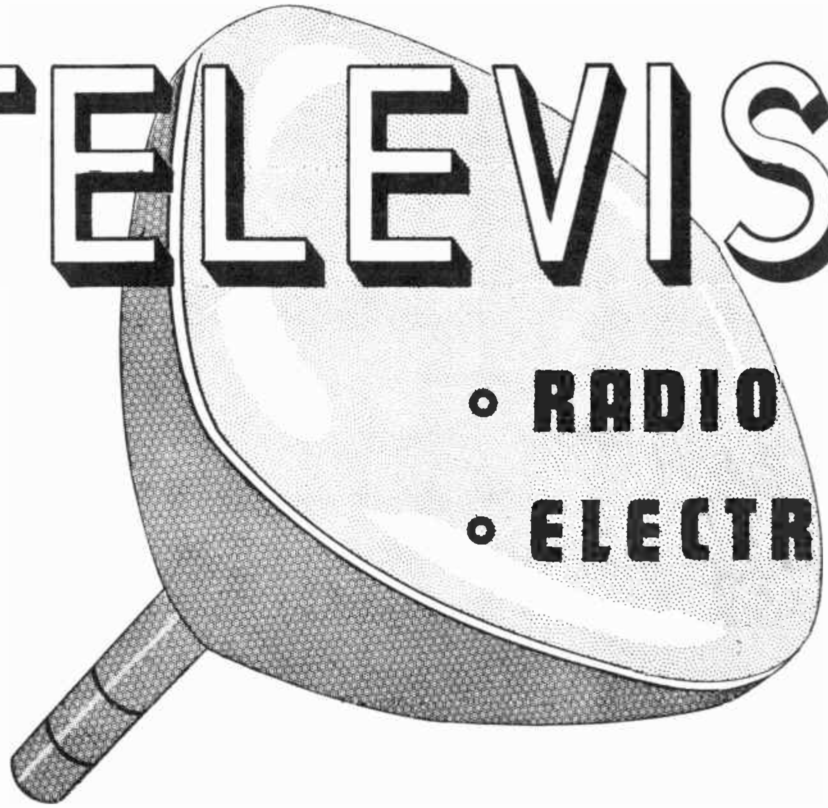

- RADIO
- ELECTRONICS

LESSON 71 — HIGH-VOLTAGE MEASUREMENTS AND TESTS

Coyne School

practical home training

Chicago, Illinois

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Lesson 71

HIGH-VOLTAGE MEASUREMENTS AND TESTS

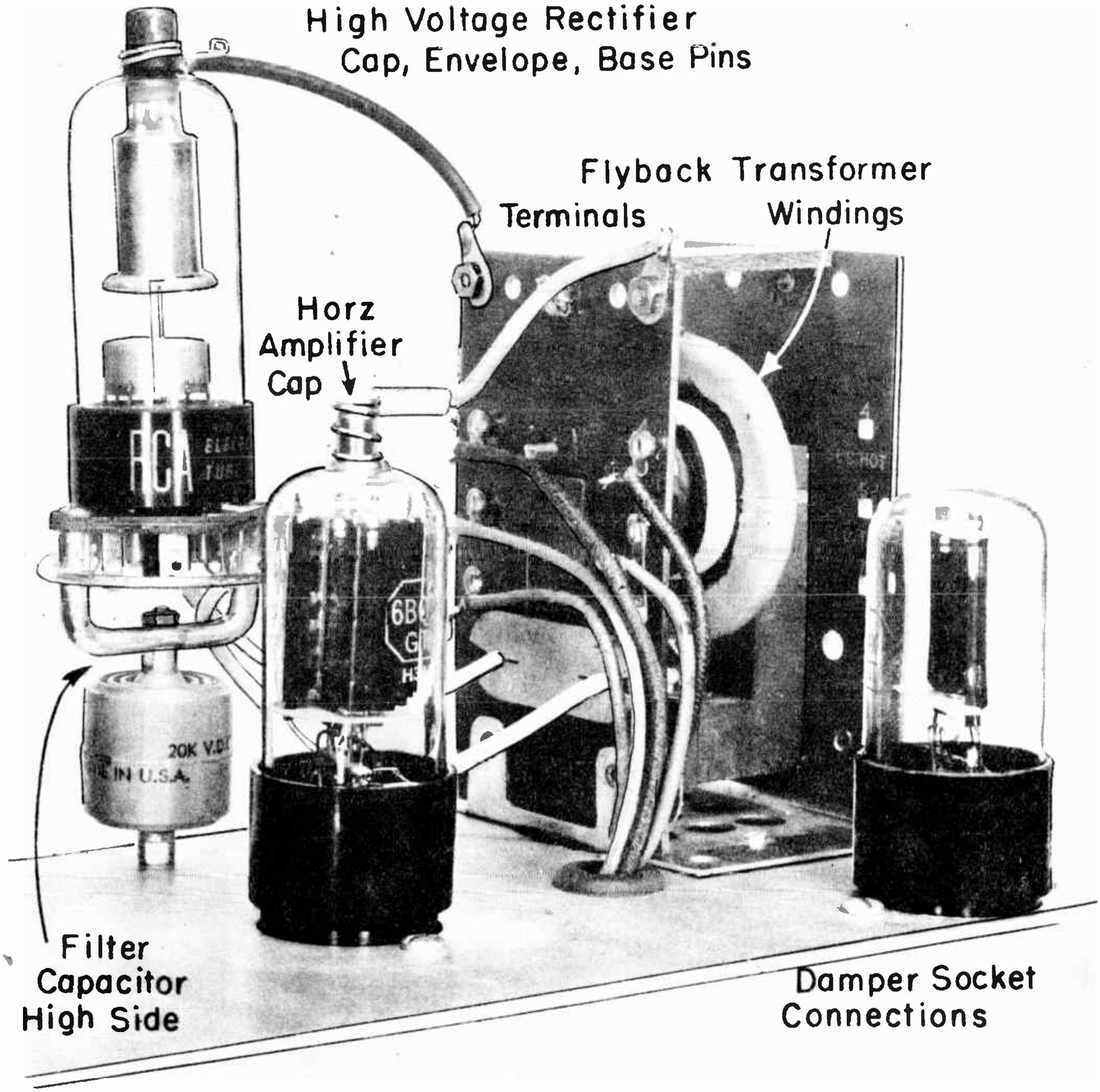

Fig. 1. Points on a flyback system at which high voltages or resulting electric fields may be measured or tested with suitable equipment.

In several other lessons we have seen how necessary it is to have second anode voltages suited to the type of picture tube and to the operating conditions. An experienced technician who has encountered all kinds of troubles and has learned to recognize probable causes can make a fair estimate as to whether a picture tube is operating with a

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suitable second anode voltage, but it is far better to measure the voltage and thus avoid hunting for troubles not present while missing others which are the real causes for difficulty.

Before discussing methods of measurement it is well to know that high-voltage power supplies in all modern television receivers are intentionally designed to have poor voltage regulation. Only a little added load or a small reduction of load resistance causes an almost instantaneous drop of voltage to a fraction of its normal value. This is why a high-voltage shock may be painful but is not particularly dangerous to anyone in normal health.

Poor regulation causes difficulties in voltage measurement. Even though you use a voltmeter fitted with a high-voltage probe in which resistance is hundreds of megohms, the instrument may draw current comparable in value to that flowing in the second anode, and indicated voltage may be somewhat lower than exists while no measurements are being made. Any method of measurment with which resistance much less than 200 megohms is connected between second anode and ground gives little useful information.

We shall consider first some of the rules which must be followed if you are to avoid the shock hazard. To begin with, your hands, your shoes, the work bench, and the floor on which you stand must be dry. Instrument probes and other connectors for the high sides of measured circuits must be both clean and dry. High potentials can cause discharges over moisture films to considerable distances, much farther than you would expect.

While power is turned on use only one hand near the tested apparatus, and to be sure, keep the other hand in your pocket. This prevents possible shock currents from passing through your body and vital organs, assuming that the floor and your shoes are dry. Regardless of their insulation, do not touch second anode leads or cables while the receiver is alive.

Fig. 2 is a picture of a high-voltage probe such as may be used on either a vacuum tube voltmeter or a high-resistance moving-coil d-c voltmeter. Extending back from the contact tip, at the left, is transparent plastic insulation. Back of this insulation are barrier discs which would force leakage current to travel a longer path to the handle. Grasp the probe only by its handle, and keep your fingers back of the barriers, not on them.

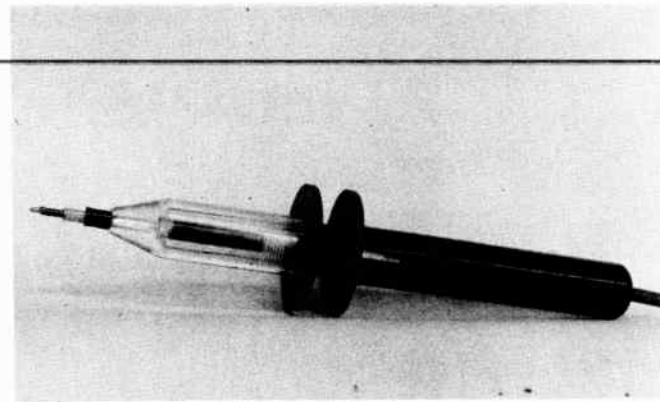

Fig. 2. A high-voltage probe for connection to a vacuum tube voltmeter or to a moving coil d-c voltmeter.

The handle is of high-quality insulation such as Bakelite or polystyrene. Extending from the back of the handle and leading to a connector for the meter is a flexible cable insulated for something like 50,000 volts. This lead connects inside the handle to a resistance element that extends forward to the metal contact tip. All except a small fraction of an inch of tip is covered with additional insulation, such as high-voltage spaghetti, to prevent unwanted contacts.

Before commencing to make measurement be sure to discharge all filter and tube coating capacitances if the receiver has been alive during the past half hour. Considering a second anode circuit such as that of Fig. 3, it is apparent that charges on the capacitances when the receiver is turned off have nowhere to go except through very slow leakages, unless you touch some part of the circuit.

With an all-glass magnetically deflected tube grasp the second anode lead by its insulation, pull the cable connector off the tube cap and touch the connector to chassis metal.

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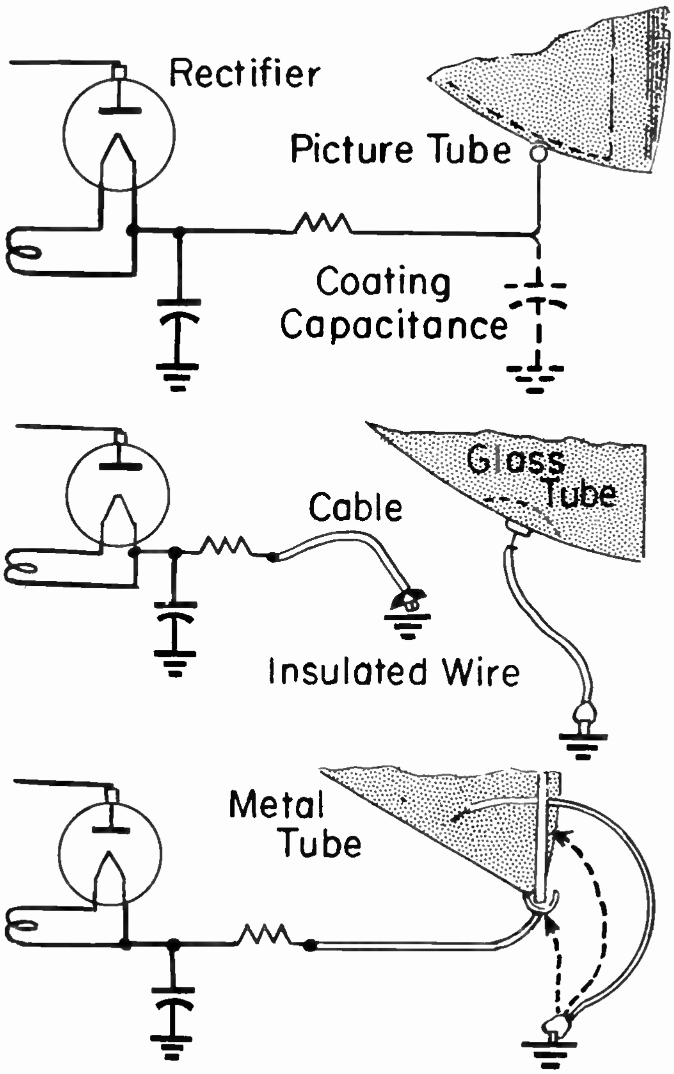

Fig. 3. Methods of discharging filter capacitors and capacitances of picture tube coatings.

Then clip one bared end of a length of insulated wire to chassis metal and touch the other bared end to the second anode connector on the picture tube, to discharge the coatings.

If the picture tube has a metal shell or cone, clip one end of the length of insulated wire securely to chassis metal and touch the other end to any point on the metal shell or cone, or to the metal lip which is around the face, or to an exposed connector on the end of the second anode cable while this connector remains on the lip of the picture tube. A metal picture tube has no coatings to be discharged.

With electrostatic picture tubes you can discharge the filter capacitors if their terminals or the rectifier socket lugs are accessible. Use the insulated wire with one end clipped to chassis metal. If connections are not accessible for discharging they would not be accessible for measuring anode voltage, and must be made so.

The safe way to proceed with measurements of second anode voltage is as follows:

1. Pull the receiver power cord from the a-c receptacle, or at least make sure that the power switch is turned off.

2. Make all test connections to the second anode circuit in such manner that they won't have to be held by hand. When using a high-voltage probe either fit it with a spring clip or else use a short insulated wire clipped at one end to the point of measurement and at the other to the tip of the probe. In some cases you can support or wedge the probe so that its tip will remain firmly on the point of measurement.

3. Be sure to connect the low-side lead of any testing meter to chassis ground or B-minus to prevent breakdown of insulation inside the instrument.

4. Insert the plug of the power cord in the line receptacle or turn on the receiver switch. Make all necessary observations or meter readings.

5. Pull the power cord plug or make sure to turn off the receiver switch before touching the test connections, also discharge the filter capacitances unless measurements have been made with a meter and high-voltage probe. The capacitances discharge almost immediately through probe and meter resistance to ground.

Although this procedure is the safe method, you undoubtedly will form the habit of hand-holding a high-voltage probe while measuring voltages. This probably is safe enough after a little experience, but use the really safe method when potentials are likely to exceed 14,000 or 15,000 volts.

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Do not use meters and high-voltage probes for measurements at plate terminals or caps of horizontal output amplifiers in flyback systems nor of high-voltage rectifiers in any system. The extremely high pulses at these points make indications of d-c meters practically meaningless, and may damage your instruments.

HIGH-VOLTAGE PROBES AS VOLTMETER MULTIPLIERS. A high-voltage probe connected to either the d-c terminal of a vacuum tube voltmeter or to a moving coil d-c voltmeter is merely an added multiplier resistance to increase the range of measurement. How much resistance is required in a probe depends on the current drawn by the meter at full scale and on the number of volts to be indicated at full scale with the probe in use. Internal resistances, even of vacuum tube voltmeters, are small in comparison with probe resistances.

Vacuum tube voltmeters of various makes and models usually draw 40 to 90 microamperes of current at full scale, on any of their voltage ranges. All moving coil d-c voltmeters of 20,000 ohms per volt sensitivity draw 50 microamperes at full scale. D-c input resistances of vacuum tube voltmeters are stated in their specifications. Common values are between 10 and 20 megohms on all ranges. D-c resistance of a moving coil voltmeter is, of course, the product of sensitivity in ohms per volt and the number of volts at full-scale on the range to be used. For example, with a meter of 20,000 ohms per volt sensitivity used on a range of 1,000 volts the resistance is 1,000 times 20,000 or is 20 megohms.

Probe resistance for any d-c meter, either VTVM or moving coil voltmeter, may be computed in three steps when you know the internal resistance of the meter, the volts range to be employed during high-voltage measurements, and the maximum or full-scale volts to be measured with the probe in use. We determine first the meter current in microamperes at full scale, which is the same with or without a probe. This current value is employed for determining total resistance of meter and probe. Then meter resistance is subtracted to learn required resistance for the probe. The three steps are as follows:

1. $\text{Microamperes, full-scale} = \dfrac{\text{full scale volts of meter range}}{\text{meter resistance, megohms}}$

2. $\text{Total required megohms} = \dfrac{\text{high volts at full-scale}}{\text{microamperes, full-scale}}$

3. Megohms for probe = total megohms - meter megohms

Example: A VTVM has d-c input resistance of 11 megohms. It is to be used on its 1,000-volt scale and is to indicate 20,000 volts at full-scale. This means that all pointer indications on the 1,000-volt scale are to be multiplied by 20.

1. $\dfrac{1000}{11} =$ 90.91 microamps, full-scale.

2. $\dfrac{20000}{90.91} =$ 220 megs, approx, total R.

3. 220 - 11 = 209 megs, probe resistance.

High-voltage probes may be purchased with correct resistances if you specify the make and model of the meter with which they are to be used. In most of these probes the resistance element is removable and interchangeable with other values. Thus a single probe, with two or more resistance elements, may be used with various meters and for measurement of various full-scale high voltages.

If you use a VTVM, or use a moving coil d-c voltmeter of at least 20,000 ohms per volt sensitivity on a high range, and if the probe raises the full-scale indication to 20,000 ohms or more, connecting the probe and meter to a second anode should not appreciably drop the voltage. That is, indicated voltages will be very little less than second anode voltages without the measuring equipment connected.

The effect of measuring equipment may be checked in this manner. Make all connections for measuring second anode voltage. Turn on the receiver, let it warm up thoroughly, then adjust brightness and contrast so that pictures are barely visible. Watch the pictures while disconnecting the measuring equipment. If there is negligible

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increase of brightness, or no increase, the probe and meter are not altering second anode voltage enough to affect service operations. If brightness increases noticeably, total resistance of probe and meter is too low. Use a probe with more resistance, which means higher voltages at full-scale.

It is possible to make a high-voltage multiplier for any meter by using series resistors to total the probe resistance computed from preceding formulas. The resistor pigtails must be soldered together. The units must be enclosed in insulation or else mounted on insulation so that they cannot come closer than one inch to any metal. Provide a connection at one end of the string for the meter, and at the other end a cable with high-voltage insulation for connection to the point of measurement. Such an arrangement is illustrated by Fig. 4.

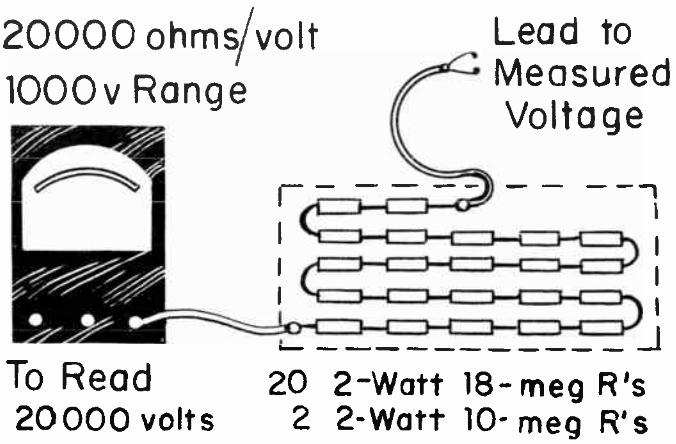

Fig. 4. Series resistors used as a high-voltage multiplier on a meter.

Use a number of resistors such that none are subjected to excessive voltage drop. Rated breakdown voltages for ordinary resistors usually are 350 for half-watt units, 500 for one-watt sizes, and 1,000 volts for two-watt sizes. Determine the required number of resistors by dividing full-scale high voltage to be measured by the voltage rating of resistors you intend to use. Allow at least two extra resistors as a safety measure.

Determine the megohms per unit by dividing the number of megohms which would be required in a probe by the number of resistors to be used. For all except one or two resistors, select a value which is the nearest preferred number of megohms in standard units. Then add the extra one or two resistors of whatever value or values will make up the required total. Resistances in Fig, 4 were worked out in this way.

SPARK TESTS. Service men sometimes check for presence or absence of second anode voltage by watching for sparks which should pass between the terminal on a second anode cable and ground while the set is turned on. This is not good practice. It gives no precise information as to actual potentials in volts, and it places an abnormal stress on insulation in the high-voltage circuit. However, since spark tests are common practice you may as well know how to make them. Instructions which follow apply to all the high-voltage power supplies unless specifically mentioned as only for some particular type.

Disconnect the terminal of the high-voltage cable from the second anode of the picture tube before turning on the set. Support the cable on any kind of insulation in such manner that its terminal is an inch or more from all metal. Turn on the set and allow time for warmup. Pick up the cable by grasping its insulating cover well back from the terminal and bring the terminal just close enough to any chassis metal to allow sparking, or until the terminal almost touches chassis metal, still with no spark. Do not touch the cable terminal directly to ground. Service men often pull the cable terminal off a glass picture tube while the set is operating, then bring the terminal near ground metal to observe sparking or lack of it.

Should there be no filter resistor in the high-voltage circuit between rectifier and lead to the picture tube, the spark will be brilliant yellow-white and will be accompanied by loud snapping noise. Such a spark is pictured by Fig. 5. At the time of this photograph second anode potential was only 6,600 volts. If there is a filter resistor, usually a half-megohm or one megohm, the spark to ground will be comparatively short, thin, and probably of blue or purple tint.

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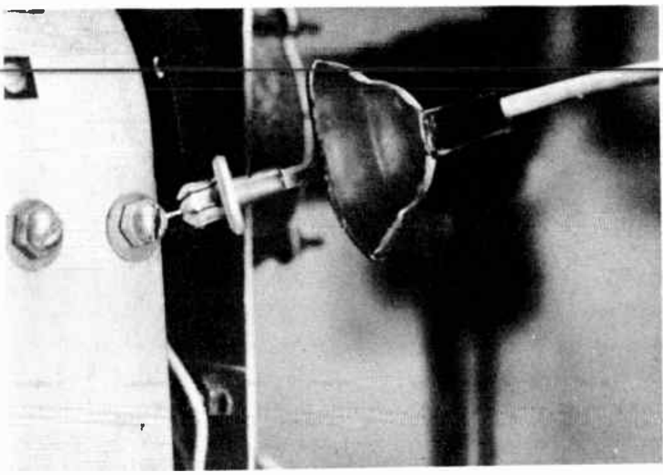

Fig. 5. Drawing a spark to ground from the terminal on a second anode cable for a glass picture tube.

A spark discharge in air, when there is no filter resistor in series with the leads, requires a potential difference of about 30,000 volts per inch of gap. Accordingly, a spark which will jump a maximum of a half-inch indicates potential difference somewhere in the neighborhood of 15,000 volts. A spark which jumps a maximum of one-third inch indicates about 10,000 volts, a quarter-inch maximum spark means about 7,500 volts, and so on. Actually a quarter-inch spark indicates somewhat more than 7,500 volts, but our rough rule of 30,000 volts per inch is close enough.

If you hold the cable terminal near the second anode connector on a picture tube, instead of near chassis metal, the spark will be much shorter. This is true of both glass and metal picture tubes.

When the cable is farther from ground metal than allows a spark there will be a corona discharge. In a fairly dark room or with parts well shaded from light you can see the corona as a continuous blue glow at the cable terminal, if the terminal is positive, and as reddish tufts on the metal, if it is negative. Corona is accompanied by a strong odor of ozone, which is being formed rapidly from oxygen in the air. You may hear a rather faint hissing noise when there is corona. The odor of ozone will appear on all spark tests, whether or not you can see a corona.

Spark tests may be made also by securely clipping or otherwise fastening one end of an insulated wire to chassis ground, then bringing the other end, bared, to the point of checking. You are safe from shock when holding this wire by its insulation, because current will follow the wire from ground rather than following your body.

The grounded wire may be brought near the second anode terminal while the high-voltage cable remains connected to the picture tube. The second anode connector on a glass picture tube may be exposed, while the set is turned off, by turning back or pushing back the insulating cup on the end of the cable. Spark lengths may be somewhat less than from the high-voltage cable to ground after the cable is disconnected from the picture tube. A high-voltage filter resistor reduces length and brilliance of the spark, just as in other tests.

Still another spark test may be made by bringing the end of a grounded insulated wire near a filament lug on the socket of the high-voltage rectifier, or near the filter capacitor terminal connected to this lug. The spark should be brilliant yellow-white. Fig. 6 is a photograph of a spark drawn to a filter capacitor terminal.

With the grounded insulated wire you can make a spark test at the cap of the high-voltage rectifier, as in Fig, 7. Here the discharge will consist of a rather thin, nearly steady bluish or purple stream. This discharge at the rectifier cap can be drawn out much longer than the brilliant sparking at the second anode cable.

Do not attempt spark tests at the cap of a horizontal output amplifier working into a flyback high-voltage transformer. The discharge would consist of a very hot arc, with a flaming center surrounded by a bright halo. Such a discharge does one of three things; it blows the fuse which protects the amplifier and transformer, it ruins the amplifier, or it burns out the transformer winding.

Do not try spark tests at the high side of the damper in a flyback system, nor at any point connected to the high side. The high side of the damper may be either its cathode

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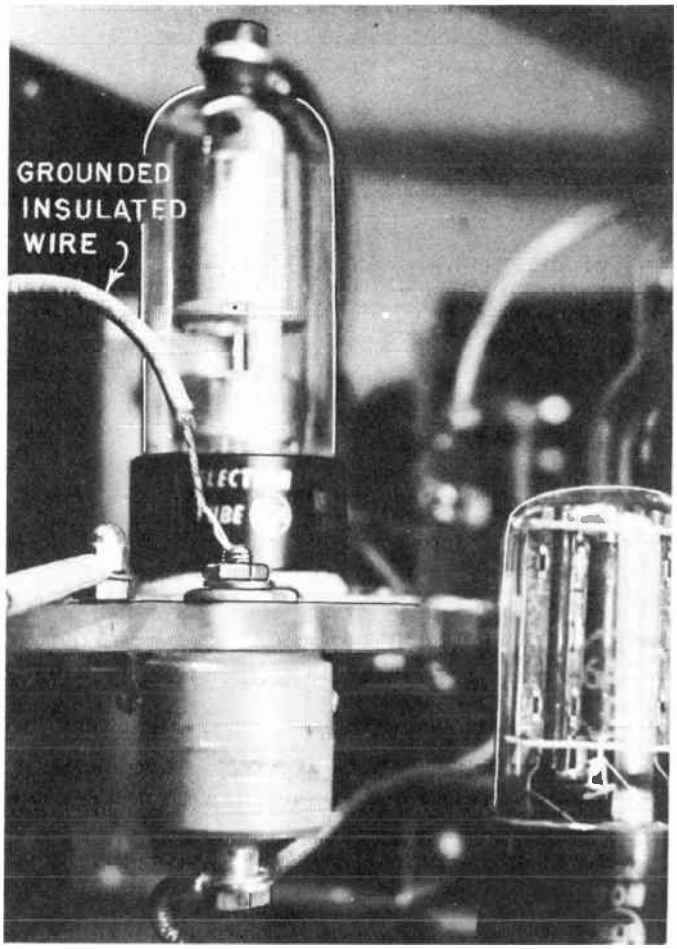

Fig. 6. A spark test at the high side of a high-voltage filter capacitor.

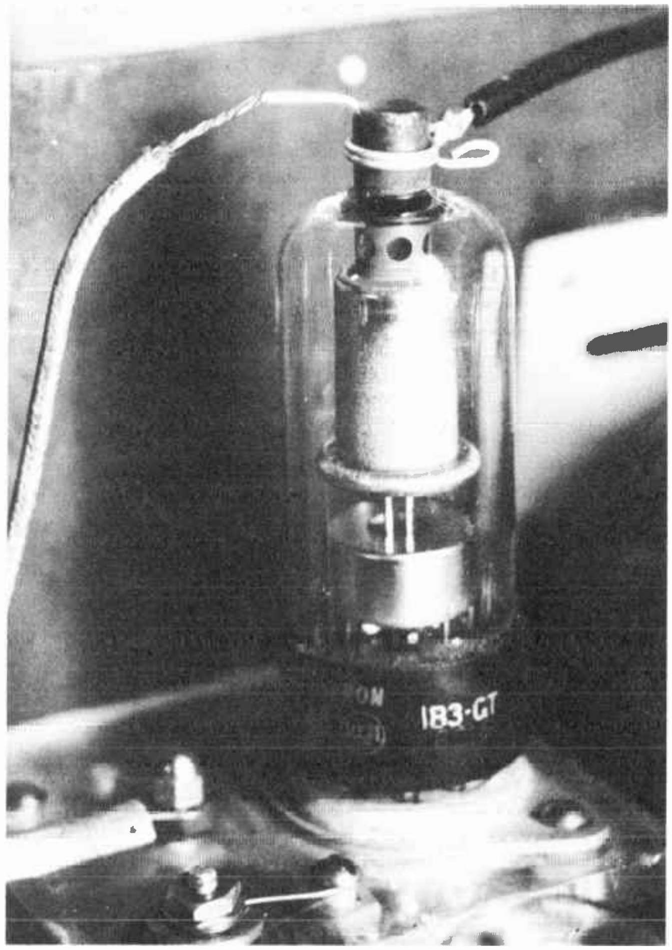

Fig. 7. A longer spark will pass between the grounded wire and the cap of the high-voltage rectifier.

or its plate, depending on the type of output transformer. A discharge from the high side of a damper or damper circuit to ground usually so overloads the output transformer as to burn it out.

NEON GLOW TESTS. Gas within the bulb of a small neon lamp will acquire a distinct red glow when the bulb is held in strong electric fields such as exist around parts of high-voltage power supplies. Such a lamp, suitably supported, may be used for checking presence of absence of high-voltages, with no danger of damaging parts of the power system.

A suitable neon lamp is the type NE-2, obtainable from radio and television supply houses. One of these lamps is shown at the top of Fig. 8. The bulb is about 1/4-inch in diameter and somewhat less than an inch long. The two internal electrodes are connected to semi-flexible wire leads extending through the glass.

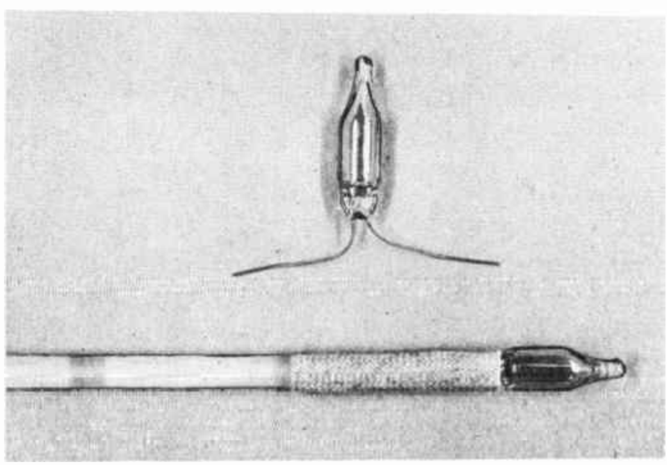

Fig. 8. A neon glow lamp, and how it may be used for checking high voltages.

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In the lower part of the picture a neon lamp is attached to a polystyrene rod 3/16 inch in diameter, also obtainable from supply houses. This rod should have total length of 8 to 10 inches. Do not use a rod of fibre or wood, because through it or over its surface there may be enough leakage to cause slight electric shock when testing at 5,000 volts or more.

The neon lamp is attached to the rod by inserting the lamp leads in a piece of spaghetti of such size as allows a snug fit on the rod, then sliding the lamp and spaghetti together over the end of the rod. Whether the two lamp leads touch each other or are separated, makes no difference in testing.

Hold the neon lamp close to or in contact with parts which are to be checked for presence or absence of high voltage. The brighter the glow or the greater the distance at which it appears, the stronger is the electric field and the higher is the voltage. About the only test for which the glow lamp is not satisfactory is at the second anode connector of the picture tube while the high-voltage cable remains connected. The field is too weak to cause distinct glow unless potential is up around 9,000 volts or more. Even then the test must be made where there is little surrounding light.

With a high-voltage supply in good order the neon lamp will glow strongly at the cap, all around the envelope, and at socket filament connections of the high-voltage rectifier, also at the high side of a filter capacitor. The glow is less bright, but still strong, at the cap and around the upper part of the envelope of the horizontal output amplifier on a flyback system.

The neon lamp will check for voltage in parts which cannot be safely tested by sparking. As examples, when the high-voltage supply is operating correctly, the lamp will glow brightly when held near any of the windings on a flyback transformer. The glow will appear also at the high-side connections to the damper tube. All in all, the neon lamp allows following high voltages all the way to the second anode cable, and effectively indicates absence of high-voltage at any point.

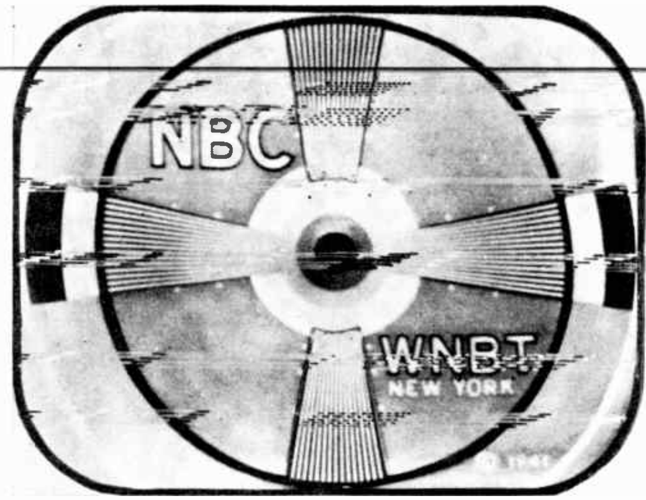

Fig. 9A.

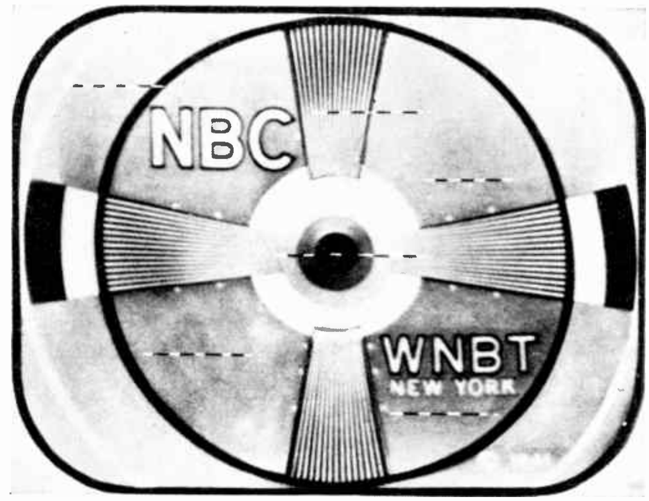

Fig. 9B.

Fig. 9. Corona or sparking cause horizontal streaks and flashes to appear on pictures and patterns.

CORONA, SPARKING, ARCING - CAUSES AND REMEDIES. Corona and sparking affect pictures somewhat as illustrated by Fig. 9. There may be light or dark horizontal streaks, or both together, or there may be bright flashes on the screen. In severe cases pictures may jump horizontally or roll vertically due to momentary loss of synchronization, just as with any electrical "noise" troubles. Sometimes there will be "tear-out" as at the bottom of the pattern in Fig. 10.

Points at which trouble exists are located by looking and listening. Corona can

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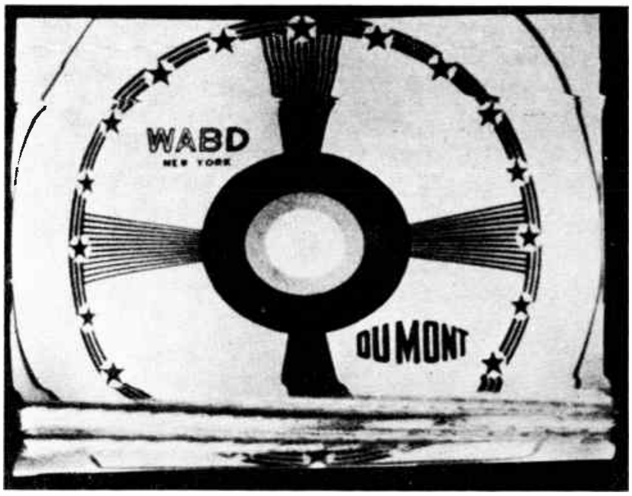

Fig. 10. There is tear-out at the bottom of this pattern, due to sparking or other strong "noise" interference.

be seen only in a darkened room or with parts well shaded from light, then appearing as faintly luminous blue glow at high-voltage conductors which are uninsulated. The distance that corona extends from bare conductors increases with higher potentials. The small current that flows in a corona discharge causes no electrical overload or breakdowns.

If space between conductors is little enough, and voltage high enough, there may be sparking before a corona forms. Sparking tends to occur in circuits where there is energy storage, either in capacitances or in magnetic fields. A spark discharge carries considerable current, and may cause electrical breakdowns as well as picture interference.

An arc is visible as a steady and fairly bright yellow-red glow, accompanied by sizzling sound. Arcs carry large currents and nearly always result in electrical breakdown or severe overheating within a short time. Overload is so great that pictures usually disappear partially or entirely.

Heavy sparking, or arcing at all, usually weakens boosted-B voltage in a flyback power supply and weakens second anode voltage in any system. Depending on how serious is the trouble, pictures may be too wide and too high, of very poor definition or very fuzzy, or else they may become narrow, dim, and indistinct.

Sparking causes crackling sound from the speaker. Effects of corona seldom are audible in sound reproduction. Arcing would not affect sound from the speaker, because arcing usually causes electrical breakdown and failure of B-power.

Causes and remedies are generally the same for corona, sparking, and arcing, since either of these faults may change intermittently to one of the others. Causes and remedies in the following list apply only to high-voltage power supply components and wiring.

A. Insulation Trouble.

Insufficient air space between bar conductors, as between chassis or shield metal and socket lugs or any other terminals. Clearance should be proportional to 1 inch per 10,000 volts of potential difference.

Dirt, dust, or moisture which lowers surface resistance of insulation. Check terminal boards of flyback transformers, also sockets for high-voltage rectifiers and dampers, and surfaces of high-voltage capacitors.

There may be leakage from transformer coils to a grounded core.

Insulation on wires and cables may not have sufficient dielectric strength, or it may be old and cracked.

Insulating grommets may be lacking in holes through chassis or shield metal through which pass high-voltage conductors.

Leakage may occur across the glass which is back of the shell on a metal picture tube, and reach conductors in the yoke coils. Yoke coils need additional insulation. Keep the glass clean and dry.

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B. Faults Which Increase Ionization of Air. Air may ionize within a space where there is high potential difference, then becoming a high-resistance conductor. Sharp points on any solder joints, but especially at lugs on the socket for the high-voltage rectifier. Joints must be rounded and smooth.

Loose wire strands or sharp, projecting ends of wires anywhere.

Bare wires bent too sharply at corners or of too small gage size. This applies especially to r-f high-voltage supplies, to be described later.

C. High Resistance. High resistance in joints or contacts, may cause minute sparks which cannot be seen.

Look for loose terminal connections, also for rosin joints or cold solder joints, and for corrosion at joints. Use a long rod of good quality insulation to press or move suspected joints while watching pictures and listening to sound.

Spliced leads instead of continuous conductors for the high-voltage rectifier filament or for the second anode cable may cause trouble.

Poor contact between high-voltage rectifier base pins and socket contacts.

D. Grounding

A poor ground contact on the outer coating of glass pictures tubes causes discharge to ground in the form of tiny sparks.

Metal supports for insulation around the lips of metal picture tubes should be grounded, oftentimes through resistors of half-megohm value. Otherwise this metal collects charges which cause intermittent weak sparking.

Arcing may occur inside of poor quality high-voltage filter capacitors. If no other fault is located, try a new capacitor. Excessive second anode voltage may cause sparkover inside of some picture tubes.

Corona, sparking, and arcing may be prevented by applying additional insulation either in liquid form or as flexible plastic tape. Where liquids are more easily applied use corona lacquer, polystyrene cement, or polyethylene cement. These dry rapidly, and can be built up in successive coats to any necessary thickness. Dielectric strength is about 15,000 volts per 1/100 inch of dry cement or lacquer. Beeswax or any wax such as found in paper capacitors can be melted and applied as a thick coating where working temperatures will not cause the wax to flow away.

Flexible insulation is easily applied to parts such as surfaces of shield cans and chassis metal, insulated wires and cables, coils of transformers and yokes, and cores of transformers. You may use electrical tape or plastic tape whose dielectric strength is about 1,000 volts per thousandth inch of thickness. A convenient size is 1/2-inch wide and 10 thousandths thick, with dielectric strength of 10,000 volts per one layer, and somewhat less than 20,000 volts for two layers.

High-voltage spaghetti may be slipped over wires or cables which need extra insulation. Spaghetti may be put over a wire and pushed close against solder terminal lugs or any other form of terminal connection.

A corona ring should be connected to the lug for pin 7 of 1B3-GT high-voltage rectifiers. This pin connects to one end of the filament and also to the internal shield of the rectifier. A ring for the 1X2-A rectifier should be connected to the socket lug for the side of the filament that goes to the second anode cable.

When there is no ring, corona trouble may be lessened in some cases by connecting together the socket lugs for pins 1, 3, 5 and 8 on a 1B3-GT rectifier, and completing this connection to the lug for pin 7. Use bare

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hookup wire or any heavier wire. Make the joints on the socket lugs smooth and round.

R-F HIGH-VOLTAGE SUPPLIES

Although flyback high-voltage supplies are almost universal in television sets now manufactured, until quite recently many makes and models of receivers employed what is called the r-f (radio-frequency) type of high-voltage supply for second anodes of their picture tubes. These r-f high-voltage supplies were used with picture tubes of sizes all the way from 7-inch to 16-inch diameter, and with both electrostatic and magnetic deflection systems. Consequently many r-f high-voltage supplies still require regular servicing.

The majority of receivers using the r-f method of supplying high-voltage for the picture tubes are of the transformerless variety with 7-inch electrostatic picture tubes, which operate well with about 5,000 volts on the second anode. But many popular sets with magnetically deflected picture tubes have this type of power supply, furnishing all the way from 8,000 to as much as 14,000 second anode volts. So far as d-c output voltage is concerned, there is no great difficulty in building r-f power supplies furnishing 30,000 to 50,000 volts.

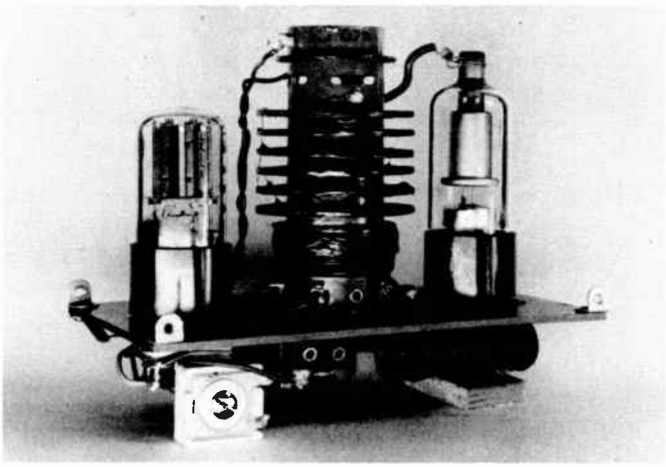

Fig. 11. An r-f high-voltage power supply with shielding cover removed. Note the voltage adjusting capacitor at the lower left.

Fig. 11 is a picture of a fairly typical r-f high-voltage supply removed from its protective housing or shield. At the left is an oscillator tube producing sine-wave current and voltage. The oscillating frequency varies in different receivers, ranging all the way from 90 to 300 kilocycles. This is in the range of radio frequencies, hence the name r-f high-voltage system.

In the center of the shelf of the unit pictured is an air-core transformer with four windings. The winding made of many thin pie sections delivers stepped-up sine-wave voltage to the plate of the rectifier at the right. D-c voltage from the rectifier cathode is filtered and then goes to the picture tube second anode.

Because of the high operating voltages, strong radio-frequency fields appear around the oscillator, transformer, and rectifier. These fields, and others due to harmonics, could cause severe interference with pictures. To prevent such trouble the entire high-voltage supply unit is enclosed within and shielded by a large sheet metal enclosure which usually has fewer ventilating openings than enclosures for flyback supplies. The shield of the r-f supply may be fastened directly to the receiver chassis, for grounding, or may be grounded for radio frequencies by connection to chassis metal through one or more capacitors and paralleled resistors.

Fig. 12 shows the underside of the same power supply pictured in Fig. 11. Circuits such as found in these r-f high-voltage systems are shown by Fig. 13. In this particular system the oscillator is a beam power tube with plate and screen connected together, at the socket, for operation as a heavy-duty triode.

In the oscillator grid circuit, between grid and cathode, is a feedback winding mounted at the top of the transformer tubing. Across this winding is a capacitor for tuning to resonance at the operating frequency. Capacitor Cg and resistor Rg, in parallel with each other and in series with the feedback winding, provide grid-leak bias for the oscillator. As you know, practically all sine-wave oscillators are biased in this manner.

Below the feedback coil is the high-voltage winding connected to the rectifier

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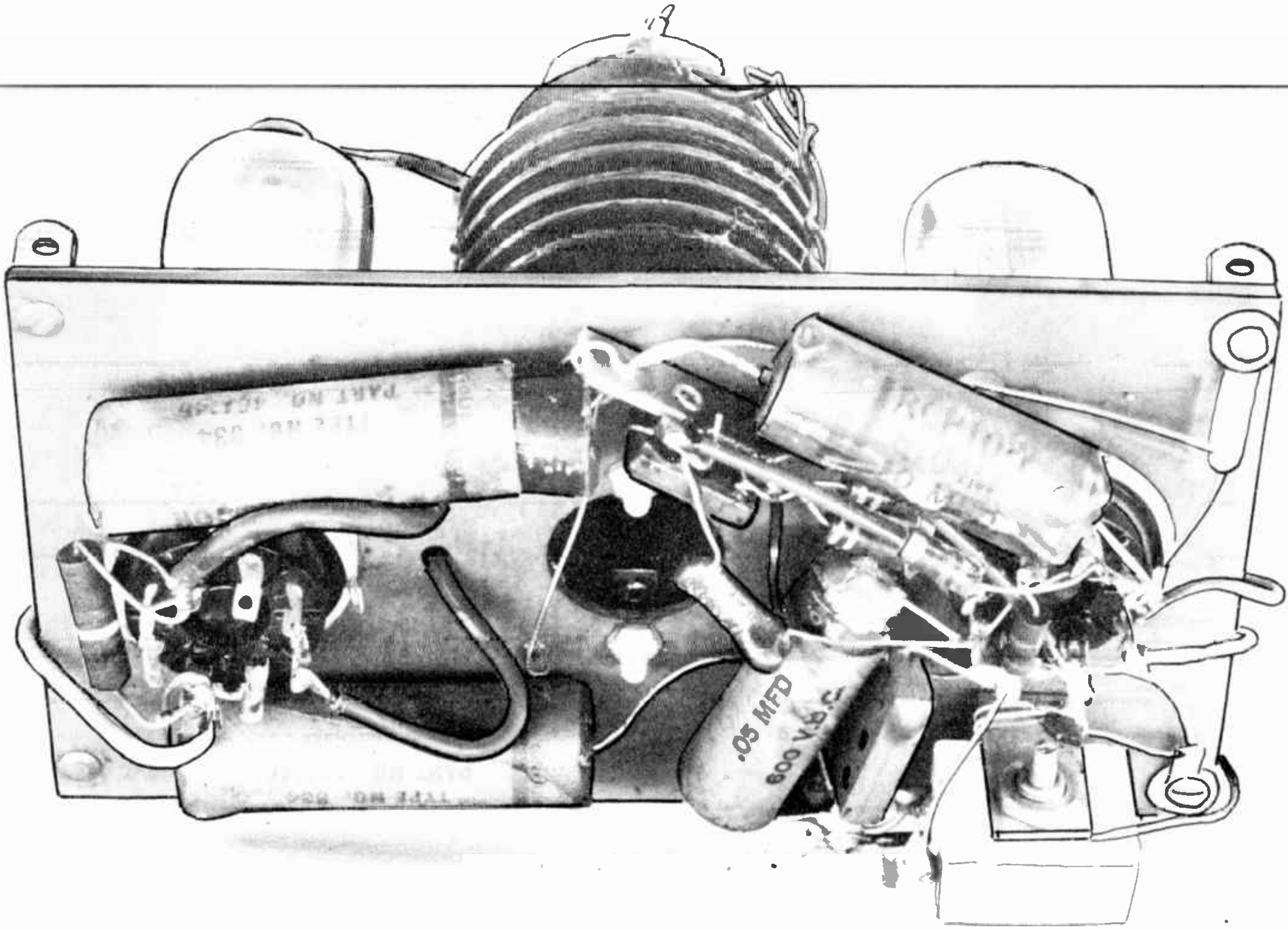

Fig. 12. The underside of an r-f high-voltage power unit.

plate. Next below is the plate winding, in the plate circuit of the oscillator. This plate winding is tuned to the operating radio frequency by adjustable capacitor Ct. At the bottom of the transformer tubing is a winding of one or two turns furnishing filament voltage and heating current for the rectifier.

In the oscillator heater lead that extends through the shield to the heater winding on a power transformer is an r-f choke bypassed with a capacitor to ground. In the B+ lead for the oscillator plate circuit is another r-f choke bypassed with a capacitor to ground. High inductive reactance of these chokes prevents high-frequency currents from getting out into other receiver circuits, while low reactance of the bypass capacitors carries these currents to ground.

The filter system on the output of the high-voltage rectifier consists of capacitor Cf to ground and of resistor Rf in series with the lead to the picture tube second anode. This filter system is like those used on high-voltage rectifiers in flyback power supplies. Capacitor Cf nearly always has a value of 500 mmf, with d-c voltage rating of 10,000, 15,000, or 20,000 volts, as may be required for the strength of second anode voltage.

The radio frequency at which the high-voltage system operates actually is fixed within narrow limits by transformer construction. Inductance of the high-voltage winding in combination with distributed and stray capacitances of wiring and other parts cause resonance at some certain frequency. The oscillator plate winding is tuned to or close to this self-resonant frequency by means of the adjustable capacitor Ct of Fig. 13. The feedback winding is tuned by its own capacitor.

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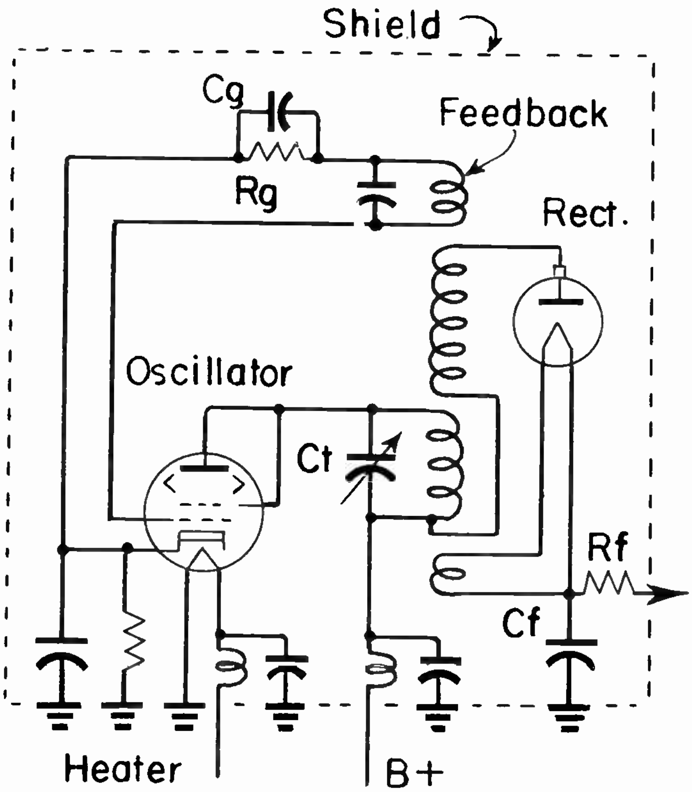

Fig. 13. Circuit connections for an r-f high-voltage system employing "tickler" feedback to the oscillator grid.

In all but a few of the earlier r-f power supplies the high-voltage rectifier is a type 1B3-GT. Maximum rated operating frequency for this tube is 300 kilocycles. As a consequence we find frequencies right up or near this limit, say 285 kc, but only in rare cases is the frequency more than 300 kc.

The tuning capacitor for the oscillator plate winding in almost all receivers is a mica-dielectric compression type having a screw adjustment with screw driver slot or a nut to be engaged by a socket wrench. Maximum and minimum capacitances depend, of course, on the operating frequency and on the inductance of the plate winding. Capacitance ranges commonly are 125 to 600 mmf, or 400 to 1400 mmf.

The "tickler" feedback of Fig. 13 is only one of several methods for returning part of the oscillator output energy to its grid. At A of Fig. 14 is one example of what we call a series feedback. The grid or grids of the oscillator are connected to the ground return of the high-voltage winding on the transformer. In this return are the paralleled capacitor and resistor providing grid-leak bias for the oscillator. The transformer plate winding is tuned by capacitor Ct. R-f chokes (RFC) are in the B+ lead for the oscillator plate circuit and in the ground return for grids and the high-voltage winding

At B of Fig. 14 still another method of feedback is represented in the manner usu-

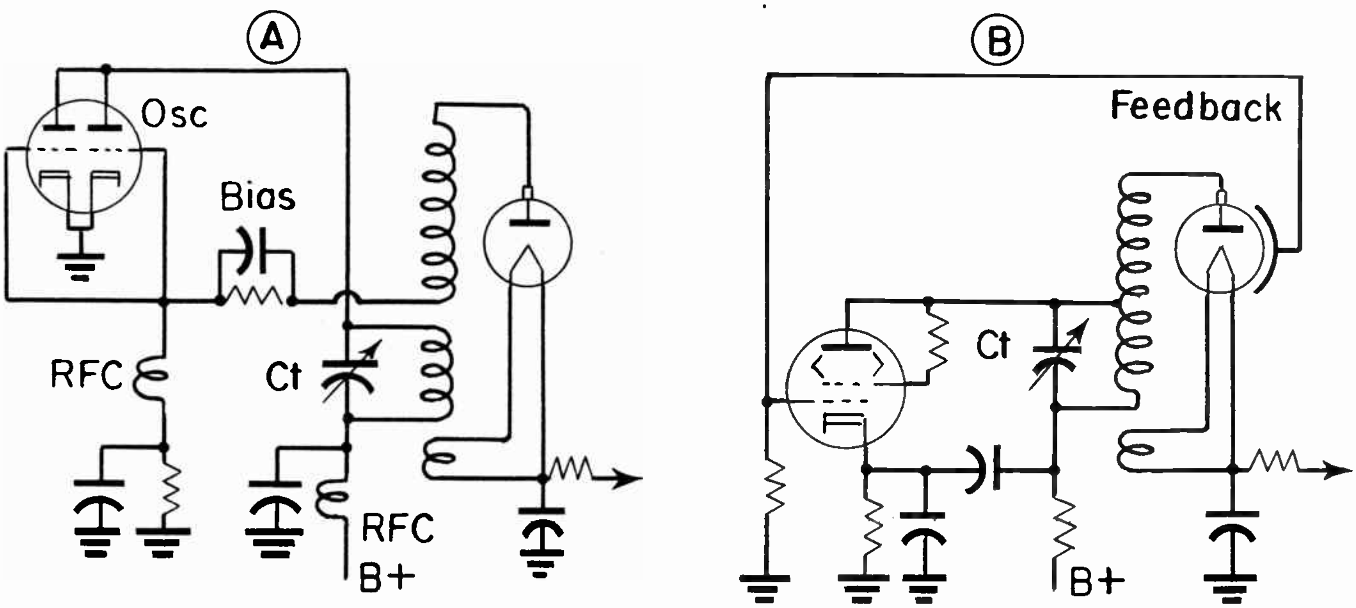

Fig. 14. A series feedback (a) and a capacitive feedback (B) for oscillator grids in r-f high-voltage supplies.

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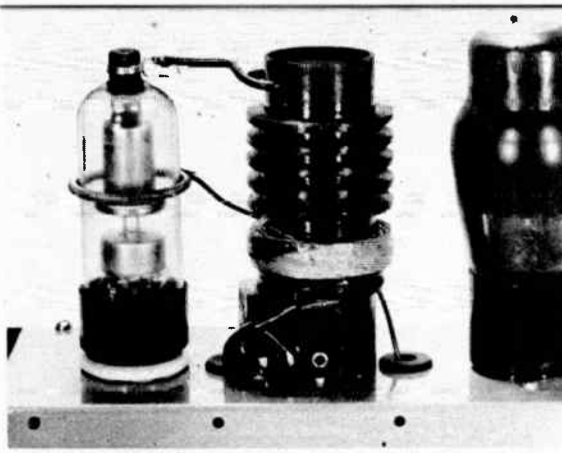

Fig. 15. A feedback ring around the envelope of a high-voltage rectifier.

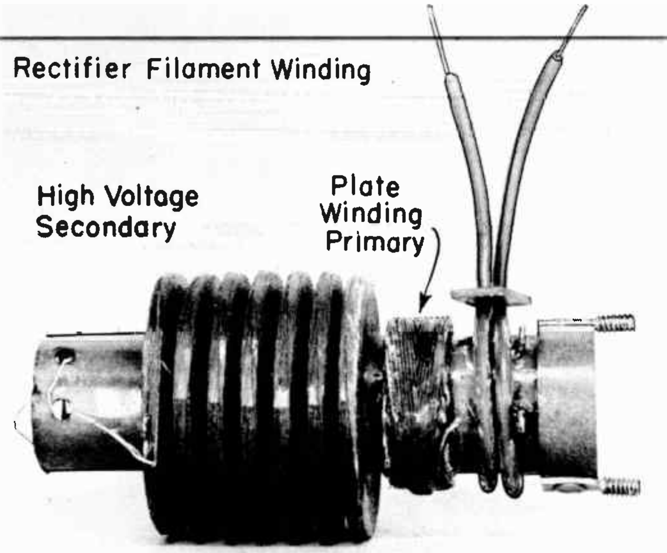

Fig. 16. How windings are arranged on a tube of insulation to form the air-core transformer of an r-f power supply.

ally employed on service diagrams. An actual application is illustrated by Fig. 15. Around the outside of the glass envelope of the high-voltage rectifier is a small coiled spring, or sometimes a metal band forming a fairly snug fit. This ring or band acts as one plate of a capacitor, with the glass envelope as dielectric, to pick up oscillating energy from the rectifier plate and return this energy to the grid.

With most r-f power supplies we find at the oscillator plate and in the plate winding of the transformer a nearly pure sine wave voltage. Peak-to-peak value of this a-c plate output commonly ranges from 400 to 600 volts. The step-up voltage ratio between transformer plate winding and high-voltage winding usually is anything from about 25-to-1 up to 35-to-1. Because of energy losses, turns ratios are made somewhat greater, being from 35-to-1 up to something like 50-to-1.

If we assume a voltage step-up of 30 times and 500 peak-to-peak volts from the oscillator plate the result will be 15,000 peak-to-peak volts. Rectified voltage cannot exceed half of this peak-to-peak value, which would be the amplitude of positive alternations. This would give a d-c high-voltage output from the rectifier of something less than 7,500 volts for our assumed conditions.

The windings and their arrangement on a typical r-f high-voltage transformer show clearly in Fig. 16. Because the high-voltage secondary must contain such a great number of turns it is made with a number of pie sections to reduce distributed capacitance. This winding often is made with Litz wire, which greatly lessens skin-effect losses at the radio frequencies used in power supplies.

The oscillator plate winding, immediately at the right of the high-voltage winding in the picture, is a duolateral type. There is no feedback winding on this particular unit. To the right of the plate winding are two turns of heavily insulated wire which form the filament winding for the high-voltage rectifier. These rectifier filament windings for r-f power systems are like the windings on flyback transformers.

Oscillators for r-f high-voltage supplies most often are beam power tubes such as 6Y6-G, 6V6-GT, and the miniature 6AQ5. In transformerless sets having series filaments the r-f oscillators often are GZ types such as 25L6, 35L6, and 50L6. These beam power tubes sometimes are used singly, and again in pairs with like elements connected in parallel. Operation may be as a straight beam

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power tube, or plate and screen may be tied together for operation as a triode.

A good many r-f oscillators are twin triodes such as the 6SN7-GT and the miniature 12AU7. These are used with the two plates, the two grids, and the two cathodes tied together at the socket. In a few receivers the r-f oscillator is a 6C4 miniature power triode.

In transformerless sets having no doublers for B-voltage the r-f oscillators are operated at 115 to possibly 140 d-c volts on the plates. In receivers having regular transformer types of d-c power supply the r-f oscillators are operated with 250 to 350 volts on the plates.

R-f oscillator grid biases, as measured from grid to cathode with a VTVM while the tube is oscillating, range from 20 to as much as 50 negative volts. Naturally, we find the lesser negative biases with the lower plate voltages, and more strongly negative biases with high plate voltages. Because bias voltage results from grid-leak action this voltage will be practically zero between grid and cathode should the tube fail to oscillate.

ADJUSTMENT OF SECOND ANODE VOLTAGE. With r-f high-voltage supplies having a trimmer capacitor across the oscillator plate winding, the closer the plate circuit is tuned to the self-resonant frequency of the high-voltage secondary the higher will be d-c voltage output to the second anode of the picture tube. With the plate winding tuned to a frequency either lower or higher than that of secondary self-resonance, second anode voltage will drop below its maximum possible value.

Tuning should not be for maximum possible output voltage because frequency and output then will fluctuate. It is considered best practice to tune the oscillator plate winding to a frequency sufficiently lower than secondary self-resonance to provide the desired second anode voltage. The trimmer adjuster always is accessible or should be accessible from outside the power supply shield, usually through an opening in the shield or else from underneath the power supply shelf or chassis plate.

Trimmer capacitors nearly always are constructed so that the adjusting screw is grounded and is insulated from both sets of capacitor plates. However, in case the screw should be hot, it is advisable to make adjustments with a non-metallic screw driver such as used for alignment work. Procedure is as follows:

1. Set the contrast and brightness controls at their minimum positions.

2. Connect a high-resistance d-c voltmeter or a VTVM through a high-voltage probe to the picture tube second anode connector or to the power supply output at the filter. Be sure to connect the negative lead of the meter to chassis ground.

3. Adjust the trimmer capacitor for lowest frequency, with plates fully compressed.

4. Turn on the receiver and VTVM. Let them warm up thoroughly.

5. While watching the voltmeter, slowly change the trimmer for less capacitance and higher tuned frequency. Voltage should increase. Voltage may be zero when you commence the adjustment, because the oscillator tube is not oscillating. The meter pointer will jump up-scale when oscillation begins.

Adjust the trimmer for the desired second anode voltage, then very slowly for a slightly higher voltage. Then turn the trimmer far enough back to return to the desired voltage. This is done because mica compression capacitors usually hold an adjustment better when it is made by tightening the adjustment rather than by loosening it.

Do not experiment with producing excessively high second anode voltage. With some power supplies this voltage can be made high enough to puncture insulation or possibly to damage the picture tube screen.

When there is a spring or ring on the high-voltage rectifier (Fig. 15) second anode

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voltage is altered by sliding this feedback member up or down on the tube envelope. Move the spring or ring only with a rod or fairly long alignment tool made entirely of insulating material. Stay clear of the rectifier cap. Proceed as follows:

1 and 2. Same as these steps when there is a trimmer capacitor.

3. Move the feedback ring so that it centers approximately around the bottom of the plate cup in the rectifier tube.

4. Turn on the receiver and VTVM. Let them warm up.

5. Slowly and carefully raise the feedback ring to the position giving desired second anode voltage, or, if raising the ring does not cause a desired voltage, try pushing the ring downward, even to a position slightly below the bottom edge of the rectifier plate cup should this be necessary.

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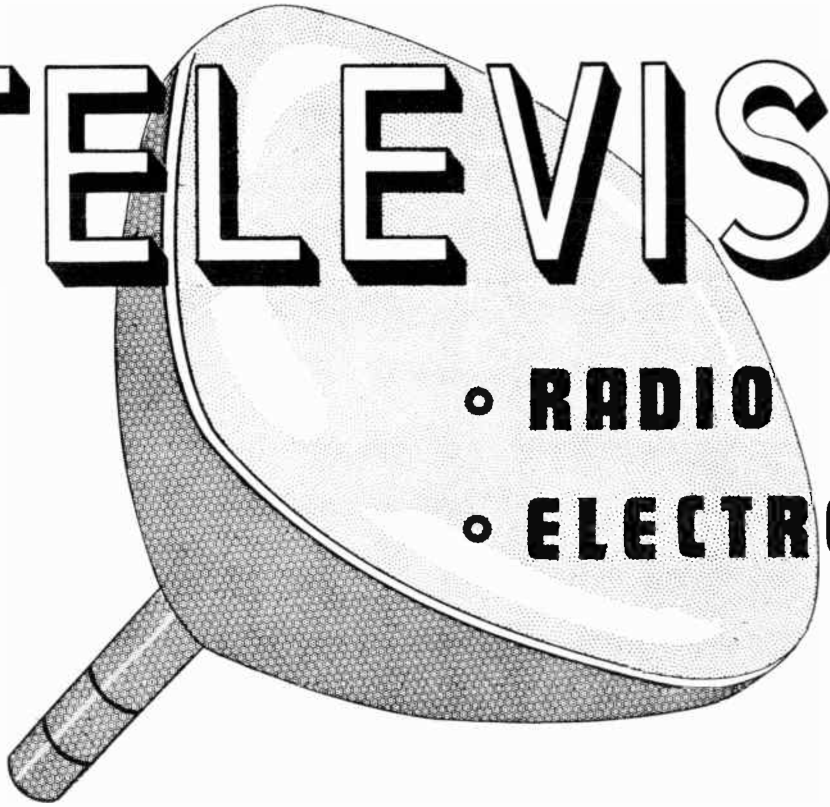

LESSON 72 — KEEPING SIGNALS WHERE THEY BELONG

Coyne School

practical home training

Chicago, Illinois

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Lesson 72

KEEPING SIGNALS WHERE THEY BELONG

You would find it difficult to name many stages of a television receiver in which signals enter other than at the grid circuit and leave other than from the plate circuit. Furthermore, it is a general rule that signals should travel this way in orderly fashion right through from antenna to picture tube and speaker, without wandering at random between sections, or turning backward except in a few places such as afc systems.

It would require nothing more than adequate insulation to keep television signals where they belong were we dealing only with direct currents and with very low frequencies. But when frequencies exceed a few kilocycles it becomes astonishingly easy for signals to go almost anywhere than the right places, and decidedly difficult to confine them to proper paths. Keeping high-frequency signals where they belong requires careful attention to shielding, decoupling, and dressing.

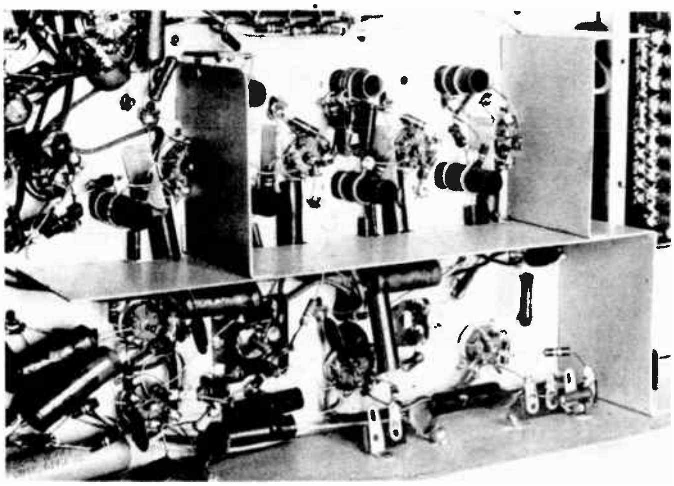

Fig. 1. Shielding partitions or barriers between i-f and sound amplifiers underneath the chassis of a television receiver.

Shielding prevents electrostatic and magnetic fields which arise in one circuit from carrying emf's into other circuits where the emf's are not wanted. Decoupling, as the name implies, prevents couplings which would allow energy transfers where they can do nothing but harm. Dressing means placing conductors and circuit components in such positions that unwanted couplings are avoided.

SHIELDING. Between any two separated conductors, wires or circuit components, there is capacitance. Alternating currents and voltages will flow in this capacitance, as in any other capacitance. The higher the frequency the less is the capacitive reactance and the greater is the transfer of signal current and voltage between the separated conductors. Signal transfer takes place through electric fields in air spaces between conductors which operate constantly or intermittently at different potentials.

Electric or electrostatic field lines may be prevented from extending between conductors by placing between the conductors a sheet of metal which is grounded. This grounded metal forms a shield. The action is illustrated by Fig. 2. At any instant (A) during which one conductor is positive with reference to ground it attracts free negative electrons to the shield surface which is toward the positive conductor. Field lines from the positive conductor end on the negative electrons, therefore cannot pass through the shield to reach conductors on the other side.

When the conductor becomes negative (B) it repels negative electrons away from the adjacent surface of the shield metal, and leaves this surface with a positive charge. Then negative field lines end on the positive charge and do not pass through the shield.

The shield may be of any material in which free electrons can move easily to form charges at the surfaces. Electrons move easily in all metals. Consequently, the shield may be any kind of metal, such as steel, aluminum, brass, or copper. Whether the shield is thick or thin makes no difference so far as this electric or electrostatic shielding effect is concerned.

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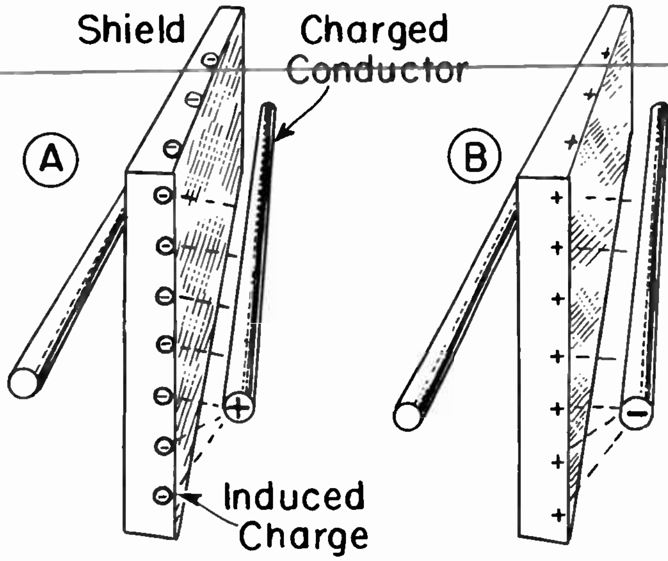

Fig. 2. How charged conductors induce opposite charges in shielding metal.

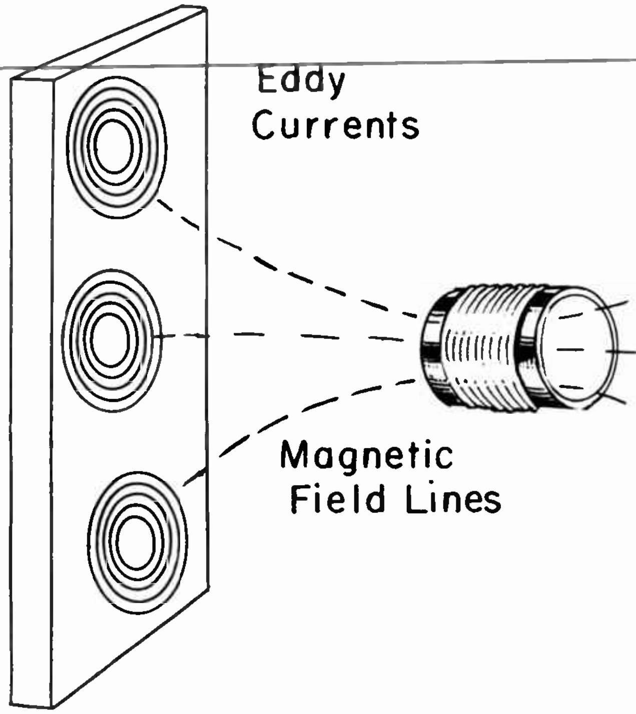

Fig. 3. Magnetic shielding at high frequencies is due to opposing magnetic fields produced by eddy currents in shielding metal.

When maximum electric shielding is wanted, as in test instruments working at radio frequencies, shield joints are closed securely against leakage of field lines. Joints in steel and aluminum usually are crimped or spot welded. Copper and brass may have soldered joints. Covers overlap the main body of shield enclosures, and are held by closely spaced screws or studs.

At radio frequencies the same shield that prevents capacitive or electric coupling also confines magnetic lines of force to prevent inductive or magnetic coupling. Magnetic lines of force which reach the shield induce eddy currents in the shield metal. As illustrated by Fig. 3, these eddy currents circulate in the shield metal, around the magnetic lines of force. The eddy currents produce magnetic fields and field lines of their own. Direction of the eddy current fields is opposite to that of the inducing field. Eddy current fields thus cancel the inducing field to a greater or less extent, and magnetic forces do not get through the shield.

Effectiveness of magnetic shielding increases with "permeability" of the shield metal. Permeability is a measure of the ease with which magnetic forces act in a material. At low frequencies the permeability of steel and iron is far greater than of other metals. But as frequency increases, the permeabilities of all metals approach more and more closely to the same value, and at radio frequencies there is no important difference between permeabilities of steel, aluminum, brass, and copper. Therefore, at radio frequencies any of these metals form an effective magnetic shield, as well as an electric or electrostatic shield.

Keeping in mind that magnetic shielding results from formation of eddy currents, it becomes evident that the stronger these currents the stronger will be their opposing fields and the more effective will be the magnetic shielding. To allow induction of strong eddy currents the shield metal should be of good conductivity. Shields of aluminum, brass, or copper have high conductivity. By using steel of fair thickness, say 0.020 inch or more, we obtain enough conductivity for fairly good magnetic shielding at high frequencies.

SHIELDING OF INDUCTORS. In other lessons we have seen many pictures of coupling inductors and transformers enclosed within metal shield cans. Still another example is shown by Fig. 4. Shield cans nearly

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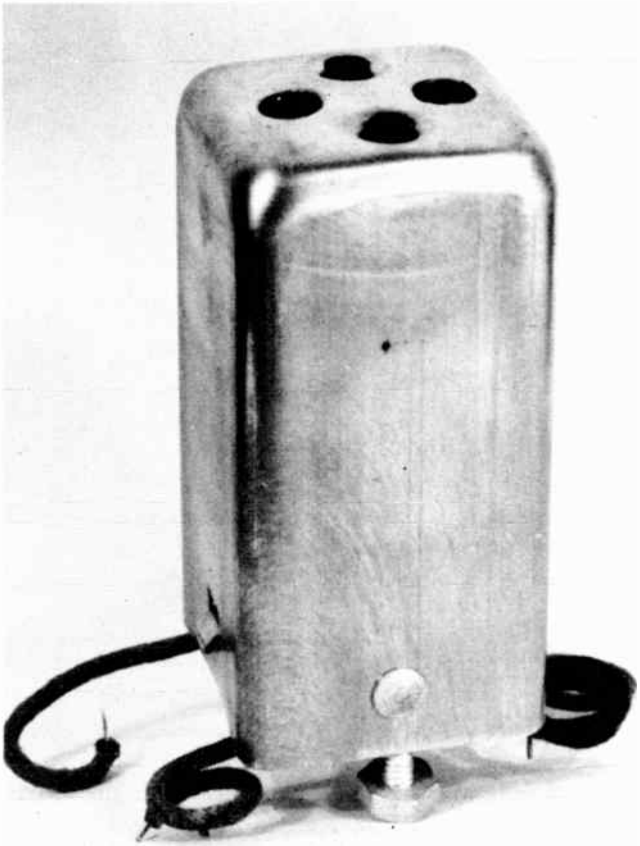

Fig. 4. Shield cans may be used to enclose all kinds of inductors.

always are placed over high-frequency inductors mounted on the tops of chasses. Partitions, barrier shields, or box-like enclosures often are used around inductors mounted underneath a chassis.

When an inductor is wholly or partially enclosed by a metal shield the inductance is less than with no shield. This is because the shield limits and reduces the magnetic field of the coil. Since inductance is made less, resonant frequency of the inductor circuit is raised. Adding a coil shield always raises the frequency; removing a coil shield always lowers the resonant frequency of a tuned circuit.

Changes of resonant frequency due to adding shields are less when the shields are grounded than when they are ungrounded. This is one reason why shields always are grounded, or are connected to B-minus lines, or to tube cathodes. It is desirable that resonance and tuning be affected as little as possible by shielding, and grounding the shields does just this.

Shielding adds somewhat to distributed and stray capacitance of an inductor circuit, but this effect is small compared to that of lowered inductance. The combination of lowered inductance and added capacitance reduces the Q-factor of the tuned circuit. The formation of eddy currents in shield metal requires energy, which is taken away from the inductor circuit. All this means that shielded inductors tune less sharply, and have greater losses and lesser gains than the same circuits without shield.

When making service adjustments on high-frequency tuned circuits it is necessary that all regular shielding and all shield cans remain in their normal positions. If adjustments are made while shields are removed, replacing the shields will change the performance.

The greater the diameter and length of a shield can in proportion to diameter of an enclosed coil the less will be the effect of the shield on tuning and the less will be energy loss. With shield diameter three or more times the coil diameter the effects at television intermediate frequencies are so small as to be unimportant, but shield diameter only $1\frac{1}{2}$ times coil diameter increases losses by about six times. The end of a shield should clear the end of the coil winding by one or more times the coil diameter if losses are to remain fairly low.

<u>TUBE SHIELDS.</u> Fig. 5 is a picture of a television chassis on which metal shields enclose all of the i-f amplifier tubes, the video detector, and the sound amplifiers. These tubes are shielded on many receivers, but on others they are not shielded. On tuners it is general practice to provide a shield for the r-f oscillator, and sometimes for the r-f amplifier and for the mixer. Mixers often are unshielded, unless they consist of one section of a tube in which the other section is the r-f oscillator.

Tube shields are grounded to chassis metal by some type of fastening which also holds the shield securely in position. On the

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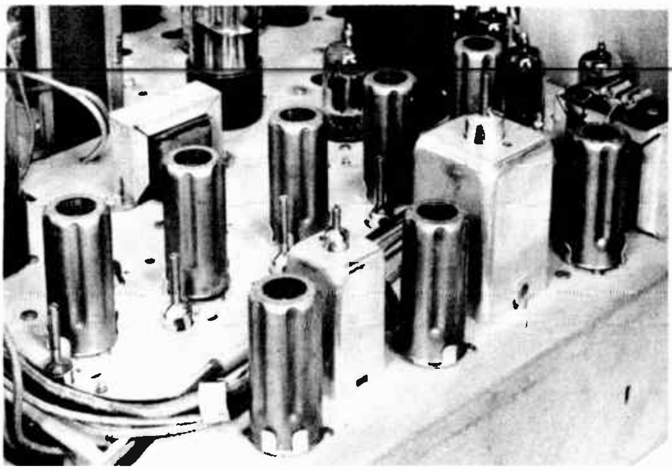

Fig. 5. Tubes which operate at intermediate frequencies and at carrier frequencies often are enclosed within metal shields.

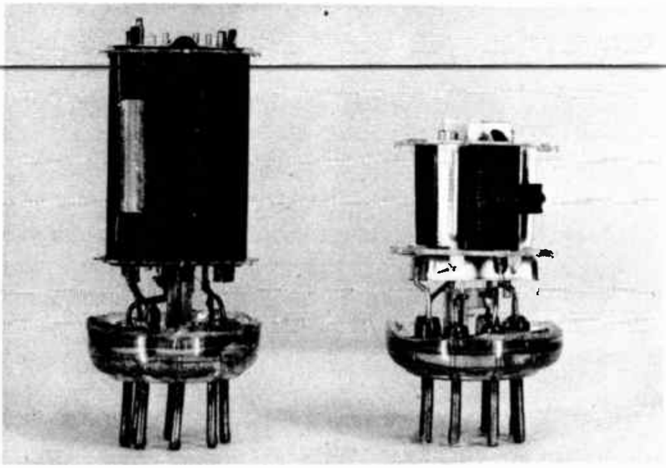

Fig. 6. The glass envelopes of these miniature tubes have been removed to more clearly show the internal shields.

chassis photograph you can see that the shields are held by clips attached to the chassis.

Placing a grounded shield over a tube may alter the internal or inter-element capacitances of the tube. If the capacitances are altered this will change the resonant frequencies of tuned circuits connected to the tube elements. Omission of a shield from an r-f oscillator may so alter the tuned frequencies that a fine tuning control cannot bring them back into line.

Adding a shield over a tube may increase some of the tube capacitances, it may decrease other capacitances, or it may have no effect on capacitance values. This is true of input capacitances, of output capacitances, and of grid-to-plate capacitances. What happens in any particular case depends entirely on the type of tube and on its internal construction.

Many miniature voltage amplifying pentodes of types used in i-f amplifiers, video amplifiers, and tuners are constructed with internal shields. Fig. 6 shows two such tubes with their glass envelopes removed to more clearly expose the elements. On the tube at the left the internal shield is the large black cylinder which completely surrounds all other elements. On the tube at the right the black pieces are the plate. The shield consists of bright pieces of metal which you can see between sections of the plate and at the right of the plate. Internal shields, when used, are connected to the same base pin as the suppressor of the pentodes. Grounding the suppressor or connecting it to the cathode effectively grounds the internal shield.

Internal shields are found also in some twin diodes, twin triodes, combination triode-pentodes, and converters of miniature styles. In these tubes the internal shield may be connected to the same pin as the suppressor or else to a separate base pin, all depending on the particular type of tube.

The effectiveness of an internal shield depends on how completely it encloses active elements, on the frequencies at which the tube operates, and on its position in relation to other tubes and components which require shielding. When set designers determine that internal shielding alone will not be adequate, they add external shields. It never is advisable to discard tube shields which are on a receiver as originally built, although in some cases the addition of shields and returning the circuits may overcome certain troubles.

Metal tubes do not require an external shield, because the metal envelope of the tube forms a completely effective shield when grounded. The metal envelope most often connects to number 1 base pin, and when

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this pin is grounded the shielding envelope is grounded.

The metal shell around the bases of lock-in tubes provides a certain amount of shielding. This shell is connected to the metal plug or locating pin which extends downward from the center of the base. This plug engages a metal lined opening of the socket. An extension of this metal liner forms a solder lug easily accessible from under the socket. Grounding this solder lug grounds the base shell. Lock-in tubes which operate at high frequencies often are provided with an external shield which fits down over the metal shell of the base and makes close contact with the shell. Grounding the center lug of the socket thus grounds the external shield.

STAGE SHIELDING. Amplifying stages which have high gain and which operate at high frequencies require shielding. An example is shown by Fig. 1 of this lesson. Below the long barrier running from left to right are the sound amplifier, sound limiter, and sound demodulator stages, also the audio voltage amplifying tube.

In the large center compartment above the barrier are the i-f amplifiers and their interstage couplings. At the left of the i-f amplifiers is the video detector, and toward the right is the tuner.

Tuners, which operate at the highest television frequencies, are quite well shielded by the metal sub-chassis which carries their tube bases, inductors, capacitors, and switching mechanism. The tuner of Fig. 7 is almost completely enclosed by metal which acts as shielding. Slots in the cover plate on the near side of this unit allow making service adjustments without removing any of the shielding. The oscillator tube, at the left, is fitted with an external shield. The r-f amplifier and mixer tubes of this particular design operate without external shields.

Any parts mounted on top of a chassis are well shielded from all parts mounted underneath. Inductors for r-f oscillators in many sound radio receivers are placed under the chassis, where they are shielded from other tuned circuits located on top of the chassis.

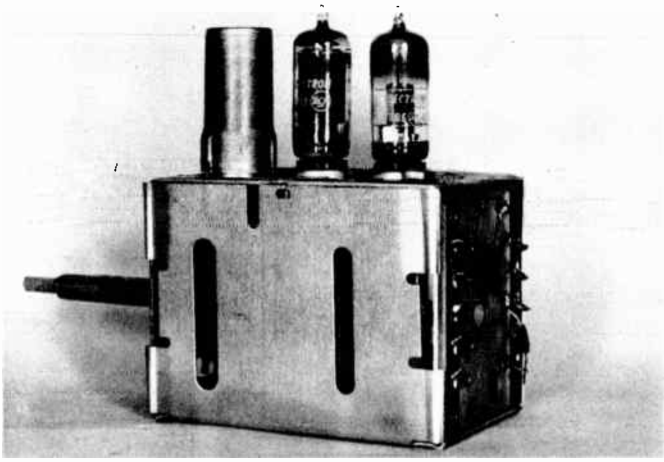

Fig. 7. A television tuner with its shield in place.

When a high-frequency tube is biased by the grid leak method, and when the grid circuit inductors are enclosed within shielding, it is good practice to place the biasing capacitor and resistor inside the same shielding.

Tubes and circuits operating at audio frequencies, between sound demodulator and speaker, seldom are provided with shielding. There is, however, one important exception in leads to volume controls and tone controls. These controls always are on the front of the chassis, accessible to the operator, while audio amplifiers often are well back on the chassis. Pickup of hum voltages and other audio interference or emf's causing audio distortion is prevented by using shielded wire or cable for leads to the volume and tone controls.

Shielded audio leads must be kept as close as possible to chassis metal along the entire run. The cable shield must be securely grounded at chassis metal at both ends, either by tight clips or by soldering. If the cable is more than about ten inches long it should be grounded to the chassis at intermediate points as well as at the ends.

One shield which usually is present in television receivers, but which cannot be seen, is the static shield between primary

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and secondaries of the d-c power supply transformer. We looked at such shielding in the lesson on "Television Alignment". The purpose is to prevent pickup of noise voltages and other interference from power lines, and to prevent passage of high frequencies from the receiver out into the power lines.

SHIELDING FOR POWER-LINE FREQUENCIES. When we get into frequencies so low as those of a-c power lines and of the lower notes in audio signals we are concerned with magnetic shielding more than with electrostatic shielding, because magnetic fields may be strong but electric fields always are relatively weak. For magnetic shielding to be useful at low frequencies the shielding metal must be of high permeability.

In metal of high permeability it is very easy for magnetic lines of force to flow. Such metal acts for magnetic lines or magnetic "flux" in the same manner that good conductors, such as copper, act for electric currents. When any circuit component is surrounded by a shield of high-permeability metal, low-frequency magnetic lines of force are diverted through the shield metal, they remain in this metal, and do not get through to the shielded component. Low-frequency magnetic shielding depends on diversion of magnetic flux, it does not depend on formation of eddy currents and resulting opposing fields.

The only metals having high permeabilities are iron and its various alloys, including steel. Steel shells around the outside of power transformer windings and the steel in chasses provide fairly effective shielding for power-line frequencies. Permeability greater than in ordinary steel is available in a wide variety of iron alloys which contain large percentages of nickel. These include Permalloy, Mu metal, Nicaloi, and others. They are used where magnetic shielding is needed for inductors operating at low frequencies.

If all the magnetic lines of force produced by the primary of a power transformer remained in the core metal and thus passed through the secondaries there would be no external magnetic field. But in practical

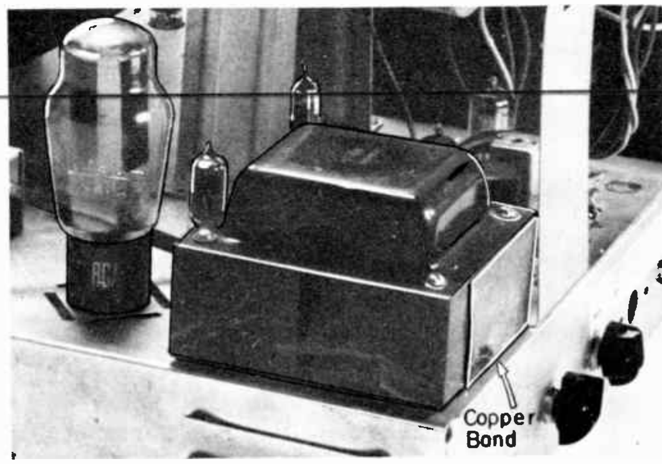

Fig. 8. The purpose of a copper band on a power transformer is to lessen radiation of leakage fields.

transformers, there is leakage flux, which consists of lines of force that do not pass through the secondaries and which extend outside the transformer.

Magnetic fields due to leakage flux may be reduced, as illustrated in Fig. 8, by placing a wide band of copper around the core and windings. Leakage flux induces circulating currents in the copper band. These currents produce magnetic fields which oppose the leakage flux lines and largely cancel the magnetic field which otherwise would extend around the transformer.

DECOUPLING. When any one impedance is included in two or more signal circuits, signal currents in each circuit will accompany signal voltages in that one impedance. The impedance may be chiefly resistance, chiefly capacitive reactance, chiefly inductive reactance, or any combination. The common impedance puts signal voltages of each circuit into all the other circuits, because the impedance across which signal voltages appear is included in all the circuits. This means that all the circuits are coupled together through the impedance which is common to all of them.

Such random couplings may lead to a great variety of troubles. As one example, low frequencies put into high-frequency circuits may cause wide horizontal bars on the picture tube, as at A of Fig. 9, or may cause many horizontal lines. Higher frequencies may cause wide vertical lines, as at B, or narrow lines which shift one way and another.

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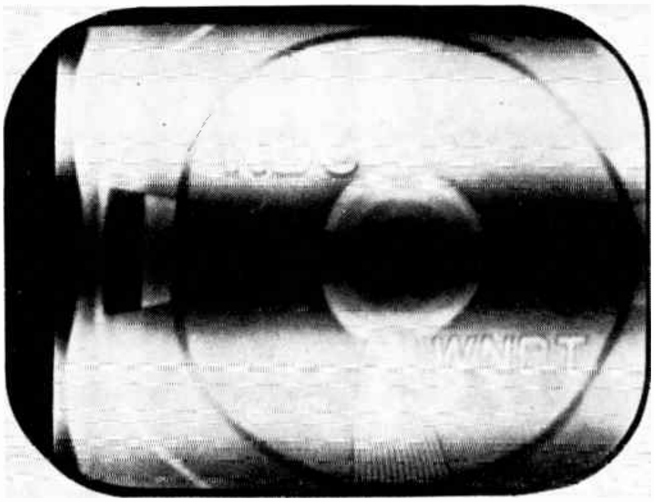

Fig. 9A

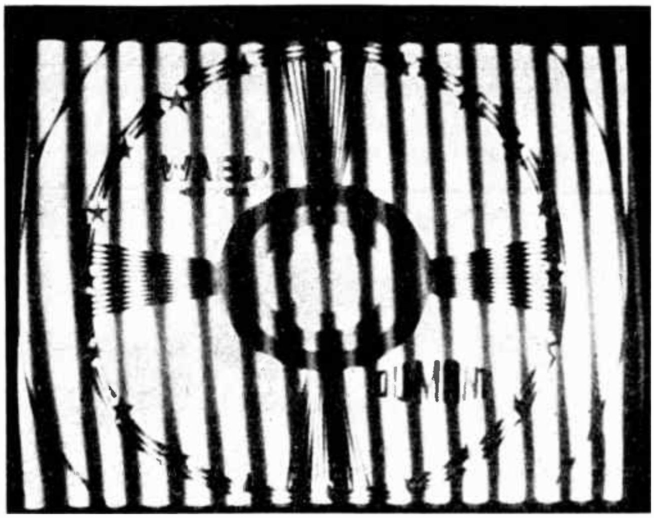

Fig. 9B

Fig. 9. Effects such as these may result from lack of adequate decoupling.

Many unwanted couplings exist in circuits such as that of diagram A in Fig. 10. The grid signal circuit extends through resistor Ra and various parts of the agc system before getting back to the tube cathode. The plate signal circuit extends through resistor Ro to the common B-power supply and through filter capacitor Cf before passing through ground back to the tube cathode. The screen circuit gets mixed up with the plate circuit in the B-plus wiring. Signal circuits for both plate and grid pass through cathode resistor Rk. Signal currents from other stages similarly wired would get into the stage shown here through connections to B-power and agc systems.

Decoupling has been applied to the circuit in diagram B. We have added four more capacitors and two more resistors. The capacitors may be called bypass capacitors because they bypass signal currents and voltages around impedances which might cause troublesome couplings.

Consider first the grid circuit of diagram B. We have not distrubed capacitor Cg, through which signals reach this stage,

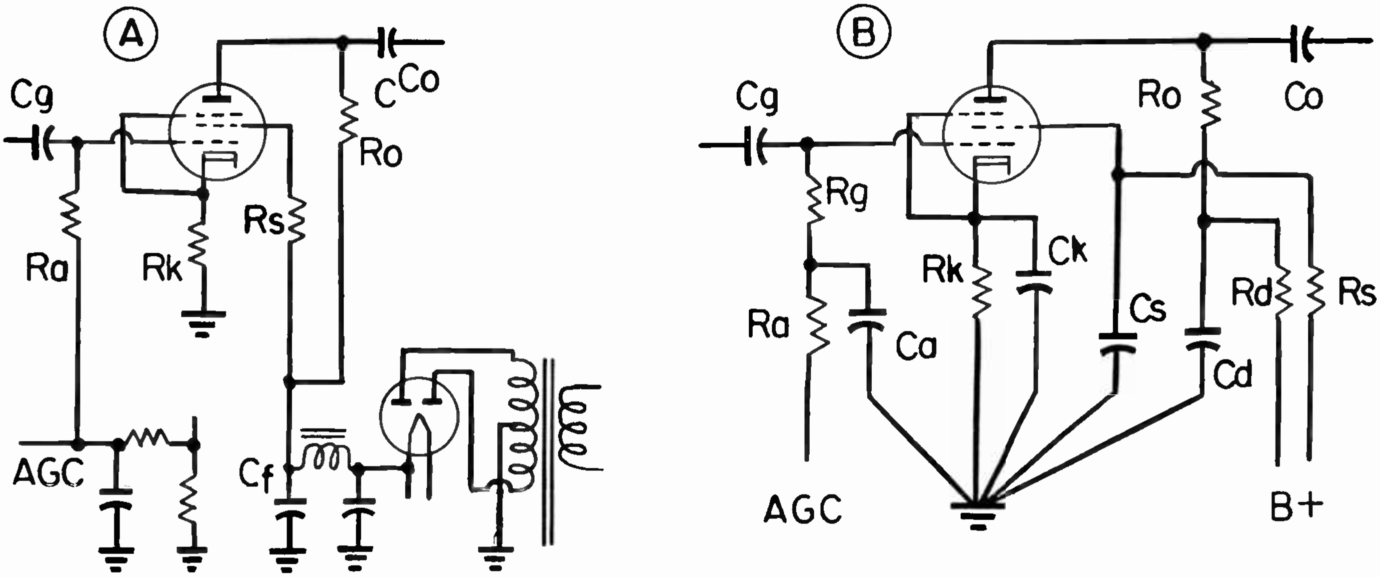

Fig. 10. There is insufficient decoupling of circuits at A, while all the tube circuits have been decoupled at B.

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nor resistor Rg across which the incoming signal voltages appear. But at the bottom of Rg the signal currents now have a choice of two paths, one through small reactance of capacitor Ca and the other through high resistance which has been added at Ra.

Nearly all the signal current will take the easy path through capacitor Ca. Resistor Ra acts to oppose signal currents while completing the d-c return path which is necessary for all grids. Grid signals which pass through Ca go to ground, thence through small reactance of capacitor Ck and to the tube cathode.

Look next at the plate circuit. We have not distrubed plate load resistor Ro, in which are the output signal current and voltage, nor capacitor Co which carries the output signal to following stages or circuits. But at the bottom of Ro the signal current may go through small reactance of capacitor Cd or through high resistance added at Rd. Naturally, most of the signal will take the easy path through Cd to ground, then through Ck to the tube cathode.

When reactances or impedances at Ca, Cd, and Ck are small enough in comparison with resistances or impedances at Ra and Rd, grid and plate signals from Rg and Ro will be forced to complete their paths to the tube cathode without encountering any considerable impedances which are also in other signal circuits. There will be no unwanted couplings or, at least, such couplings will be so weak as to cause no trouble.

The screen of the tube is decoupled by capacitor Cs, which is shown as going to ground. Oftentimes this screen decoupling or bypass capacitor goes directly to the tube cathode rather than first to ground. When Cs is of large capacitance and accompanying small reactance, there can be little if any r-f potential difference across it. This means that the screen will be held at practically the same r-f potential as the cathode.

It is highly important that there be no alternating voltage between screen and cathode, for the following reason. The screen is just outside the grid, therefore is close to the cathode. Any alternating voltage on the screen will vary plate current almost as much as though the same alternating voltage were to reach the grid. We learned this fact long ago, when observing how screen voltage affects plate current in a pentode or a beam tube.

Adequate decoupling becomes increasingly important as operating frequencies go up. It is just as important to have adequate decoupling in high-gain circuits, regardless of frequency. We always find numerous decoupling capacitors and resistors in tuners, in i-f amplifiers, in video amplifiers, in sound amplifiers, and in audio voltage and power amplifiers. There is least need for decoupling in sync and sweep circuits which operate with neither high gain nor at high frequencies.

Decoupling capacitors which are internally open circuited or which are connected with high-resistance joints in wiring cause all the troubles which would occur with no decoupling at all. In this connection we should note that any loose or corroded connection, or any solder joint which was made "cold" or left with unvaporized flux, forms such high resistance as to cause as much unwanted decoupling as would occur in an unbypassed resistor.

DECOUPLING CAPACITORS AND RESISTORS. When signal current has its choice of going through a bypass capacitor or a resistor effectively in parallel with the capacitor, the current will divide in inverse proportion to the capacitive reactance and the resistance, in ohms. Whichever of these is less than the other will take more of the total current.

In Fig. 11 is a plate circuit with a load resistor, a decoupling resistor or 1,000 ohms, and a decoupling or bypass capacitor of 500 mmf. The circuit is represented as working at four different frequencies, a carrier frequency, an intermediate frequency, a video frequency, and an audio frequency. At the capacitor symbols are marked approximate capacitive reactances, and the percentages of total signal current which will flow through the capacitors. The differences be-

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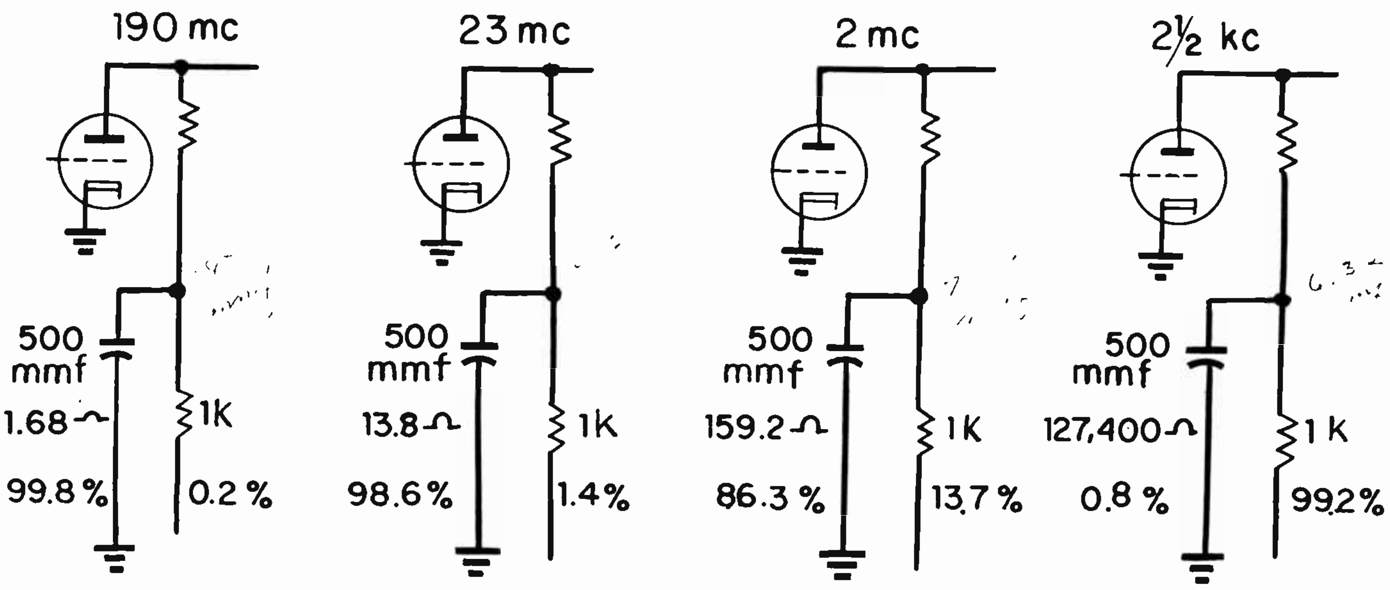

Fig. 11. How the effect of a given decoupling capacitance varies with frequency.

tween these percentages and 100 per cent are the proportions of total current going through the resistors.

At carrier and intermediate frequencies the decoupling is highly effective, with less than one per cent in one case and less than two per cent in the other case, going through the resistor, where undesired coupling might occur. At the video frequency almost 14 per cent of the total signal current goes through the resistor. This is not very good decoupling. At the audio frequency more than 99 per cent of the signal current goes through the resistor. There is practically no decoupling.

Supposing we wish to have about 99 per cent of total signal current go through the decoupling capacitor of each of the four signal frequencies. Keeping the decoupling resistance at 1,000 ohms, this would call for about 1/100 this number of ohms, or 10 ohms, as capacitive reactance in bypass capacitors. Required capacitances are shown by Fig. 12. A ratio of 1/100, reactance to resistance, means first class decoupling.

At the carrier frequency we need less than 100 mmf decoupling capacitance. At the intermediate frequency the capacitance has to be increased nearly to 700 mmf. At both carrier and intermediate frequencies we doubtless would use ceramic or mica capacitors, which are not too costly at these capacitances. At the video frequency we need almost 8,000 mmf or 0.008 mf capacitance, and nearly always would use a paper capacitor. At the audio frequency we require more than 6 mf capacitance. Such a value can be had economically only in electrolytic capacitors.

Ceramic and mica capacitors have longer average life than other types, less likelihood of current leakage, extremely high d-c resistances, and negligible inductance. Paper capacitors are less costly than ceramics or micas in large capacitance values, and commonly are available with high voltage ratings. Paper capacitors may have considerable inductance due to their rolled construction, and may have large inductive reactance at very high and ultra high frequencies. Capacitances in excess of one or two microfarads combined with high working voltages are economical only in electrolytic types. Also, large capacitances which require only moderate dimensions in electrolytics would require prohibitively great size in other types.

Ceramic and mica capacitors may be used satisfactorily at any frequencies. Paper types also are suitable for all frequencies unless their internal inductances might cause trouble. Electrolytics are satisfactory only for audio, sync, and power frequencies. They have greater or less internal inductance, and

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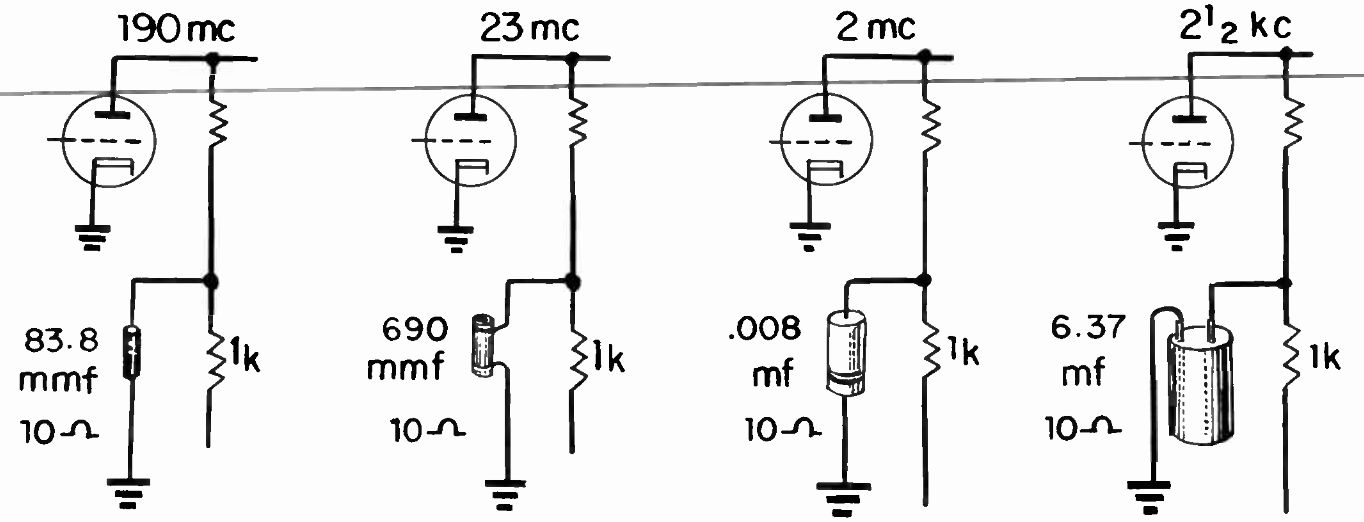

Fig. 12. How decoupling capacitance must vary with changes of frequency when a given decoupling effect is to be maintained.

all have at least some small leakage even when operated below their rated voltages. Since all ordinary electrolytics are polarized they cannot be used in circuits carrying alternating current components strong enough to overcome the accompanying direct current or voltage.

Where inductance of electrolytic capacitors may cause enough inductive reactance to cause coupling at high frequencies, the electrolytics are themselves bypassed with non-inductive paper capacitors which may have values between 0.001 and 0.25 mf, depending on the frequencies involved. Large paper capacitors which have too much inductance and inductive reactance for high frequencies may be similarly bypassed with ceramic or mica capacitors, which have negligible inductance. When you see two capacitors paralleled, check their relative values. The smaller one may be a bypass for the other.

As illustrated by Fig. 12, the value of decoupling capacitance depends on operating frequency as well as on the resistance to be bypassed. Power dissipated in a decoupling resistor is wasted, making it desirable to use small resistances for this purpose. But the less the decoupling resistance the greater must be the decoupling capacitance for any given division of signal currents. It may be more economical to use large resistance, and provide the additional B-voltage and power, than to use large and costly capacitors in circuits working at low and medium frequencies.

We should note that total decoupling resistance is the sum of resistances such as shown by Figs. 10, 11, and 12 plus all other resistances in the lines going back to the power supply filter. Decoupling resistors and capacitors are really a part of the filter system on the d-c power supply. At least, they add to the filtering effect by further reducing ripple voltage. This is apparent from Fig. 13 where, in diagram A, the decoupling units are shown near the tube, and in diagram B are shown added to the power supply filter. The arrangement at A is better for decoupling, because it avoids long unbypassed leads from load resistor Ro all the way to the power supply filter.

Diagram B of Fig. 13 illustrates also the fact that there is effective decoupling when B-voltage for one stage or section of a receiver is taken from a different point on a power filter than other stages or sections. Between the line marked B- and the line going to load resistor Ro for the amplifier tube there is the decoupling effect of resistor Rd, of capacitor Cd, and also of the capacitor which follows the filter choke of the power supply.

Decoupling resistors in a B-supply line to one or only a few tubes often are called dropping resistors, for the reason that they

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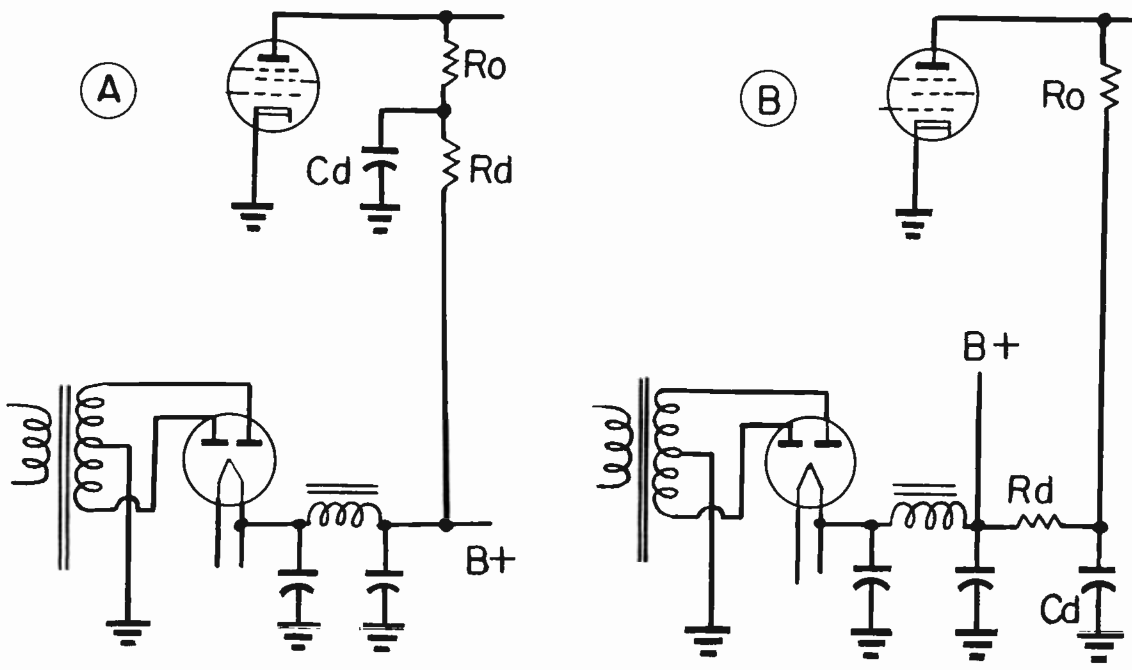

Fig. 13. Decoupling capacitors and resistors are, in effect, parts of the power supply filter system.

may serve to drop power supply voltage to a value suitable for the connected plates or screens, as well as for decoupling. Note in all cases that plate signal currents pass through load resistors marked Ro, but only to a small extent through the decoupling resistors. Therefore, the signal load is only that at Ro, it is not affected by whatever resistance may be used for decoupling - provided the bypass or decoupling capacitance is adequate.

Should you reduce the value of a dropping resistor in order to increase B-voltage at a plate or screen, as when substituting different tubes, the decoupling may be made insufficient. If such an alteration is followed by symptoms of troublesome couplings, it may be necessary to install greater decoupling capacitance.

Old electrolytic capacitors and sometimes old paper capacitors have abnormally high reactances, or may become internally open circuited. Check them as follows. Across the suspected capacitor, temporarily clip another capacitor known to be good. Across an electrolytic connect another electrolytic of approximately the same capacitance or not more than double the original capacitance, or else use a paper capacitor of greatest available capacitance. If symptoms of trouble disappear, the original capacitor doubtless is defective and should be replaced.

The decoupling ability of a capacitor may be checked by connecting across it a suitable voltmeter, applying a strong signal at the normal operating frequency, and reading the meter. A reading of more than a very small fraction of a volt usually means insufficient bypassing. For audio-frequency circuits an a-c voltmeter, an output meter, or a VTVM set for alternating voltage should be satisfactory. For higher frequencies it is necessary to use a VTVM fitted with a high-frequency probe.

HEATER DECOUPLING. Capacitance between heater and cathode in a tube may have rather small reactance at high frequencies. Then, should the cathode and heater be at widely different r-f potentials, there may be enough leakage of signal current into the heater circuit to cause coupling with other stages. Suitable decoupling will maintain cathode and heater at the same r-f potential, and thus prevent trouble.

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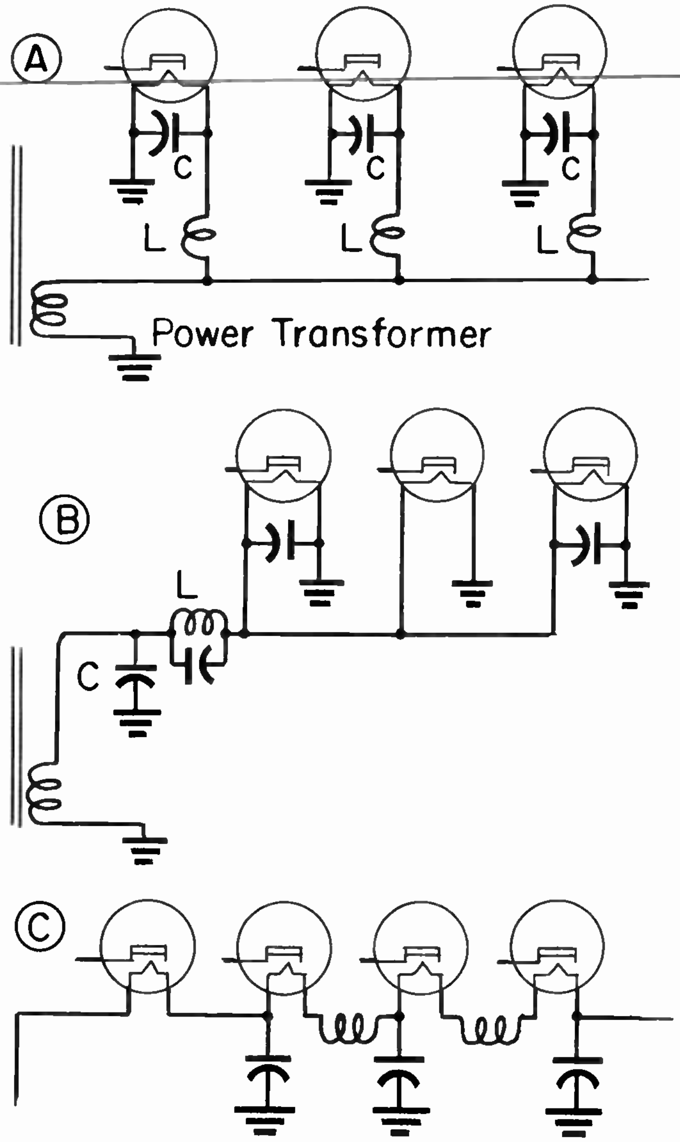

Fig. 14. Decoupling of tube heaters to prevent signal transfer through cathode-heater capacitance and common heater circuits.

Several heater decoupling methods are illustrated by Fig. 14. In diagram A there are r-f chokes L in the leads to each heater from the winding on the power transformer. These chokes have high inductive reactance at high frequencies. Signal currents in the "high side" of each heater are bypassed to ground through capacitors C.

At B is shown the arrangement used in a certain tuner, for r-f amplifier, oscillator, and mixer tubes. Between the power transformer winding and the heater line is a bypass capacitor, C, to ground, also a parallel resonant circuit including inductor L. By-pass capacitors are connected from the high sides to ground on two heaters.

Heater decoupling is especially necessary when heaters are on series strings, with the same alternating current through all heaters. Fairly typical decoupling for series heaters is shown by diagram C. R-f chokes oppose passage of signal voltages from tube to tube, while such voltages are bypassed to ground through capacitors at tubes requiring such treatment.

Heater decoupling most often is used in tuners and in i-f amplifiers. Chokes commonly have inductance of about one microhenry, with 15 to 25 turns of 1/4 to 1/2 inch diameter and lengths between 1/4 and 1/2 inch. The coils may be self-supporting or may be wound on forms.

GROUNDING. Those who serviced sound radios, before the days of television, were accustomed to thinking of all parts of a metal chassis as being at the same potential under all operating conditions. Then ground connections made anywhere on the chassis were assumed to bring grounded components to the same potential. This is approximately true when we deal with the lower frequencies, say up to about one megacycle. But at ultra-high frequencies, very-high frequencies, and even at television intermediate frequencies there may be enough inductive reactance in the conductor which is chassis metal to cause trouble with couplings. There is a decided tendency for coupling of output plate circuits back to input grid circuits of a multi-stage amplifier.

It is inductance and inductive reactance of chassis metal and of ground connections which may cause coupling, it is not resistance. Resistance of the large body and large total cross section of metal in a chassis is too small to cause trouble, even when the metal is steel.

Ground wires from any circuit component to chassis metal must be as short as possible, because inductance increases rapidly with length. There is no object in using large wire, for inductance of large wire is greater than of smaller gage sizes for any

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given length. Bare hookup wire is satisfactory.

Ground connections should be soldered to chassis metal or to lugs punched in the chassis when this is convenient. If it is desirable that ground leads attach to separate solder lugs, for easy removal and replacement during servicing, the lugs should be sweated to chassis metal. Connections which depend only on pressure of screws, studs, and nuts are likely to oxidize or loosen in old receivers. Then these connections have more than enough resistance to cause troublesome couplings.

Bypass capacitors for all the circuits of each tube should preferably be grounded to the same point, as illustrated at B of Fig. 10. Of course, this cannot be done with circuit designs which require capacitor return connections directly to a cathode.

Bypass capacitors should be placed as close as possible to socket lugs or to terminals of any parts being decoupled or bypassed. That is, cut pigtails rather short at the socket or terminal ends, and leave any necessary extra length on the grounded ends. Make sure that the outside-foil end of paper capacitors goes to ground or to the point of lower r-f potential when not to ground. Observe the polarity of electrolytic bypass capacitors.

The metal ferrule at the center of miniature sockets usually is connected to ground in tuners and i-f amplifiers. This lessens effective capacitances between socket lugs and tube pins. When you find such ground connections do not remove them, it could result in excessive feedback from plate to grid, and possible oscillation.

Which of the two heater lugs of a socket should be grounded sometimes is a question. Ground the heater lug which is closer to the more sensitive element of the tube. This usually means grounding of the heater lug which is nearer the grid lug, or maybe the one closer to the screen lug for a pentode. This grounding is made directly to chassis metal when heaters are wired in parallel, or is made through a bypass capacitor when heaters are in series, as at C of Fig. 14.

DECOUPLING WITH R-F CHOKES. It was mentioned earlier in this lesson that power dissipated in decoupling or dropping resistors for plate and screen circuits is wasted, and that voltage lost across these resistors must be made up by higher voltage from the B-power supply. When high voltages are wanted at plates and screens, and especially when large plate and screen currents would cause excessive loss of power, r-f chokes may replace decoupling resistors. The chokes have very little d-c resistance.

In diagram A of Fig. 15, r-f chokes at Ld and Ls replace decoupling resistors Rd and Rs of diagram B in Fig. 10. Although there is no saving of voltage or power, a choke may be used also for decoupling the grid circuit, as at La in diagram A of Fig. 15. The inductive reactance of a decoupling choke, measured in ohms, must have the same relation to capacitive reactance in ohms of the decoupling capacitor as would resistance to capacitive reactance in a resistor-capacitor type of filter. Signal currents divide inversely proportional to inductive and capacitive reactances just as they divide inversely proportional to resistance and capacitive reactance.

Diagram B of Fig. 15 shows an r-f choke between cathode and ground in a converter circuit. This choke completes a d-c path from cathode to ground in order that there may be grid biasing, but offers such large inductive reactance as to isolate the cathode from ground so far as signal currents are concerned.

R-f chokes are illustrated and their properties are explained in the lesson on "Inductors for Television and Radio". R-f chokes for decoupling in tuners and i-f amplifiers usually are air-core types with styles of winding having very small distributed capacitance. This avoids self-resonance at frequencies within the operating range. Chokes in different circuits must be arranged so that there can be no inductive coupling between magnetic fields of the chokes themselves. This requires ample separation, mounting with winding axes at right angles, or shielding around all except one of the chokes.

When there is shielding for one or more

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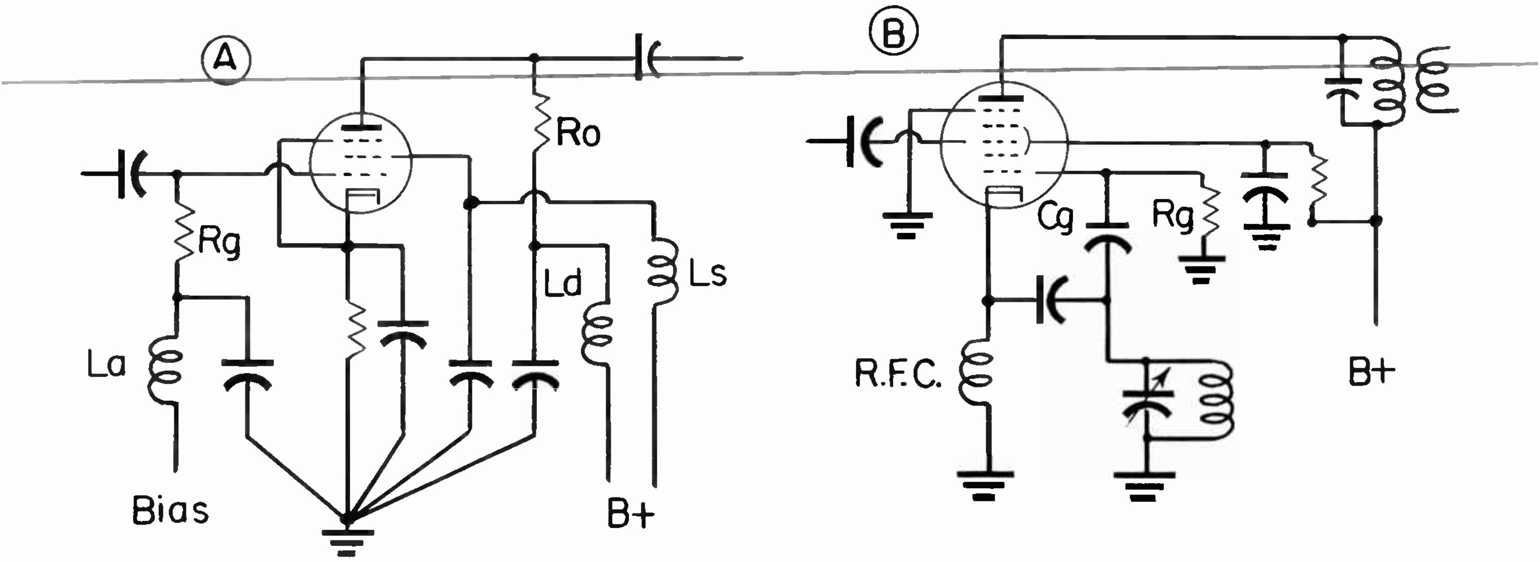

Fig. 15. Chokes instead of resistors for decoupling avoid waste of power and dropping of voltages which occur in resistors.

receiver stages, decoupling chokes should be within the same shield that encloses the tube or tubes of those stages. Chokes of exactly the same design, construction and electrical characteristics should not be used in both plate and grid circuits of the same tube. Two such chokes will be self-resonant at the same frequency, and this might make the tube act as a tuned-grid tuned-plate oscillator at the self-resonant frequency.

POWER LINE FILTERING. To prevent pickup of noise voltages and other kinds of electrical interference carried by a-c power lines a great many television sets are fitted with power line filters such as shown by Fig. 16. At A two capacitors of almost any values from 0.005 to 0.05 mf are connected from the two sides of the power line to chassis ground. At B there is a resistor to ground, in addition to the two capacitors. At C there is only a resistor to ground, with no capacitors.

The filter capacitors often are paper tubulars having d-c voltage ratings of 400 or 600 volts. Although peaks on a 115-120 volt a-c power line should not exceed 170 volts, the high ratings of capacitors help insure against making the chassis "hot" should a capacitor become shorted. In many receivers the line filter capacitors are single or dual ceramics rated at 500 volts and sometimes up to 1,000 volts. Resistors to ground usually are 1-watt sizes.

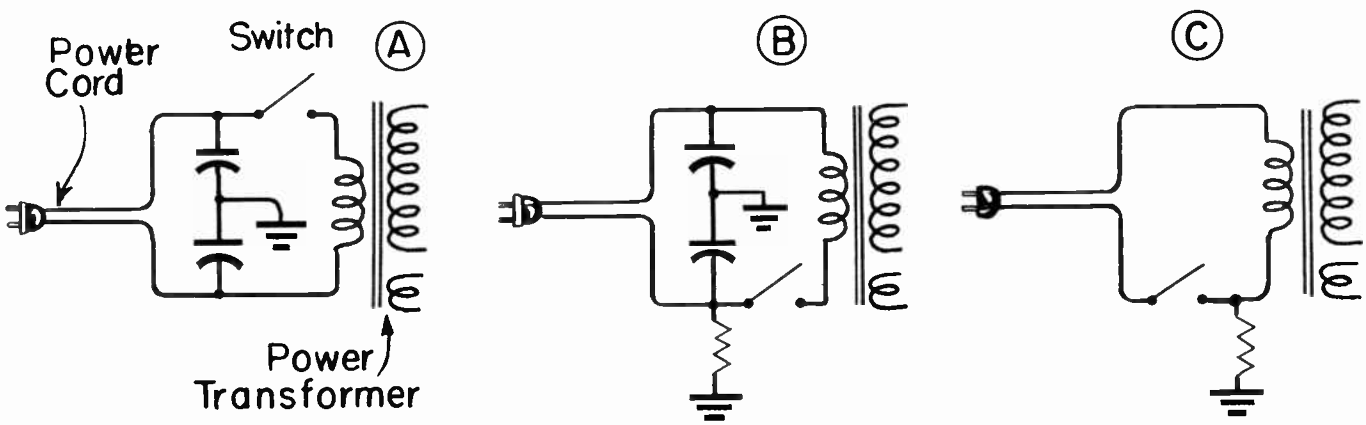

Fig. 16. Filtering for a-c power line connections to television receivers.

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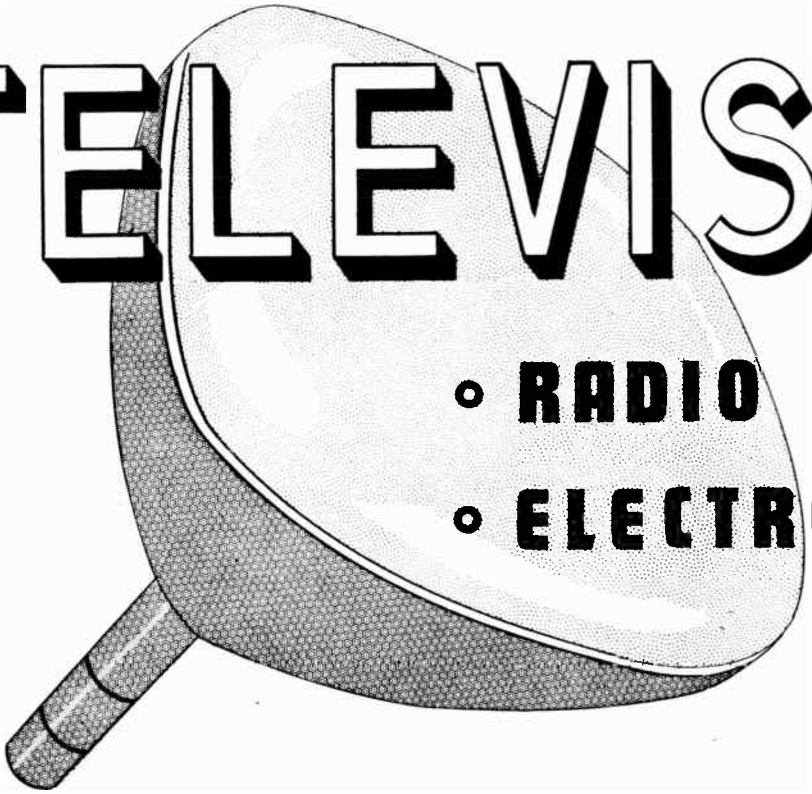

• RADIO

• ELECTRONICS

LESSON 73 — TRACING TV RECEIVER CIRCUITS

Coyne School

practical home training

Chicago, Illinois

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Lesson 73

TRACING TV RECEIVER CIRCUITS

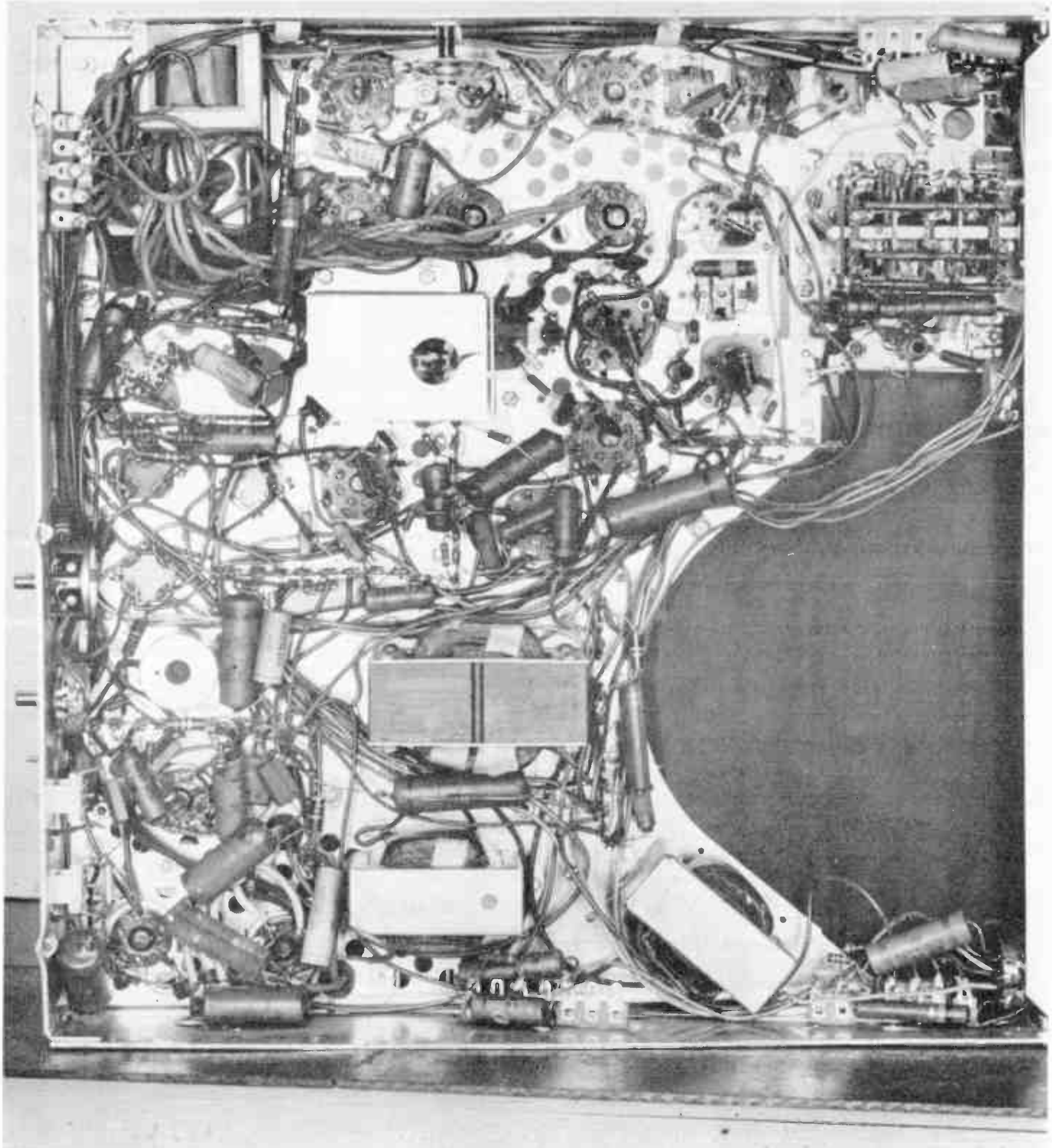

Fig. 1. Here the technician is confronted with 66 capacitors, 90 resistors, 13 inductors and possibly a couple of hundred wire connections which may give trouble.

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Most technicians would agree that servicing most often is required by some one or more of six causes, tubes, adjustments, capacitors, wiring, resistors, and inductors. In sets which have had long use tube trouble is most common for the same reason that tire failure is the most common trouble on automobiles which have run a lot of miles. Tubes and tires just naturally wear out, and must be replaced.

It doesn't take much skill to locate a tire that doesn't hold air, and it takes little more to locate a defective TV tube. When a tube fails to light or remains cold, that tube is burned out unless connections are at fault. If all tubes light and you recognize the existing trouble as indicating a fault in some one section of the set, the first step is to substitute one or more new tubes in that section. Should this substitution cause marked improvement, one or more of the original tubes are defective.

Service controls which may cause trouble include height, width, centering, focusing, drive, and alignment of i-f and sound sections. You will be astonished at how far out of line these adjustments may be while set owners still seem satisfied with the kind of pictures they see.

When you perform a complete tune-up operation, by correcting the adjustment of all service controls, the owner usually says the set didn't work so well even when it was brand new. Actually the performance has deteriorated so slowly and gradually that the owner has forgotten what really good pictures looked like.

Readjustment of service controls improves performance because of one of three reasons. First, various components have aged and changed their values. This, of course, is the prime reason for providing adjustable controls. Second, one or two components may be on the verge of complete failure. Then readjustment of service controls makes only temporary improvement. Third, a service man who lacked knowledge or test equipment or both, or possible a set owner who planned to save money, has gotten the adjustments badly out of line.

Assuming that all tubes are in fairly good condition, and that no service controls are so misadjusted as to completely ruin performance, trouble usually means that you are up against defects in capacitors, wiring connections, resistors, or inductors - a real service job in any case.

Take the matter of capacitors. Underneath the chassis of Fig. 1 are 66 large and small, fixed and adjustable capacitors which include electrolytic, paper, mica, and ceramic types. This count omits capacitors in the tuner and some canned electrolytics which are on top of the chassis. If you think existing trouble is a kind which may result from a faulty capacitor, how do you go about locating the one culprit among the sixty-odd good ones?

Along with all the capacitors there are 90 fixed resistors underneath the chassis in the photograph. How would you locate a particular resistor which symptoms indicate probably is in trouble? In addition to 66 capacitors and 90 resistors there are 13 inductors of one kind and another underneath the chassis. How many wiring connections are there? Probably no one ever counted all the connections, but on tube socket lugs alone there are 136 soldered joints, with many, many more at tie points on terminal strips.

All this points to one conclusion. In solving difficult service problems you will have to trace many circuits through many connections and parts. Most often you will commence with a service diagram for the receiver. On the manufacturer's service diagram for the TV set of Fig. 1 the tube symbols are arranged as in Fig. 2. This arrangement makes it easy to follow signal paths from antenna input all the way to picture tube and speaker, as marked with arrows. The complete diagram, as you realize, would include not only the tube symbols but also symbols for all other parts and their connections.

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LESSON 73 – TRACING TV RECEIVER CIRCUITS

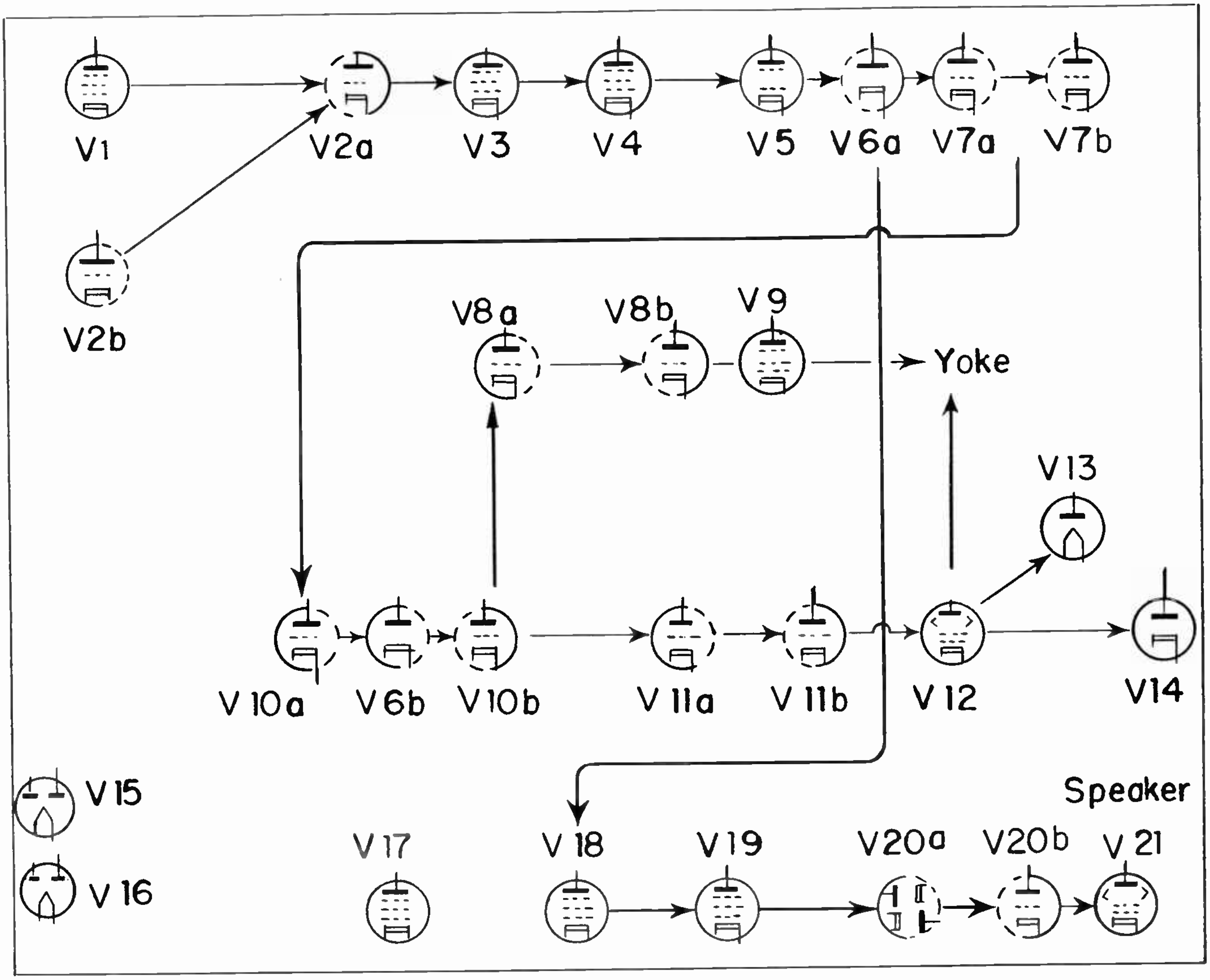

Fig. 2. Tube symbols are positioned on service diagrams to allow easy following of signal paths.

Following are names or functions of tubes identified by "V" numbers on Fig. 2.

V1 R-f amplifier, in tuner.
V2 R-f oscillator and mixer in tuner, twin triode.
V3 I-f amplifier, 1st.
V4 I-f amplifier, 2nd.
V5 I-f amplifier, 3rd.
V6 Video detector and noise supress-sor, twin triode.
V7 Video amplifiers, 1st and 2nd, twin triode.
V8 Vertical oscillator
V9 Vertical sweep amplifier.
V10 Sync amplifier
V11 Horizontal oscillator and afc tube, twin triode.
V12 Horizontal sweep (output) am-plifier,
V13 High-voltage rectifier.
V14 Damper tube
V15 Low-voltage power rectifier, to 200 volts.
V16 Low-voltage power rectifier, to 350 volts.
V17 Keyer tube for agc system
V18 Sound amplifier, 4.5 mc.
V19 Sound limiter, 4.5 mc.
V20 Sound demodulator and a-f ampli-fier, triple diode triode.
V21 Audio output amplifier.

The actual layout of tube sockets, as seen from underneath the chassis of Fig. 1, is shown by Fig. 3. Tubes and their sockets are

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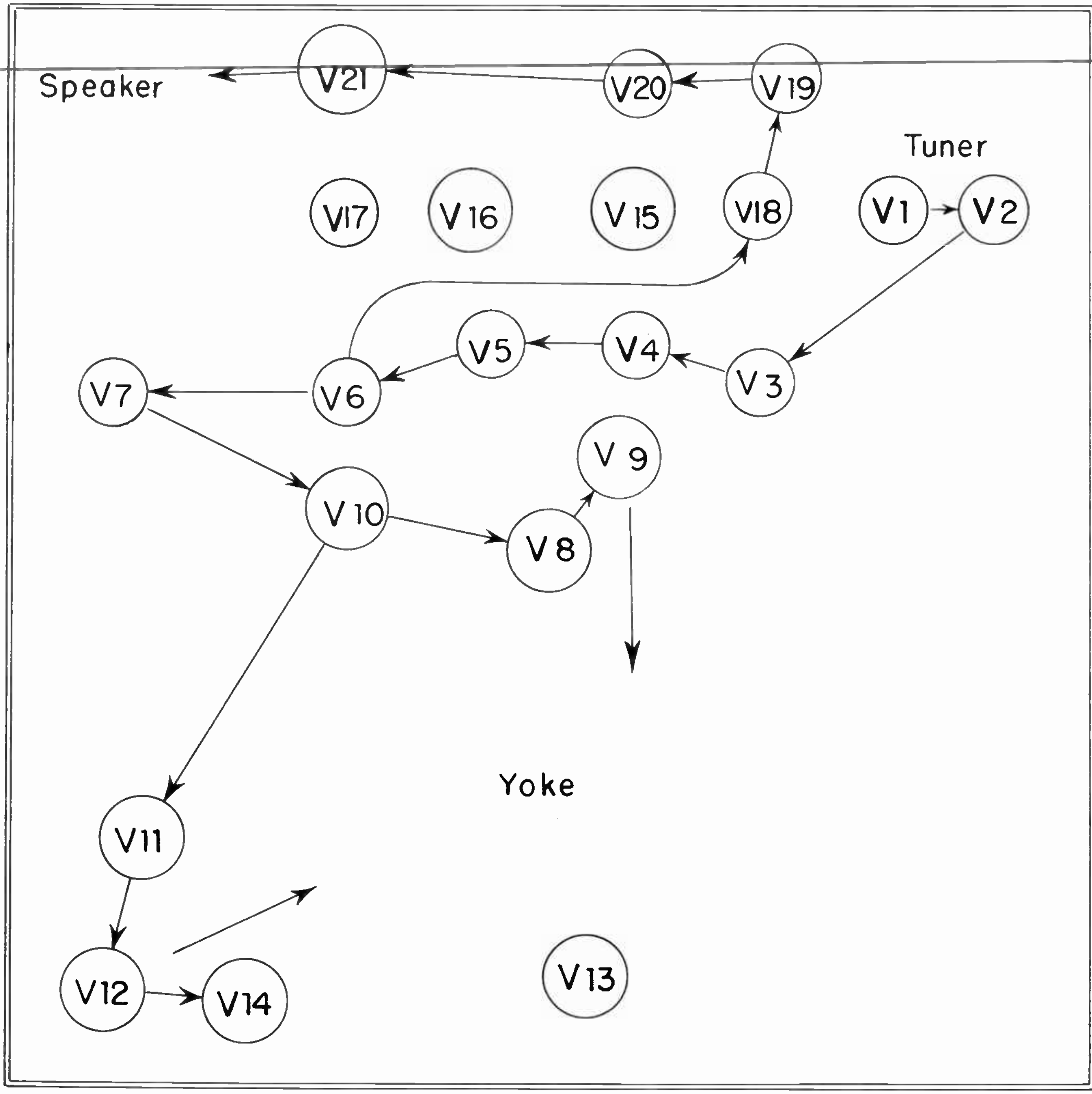

Fig. 3. Positions of sockets and tubes on a chassis are entirely unlike their positions on a service schematic.

placed for a compromise between shortest connections to other components and easiest or most practicable assembly and wiring during manufacture. There is little resemblance between relative positions of tube symbols on the service diagram and relative positions of tubes and sockets in the chassis.

Times without number you will read a service diagram while tracing circuits through chassis wiring and parts. Ordinarily you commence the process by checking tube type numbers on the diagram against type numbers on tubes in the set. When several tubes are of the same type, identify them by related groups. For example, following the tuner will be a string of i-f amplifiers, closely followed by the video detector (tube or crystal, and the video amplifier or amplifiers.

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By following speaker leads it is easy to locate a speaker coupling transformer in the chassis, and from one side of this transformer to trace leads to the plate of the audio output tube. From this output tube you can go to an a-f amplifier, a sound demodulator (often a twin diode), to sound amplifier or amplifiers, and the sound takeoff.

Sweep oscillators, sync section tubes, and horizontal afc tubes usually are grouped quite closely together. Look for any closely spaced tubes which have the type numbers shown for these functions on the service diagram.

Having located a particular tube in the chassis, you can identify by their position or numbering the socket lugs for elements shown for that tube on the service diagram symbol. There will be very few cases of trouble in which you cannot trace almost any circuit or part of a circuit once you make a tie-up between socket lug connections on the chassis and tube element connections on the service diagram.

Particular resistors usually can be identified by their color coding in relation to resistance values shown on the service diagram. Color bands change their shades on resistors which have been warm for long periods of time. This is especially true of violet (for the number 7). Blue and green, for 5 and 6, often are difficult to distinguish apart, as are also orange and yellow, for 3 and 4, on some resistors. Brown, for 1, often tends to disappear on the natural brown of the resistor insulation.

Service diagrams sometimes, and parts lists always, give wattage ratings of resistors. Soon you will learn to recognize resistor sizes or dimensions which go with certain wattage ratings. In Fig. 4 the power ratings, from top to bottom are: 1/2 watt, 1-watt, 1/2-watt, 1-watt, and 2 watts each for the three at the bottom.

Color codings for small ceramic capacitors usually are difficult to decipher. Most of these codings are "blobs" of color which too often are in positions where they cannot be seen. Also, there are so many codings and variations of codings as to make memorizing

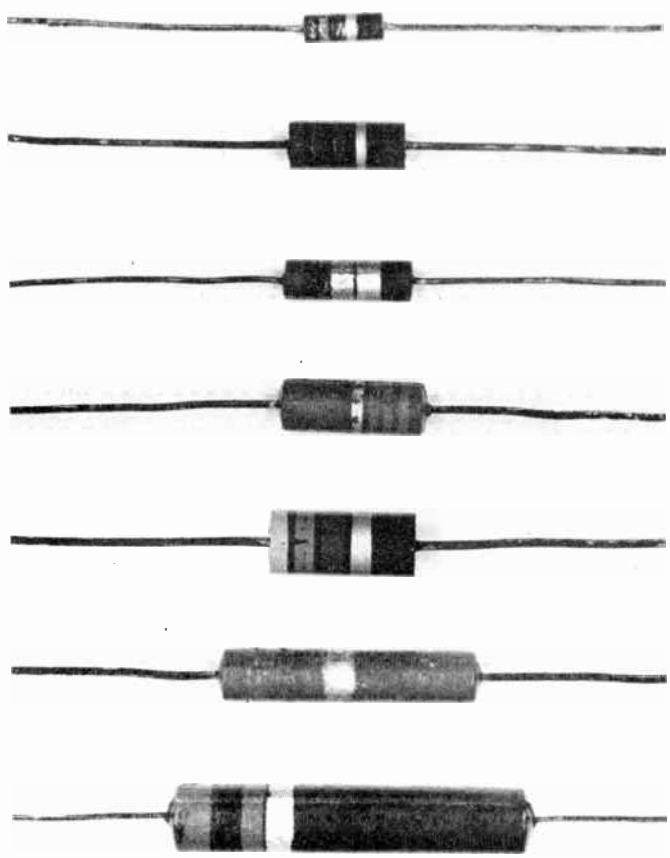

Fig. 4. Diameters and lengths of fixed resistors are roughly proportional to their wattage ratings.

them rather difficult. Mica capacitor codings are quite easy to recognize unless the unit is upside down, where dots are invisible unless you twist the capacitor enough to cause possible breakage of its pigtails or their connections.

Tubular paper capacitors ordinarily are marked with simple numerals and letter abbreviations for their capacitances and working voltages.. Too many tubular capacitors are mounted in such positions as to conceal the markings, and with leads so short that you hesitate to twist the units.

For looking at concealed codings and markings for values a decidedly useful service tool is a small round mirror on the end of a slender rod, such as used by dentists for examining teeth in the mouths of patients. Such mirrors, costing much less than a dol-

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lar, are for sale by radio and television parts houses.

mounting must be operated by the inner shaft and the outermost knob.

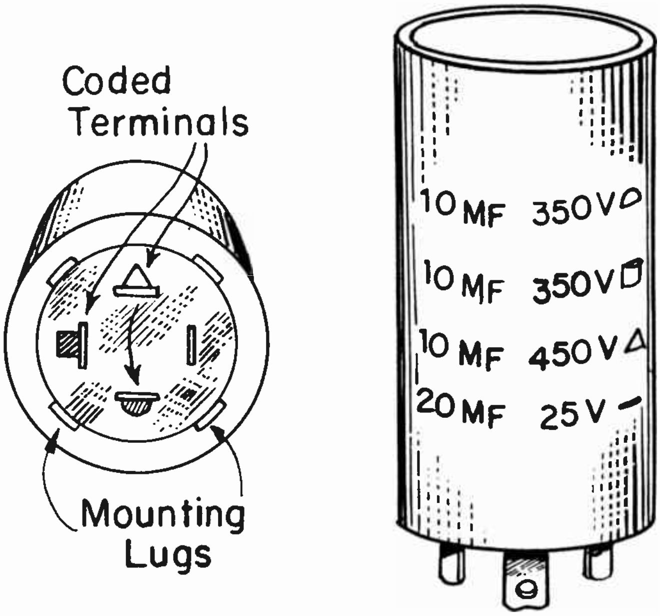

Fig. 5. Multi-section canned electrolytic capacitors may be coded in some such manner as this.

Multi-section canned electrolytic capacitors which mount on top of the chassis and have their terminals underneath usually have capacitance values and voltage ratings of the several sections marked on one side of the can. Opposite each rating is a code consisting of some certain geometrical figure, such as a square for one section, a triangle for another, and a half-circle for a third section. For some one section there may be no coding figure. The coding figures are punched in or otherwise marked on the insulation through which section terminals protrude at the exposed bottom of the can. Such coding is illustrated by Fig. 5.

There are many other receiver parts which may be of help in identifying certain circuits and their connections. Examples are service controls and operator's controls which are adjustable resistors mounted in the chassis with terminals inside or underneath. On dual concentric controls of the kind pictured in Fig. 6 always remember that the resistor element closer to the chassis mounting must be operated by the outer shaft and by the knob closer to the outside of the chassis, while the element farther from the

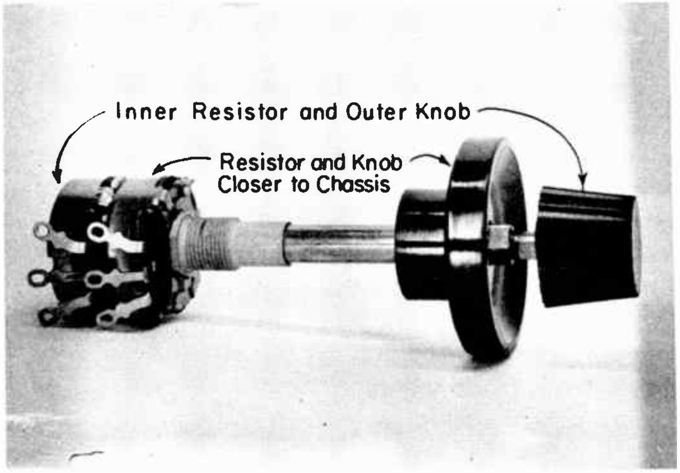

Fig. 6. Remember this relation between resistance elements and operating knobs of dual concentric controls.

For all rotary adjustable resistors, no matter what their function, you always can identify the rotor contact on a service diagram, and will know that this is the center one of three terminal lugs on the resistor itself. The two outer ends of a rotary resistor or potentiometer cannot be positively identified; they may show one way on a diagram and be connected oppositely on the chassis.

Selector switches such as used for changing between television, phonograph, and sound radio may be of great help in tracing circuits provided service diagrams clearly indicate the switch terminals and their connections for one or more functions.

Quite a number of receivers have cable connectors for the wires running from chassis to deflecting yoke, from chassis to speaker, from chassis to a separate low-voltage power supply, and to any other separate units. These connectors consist of a plug on which are projecting pins like those on tube bases, and of a socket made like a tube socket except that there is an enclosure or support for wires instead of a means for mounting in a chassis opening.

Pins and socket openings of a cable connector are numbered just as are pins of a tube base and tube socket. Pin and socket numbers are given on service diagrams that

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show circuit connections to these two parts. Thus you are enabled to identify each of the wire connections on the chassis by noting the number of the position to which it attaches on the connector plug or socket.

Coupling transformers of types enclosed within shield cans, and with terminal lugs exposed underneath the chassis often have these terminals numbered or lettered. Similar numbers or letters appear at connections to symbols for these units on service diagrams. Interstage transformers and other couplers of open construction seldom have their leads marked in any manner which is helpful in tracing circuits.

Iron-core power transformers, speaker transformers, and some oscillator feedback transformers have colored lead wires. There are standards for transformer color coding, but they are not always followed. As a rule it is safer to identify transformer leads by tracing them to socket lugs and to various service and operating adjusters than to depend on color coded leads.

Much confusion in tracing circuits on both circuit diagrams and actual chassis wiring may result from one of the simplest features, from ground connections. Chassis ground for several separate and independent circuits often is shown at a single ground symbol on service diagrams, and often is made at a single lug on a terminal strip in chasses. It is easy to fall into the error of assuming that the several grounded circuits are interconnected and are parts of a single operating circuit.

You must keep in mind that a circuit ends at a ground connection, at least so far as tracing of its leads and connections is concerned. There the traced circuit joins many other grounded circuits, and loses its separate identity. No matter how many other leads may come to the same ground, other circuits are not there connected into the one being followed.

TRACING B-PLUS LINES. When commencing to locate difficult troubles many technicians make it a practice to measure actual values of all voltages marked on either a service diagram, a chassis layout diagram, or a list of tubes and their pin numbers. When following this practice you might discover that nearly all voltages are somewhat too low, or maybe too high, while only a few are excessively low or high. Then it would be in order to check from where voltages are badly out of line back toward the B-power supply until reaching points at which voltages are slightly abnormal. At that point, or close to it electrically, you are more than likely to find the cause of trouble. Such tracing of B+ lines is one of the most common and often one of the most time-consuming service operations.

Whenever you measure all voltages, and thus determine where to begin your trouble hunting, pull the power cord plug from the line receptacle before doing any actual tracing of connections. Do this whether the receiver has a power transformer with insulated secondary or is of a type in which the chassis may be hot. This precaution will avoid shocks due to touching live connections, and shocks coming through shorts and accidental grounds, or through capacitors.

Line voltage, to which may be added some unsuspected B-voltage, can be more dangerous than the much higher voltage from a picture tube second anode circuit. This is because of the far greater current, and sustained current, that is delivered from an a-c supply line. Almost anyone can stand very high voltages when current is limited to a few milliamperes at most. Few of us can stand large currents, even at potential differences of a couple of hundred volts, without getting a painful and possibly harmful shock.

Service diagrams of many manufacturers have all the B+ lines drawn to look like lines for all other circuits. Portions of such a diagram are shown at A of Fig. 7. A few mark the various B-voltages on the lines, thus making it possible to distinguish these lines from others without having to follow them all the way to the power supply.

On some service diagrams the B+ lines are drawn much heavier than any others, as at B of Fig. 7. This saves time when following from any point of suspected trouble to the nearest connection at which there should be power supply voltage. These connections, on

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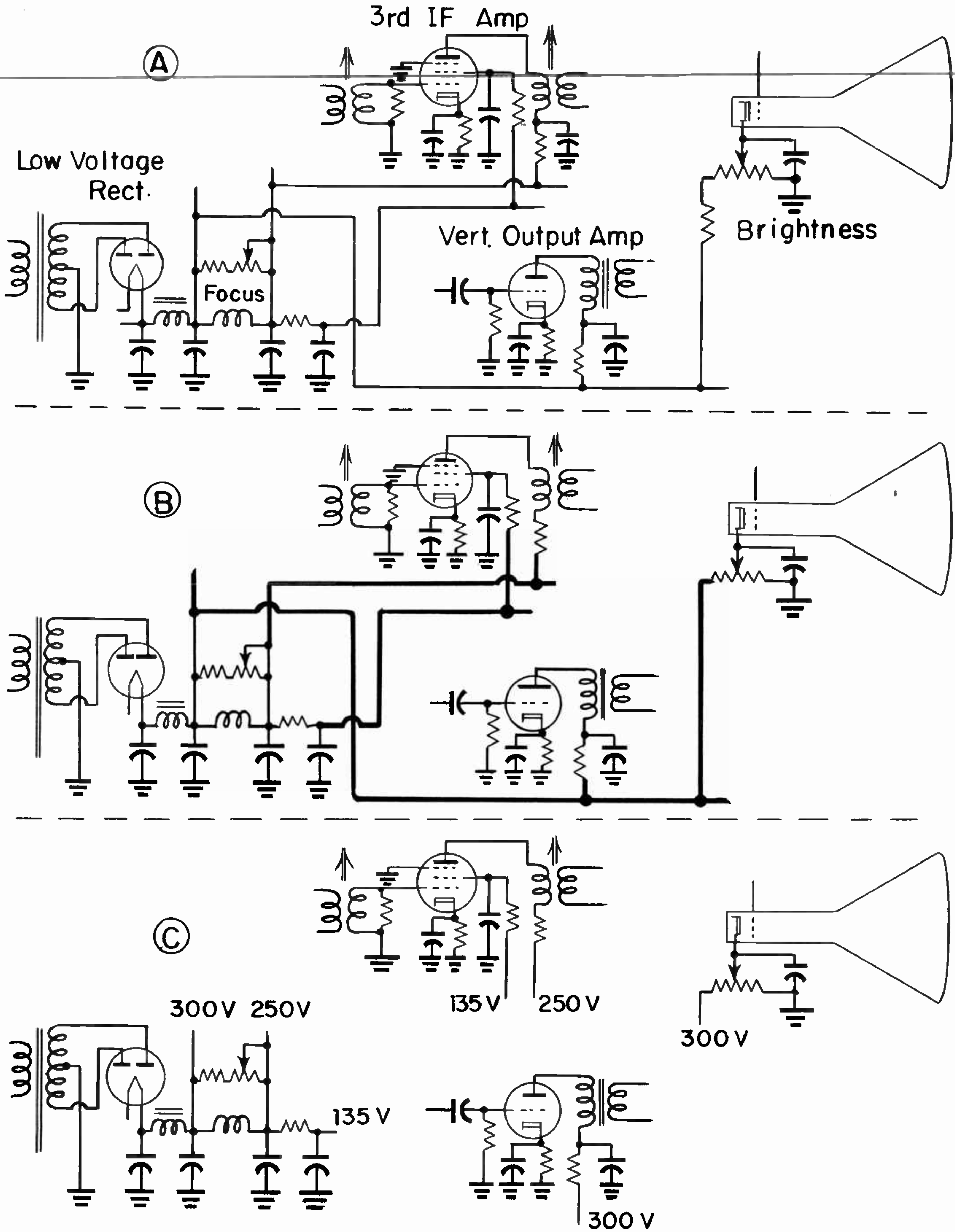

Fig. 7. Several methods of showing B+ lines on service schematic diagrams.

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the chassis, are recognized by their relations to certain resistors and other components easily located.

On still other service diagrams most of the B+ lines are omitted, as at C of Fig. 7. Then the several available B-voltages are marked at the terminals of the low-voltage power supply. These voltages are marked also at each of the many points throughout the diagram which would be connected to the power supply leads. This method simplifies a service diagram by omission of many lines. It serves the purposes for which schematic service diagrams are intended, because, even were all B+ leads shown, their relative positions and how they are interconnected on a schematic would not show how the B+ wiring actually runs on a chassis.

Fig. 8 is a copy of that portion of a service diagram which shows the low-voltage power supply. Terminals are marked 350 positive volts, 360 positive volts, 3 negative volts, and there is a chassis ground. On the remainder of the original diagram various circuits connected to these B-voltages are marked in the same general manner as at C of Fig. 7.

Fig. 9 shows the actual chassis layout for the same receiver, with only the wires you would trace in identifying various points shown by the schematic of the power supply. On the chassis there are scores of additional wires leading to various elements and to tubes indicated by circles on the layout. To learn how widely the wiring differs from the service schematic we shall compare connections of the two diagrams.

Commencing at the socket lug for pin 2 of the power rectifier, a long wire runs all the way down to the lug for filter capacitor C1. Terminals on capacitors themselves would not be so conveniently numbered, you would have to identify them by tracing the wiring.

From filter capacitor C1 a lead goes through a hole in the chassis to the filter choke, which is on top of the chassis. From the other side of the choke a lead comes back to filter capacitor C2. From this capacitor terminal there is a connection to terminal a

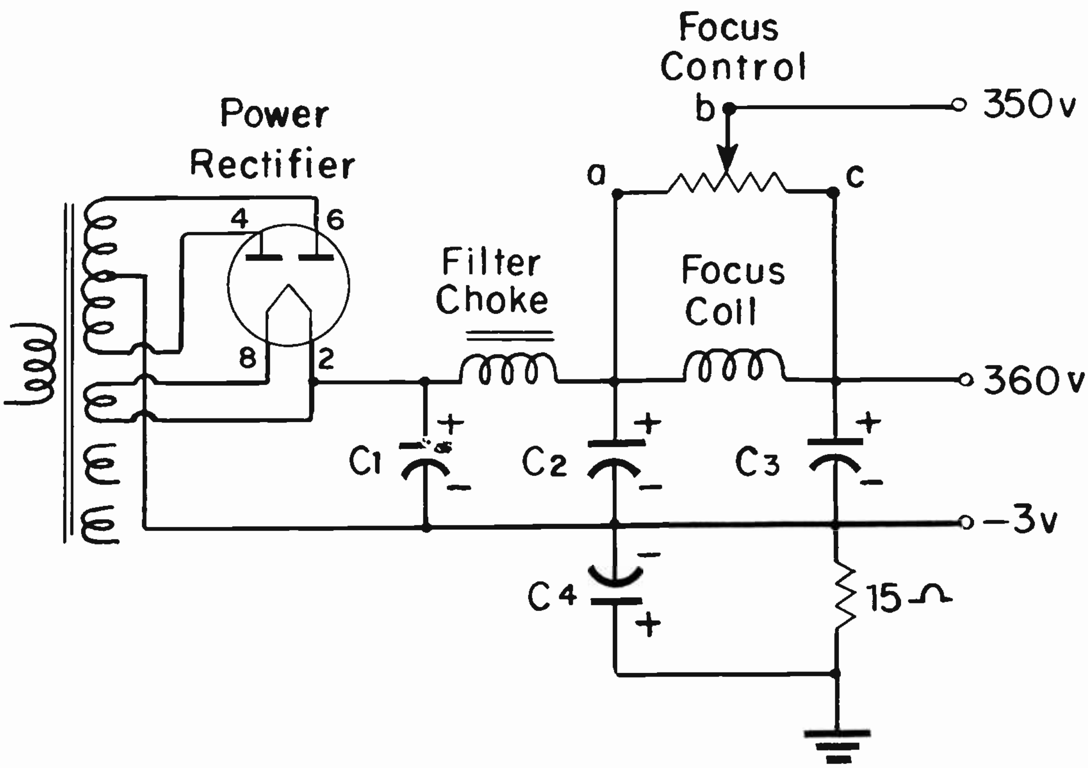

Fig. 8. This is a service schematic for a power supply showing terminals for voltages, but no leads from these terminals to other circuits.

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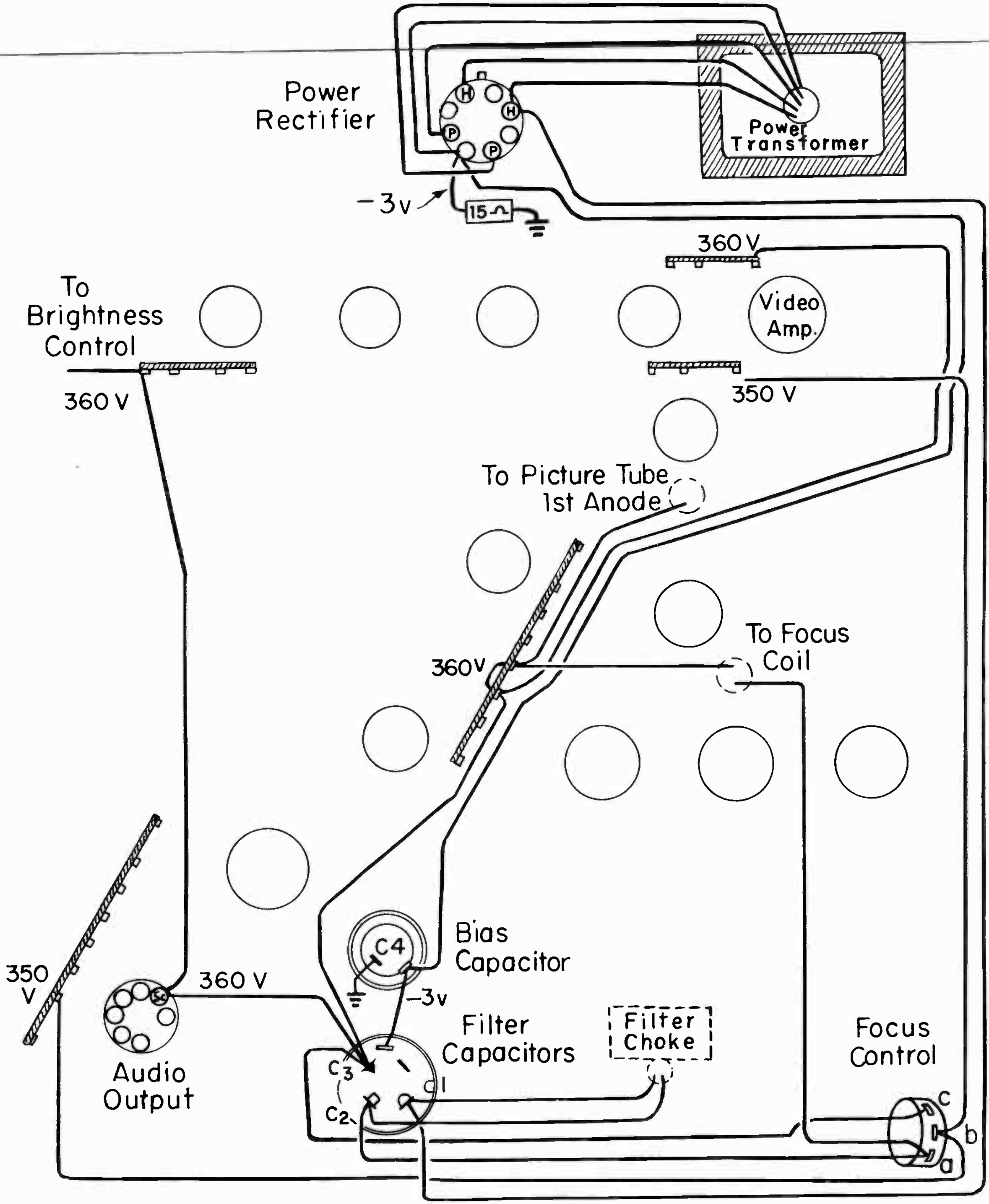

Fig. 9. Parts close together and clearly connected on a schematic may be far apart and connected only indirectly on the chassis.

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on the focus control potentiometer. Actually there would be no special marking on the pot terminal, you would locate it by tracing connections.

From terminal a on the focus control a lead goes through a hole in the chassis to the focus coil, which is on the neck of the picture tube. From the other side of the focus coil a lead goes to a lug marked "360 v" on one of the terminal strips. There would, of course, be no such marking on the real terminal strip. This lug corresponds to the 360-volt terminal on the service schematic. Now lets find the other points which are electrically the same as the 360-volt power supply terminal.

On the schematic of Fig. 8 there is a connection from the 360-volt terminal, and the focus coil, to the opposite end of the focus control, marked c on the diagram. Locate this connection on the chassis layout, imagining that you are tracing it through many other wires all cabled together.

The connection which appears so direct on the schematic is made on the chassis from the terminal strip to capacitor C3, and from this capacitor along the bottom of the chassis layout to lug c on the focus control.

Filter capacitor lug marked C3 (not really, but only on our diagrams) is directly connected to the 360-volt lug on the terminal strip, and so becomes a part of the 360-volt terminal of the service schematic. From this capacitor lug there is a connection to the socket lug for the screen (pin 6) of the audio output tube. This socket lug is a tie point for another direct connection to the brightness control, while at the same time delivering screen voltage and current to the audio output tube.

Still we are not through tracing direct connections for 360 volts. Going back to the terminal strip from which there is a connection to the focus coil, you will find another wire running up and to the right, and ending on another terminal strip above the video amplifier tube.

On the service schematic the slider of the focus control is shown as a 350-volt terminal. On the chassis layout you can follow from the slider (center terminal) to two terminal strips marked 350 volts on the layout diagram. Remember, on the chassis wiring there are none of the convenient markings used on the diagrams; you are supposed to trace the wires.

One terminal of the power supply schematic of Fig. 8 is marked 3 volts negative, with reference to chassis ground. This negative bias voltage, for grid returns of several amplifier tubes in the receiver, is secured as follows.

All direct current from plates of the power rectifier passes through the transformer winding and from the center tap into a load going to the 3-volt negative terminal and to one end of a 15-ohm resistor. None of this current flows away from the negative terminal to the grids of biased amplifier tubes, because the grids are negative. But all rectified current does flow downward through the 15-ohm resistor to ground, and through ground to tube cathodes and other grounded points in receiver circuits. With current flowing downward, the upper end of the resistor, and the bias terminal, must be negative with reference to the lower end and chassis ground.

Now trace this negative bias circuit on the chassis layout of Fig. 9. The lead from the power transformer center tap goes to the lug in position 5 on the power rectifier socket. This lug is used merely as a tie point. On the base of the rectifier tube, a 5U4-G, there is no pin in position 5. The 15-ohm biasing resistor is connected between this socket lug and ground. Another wire from this same lug runs all the way down to bias capacitor C4.

Note particularly that the wire from the transformer center tap connects to a can lug on capacitor C4. Can lugs on electrolytic capacitors always are negative terminals. There is a short connection to a can lug on filter capacitors C1, C2, and C3. Here we have the negative sides of all electrolytic capacitors of the power supply connected together, just as on the service schematic diagram. The positive side of capacitor C4 is grounded near the capacitor. Grounds for

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capacitor C4 and the 15-ohm resistor are at the same point on the service schematic, but on the chassis they are far apart.

Chassis wires which run close together or are cabled together almost always have insulations of different colors, and if you find the same color at opposite ends of a run you probably have the two ends of a single wire. However, you will find that colors fade out and change with age and heat. Red, yellow, and orange often get to look almost alike. White often changes to yellow. The color of a given insulation under the chassis, where it has been heated, often appears different from that of the same insulation and wire above the chassis, where it has remained cooler.

TRACING COMPLETE CIRCUITS. For additional practice in tracing television circuits we shall assume that there is trouble with horizontal synchronization in a receiver employing a phase detector twin-diode for the afc tube and a cathode coupled multi-vibrator as horizontal sweep oscillator. Fig. 10 is the portion of the manufacturer's service diagram including tubes, resistors, capacitors, inductors, and connections which may be related to the trouble.

Fig. 11 shows the actual chassis layout for all these parts. On all resistors and capacitors of this layout are marked the values which correspond to values marked on the service diagram. In actual practice, resistance values would be marked on the service diagram, but on the chassis you would have to recognize resistances by the color coding.

Several leads extend beyond the portion of the service diagram here reproduced,, and beyond the chassis layout diagram. These leads, marked in parentheses on the two diagrams, would have to be identified by tracing them to other sections during your work of trouble shooting.

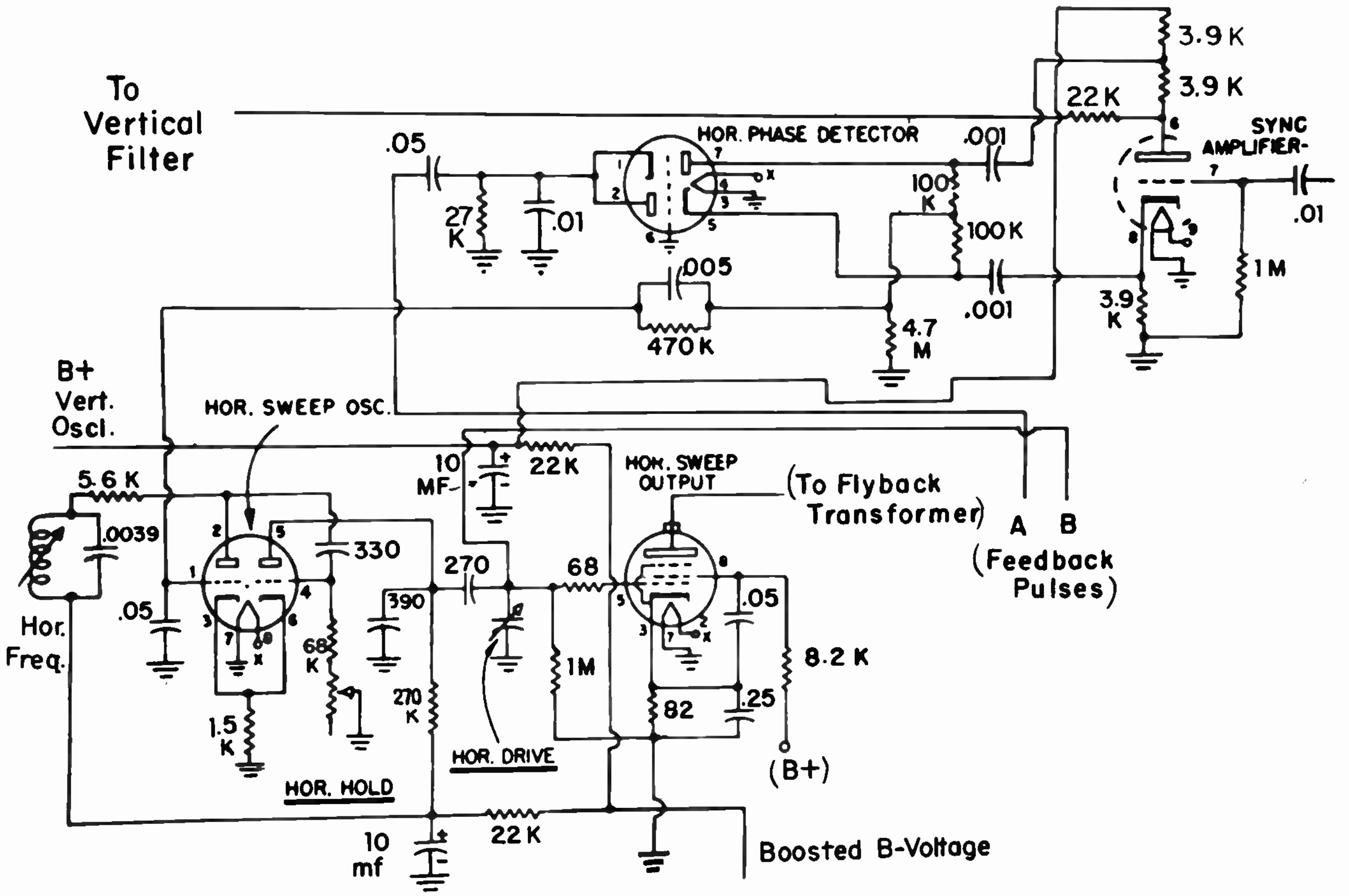

Fig. 10. The service schematic diagram with which we commence the search for synchronization trouble.

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Feedback pulses from the connection marked A are positive; they are applied to the afc tube. Feedback pulses from the connection marked B are negative; they are applied to the grid of the sweep output tube for negative peaking. Both kinds of pulses are obtained from the deflecting circuits on the horizontal flyback transformer.

In this particular receiver, plate voltages for the sync amplifier and horizontal sweep oscillator are taken from the boosted B-voltage circuit for which a lead is shown. Boosted B-voltage also goes to the vertical sweep oscillator, not included on the diagram.

In any can containing electrolytic capacitors, such as the one at the lower left in Fig. 11, are usually several units of the same or different capacitances and voltage ratings. On service diagrams the capacitor units commonly are placed at any positions which most clearly show circuit connections. The capacitor units are not grouped to indicate which ones are in any particular can.

The horizontal hold control, on the front of the chassis, is part of a dual concentric potentiometer whose other section is the vertical hold control. On the rear apron of the chassis is the horizontal frequency control, which might be called the stabilizing control for the afc system. On the rear apron is also the drive control, a compression type mica trimmer capacitor.

You should practice tracing the following connections or circuits, first on the service schematic of Fig. 10, then on the chassis layout of Fig. 11.

1. Sync amplifier tube

   Plate through 3.9K, another 3.9K, then 22K, to boosted B-voltage.

   Plate - 3.9K - .001 - plate of phase detector and 100K.

   Cathode - .001 - cathode of phase detector and 100K.

   Junction of two 100K's to 4.7M, and noise filter consisting of .005 and 470K paralleled.

   Noise filter to 1st grid of sweep oscillator.

2. Sweep oscillator tube.

   1st plate through 5.6K - horz freq control - 22K - boosted B-voltage.

   2nd grid through 68K to horizontal hold.

3. Sweep output tube

   Grid through 68 ohms to drive control.

   Grid through 68 ohms and 270 mmf to 2nd plate of sweep oscillator.

   Grid through 68 ohms and 1M to ground.

Socket lug 4 on the sweep output tube is a tie point. There is no pin in position 4 on the base of the 6BG6-G tube.

When tracing to the horizontal hold control, what did you find different on the service diagram and chassis layout? If nothing appeared wrong, you are not doing a careful job of circuit tracing. Connections are reversed on the hold control pot. As it happens, this makes no difference in this case, because the control is used as a rheostat with one end open. In other cases a reversed pair of connections might be the trouble you are looking for.

Now look at Fig. 12. It is part of the service diagram for an entirely different receiver, but it shows a sync amplifier, a horizontal phase detector, a cathode coupled multivibrator, and a horizontal sweep output tube for the same afc and oscillator system shown by Fig. 10.

In order that you may identify equivalent circuits, values of resistors and capacitors on Fig. 12 have been changed where necessary to make them the same as on Fig. 10. Original values were not alike in all cases, but they were near enough alike that performance of the two afc and oscillator systems would be practically the same.

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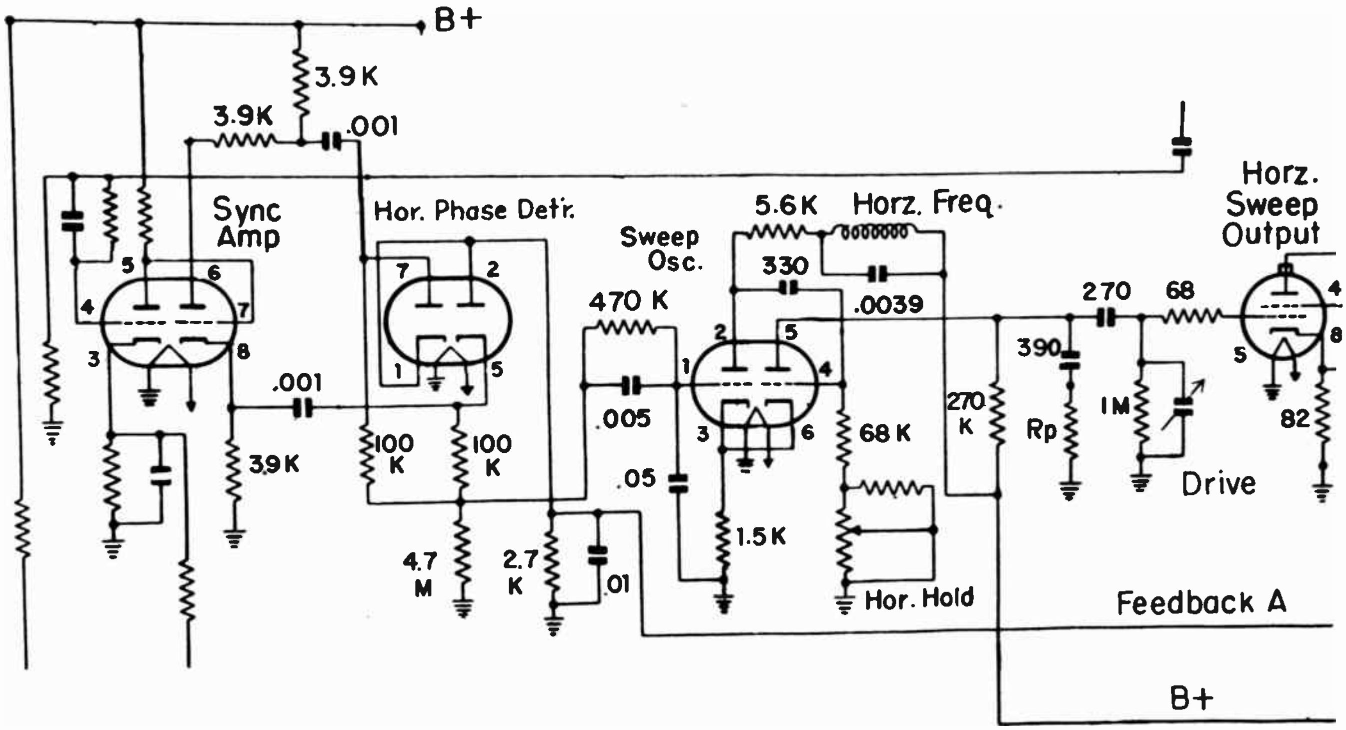

Fig. 12. This service schematic, for another make of receiver, shows the same types of circuits as Fig. 10.

You should check all the connections of Fig. 12 against those of Fig. 10, to make sure that you can recognize a type of circuit no matter how it may be drawn or arranged on service diagrams. The more important differences which you should note before commencing to trace the circuits are as follows, referring to Fig. 12.

The sync amplifier is one section of a twin triode whose other section is a d-c restorer using tube elements connected to pins 4, 5, and 6. There is no restorer tube on the diagram of Fig. 10.

There is no resistor from sync amplifier grid to ground.

On the horizontal hold control there is an extra resistor between the slider and one side of the pot.

In series with the 390-mmf sawtooth capacitor of Fig. 12 there is a negative peaking resistor marked Rp. Negative peaking on Fig. 10 is obtained from a feedback pulse. By the way, did you recognize the 390-mmf capacitor on the second plate of the oscillator in Fig. 10 as a sawtooth capacitor? If not, you should have.

Plate voltages for sync amplifier and sweep oscillator in Fig. 12 are obtained from the regular low-voltage d-c supply, not from the boosted B-voltage circuit as in Fig. 10.

The sweep output tube of Fig. 12 is a 6BQ-GT instead of the 6BG6-G of Fig. 10. This accounts for different pin numbering for some elements.

Now go ahead with your checking of all connections and circuit elements. To a novice the two diagrams would appear decidedly different, to you they should appear alike as far as operating principles are concerned.

For our next job of circuit tracing we shall work in the corner of the chassis pictured by Fig. 13. Again we have a horizontal oscillator, sync amplifier, and afc system with phase detector just like those of Figs. 10, 11, and 12 so far as electrical principles are concerned. We are looking at many variations of the same basic circuits to make it plain that an understanding of fundamental

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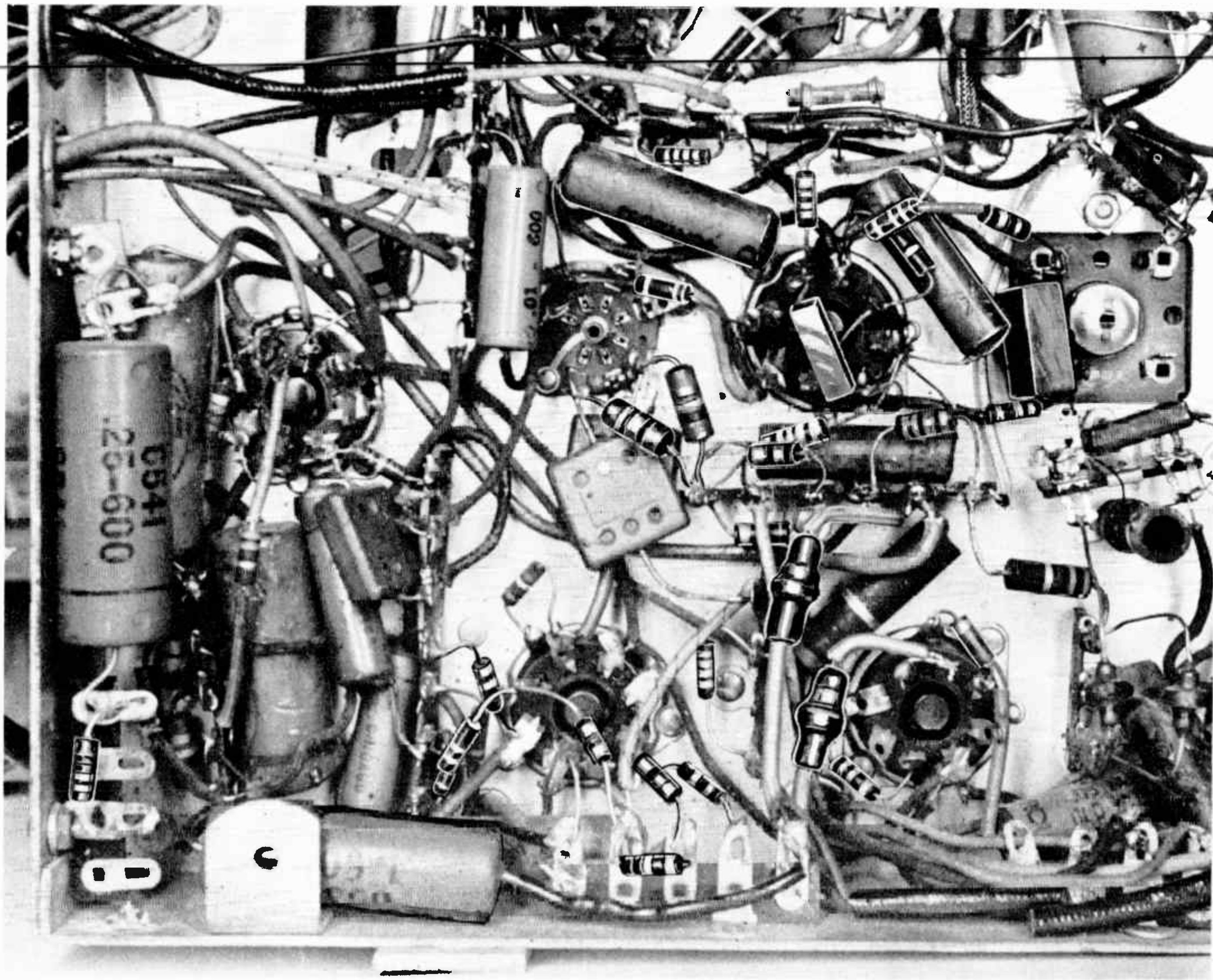

Fig. 13. In this chassis we shall examine the video amplifier and the d-c restorer in addition to the sync amplifier, afc tube, and horizontal oscillator.

principles is necessary when attempting to service all makes and models of receivers.

Our original trouble was assumed to be failure of synchronization. The cause might go further back that the sync amplifiers at which we have commenced circuit tracing in preceding examples. The fault might be in the d-c restorer circuit, where the tube acts as a sync separator, or it might be in the video amplifier circuit. Therefore, these additional circuits and tubes are shown by Fig. 13 and diagrams which are to follow.

The photograph shows part of what may be called the main chassis of our receiver. There is a separate power chassis on which is the low-voltage d-c power supply, also the horizontal output amplifier and the entire flyback horizontal sweep system. The two chasses are connected through a multi-conductor cable.

Fig. 14 is the portion of the service diagram showing circuits in which we are now interested. Were you to identify on the chassis all the elements whose values are marked at symbols on the service diagram, these values would appear as on the chassis layout of Fig. 15. Positions of all parts on this layout diagram are, as nearly as they can be clearly shown, the same as positions of the same parts on Fig. 13.

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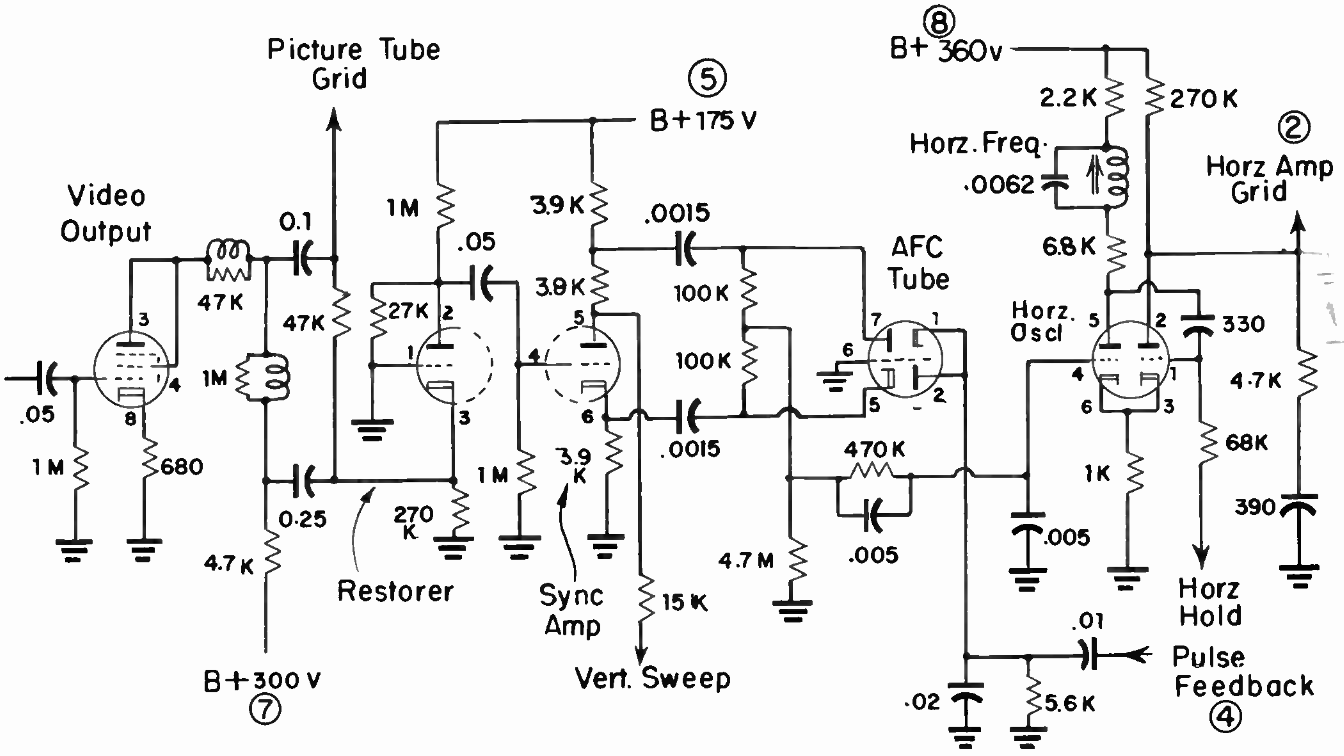

Fig. 14. The service schematic which includes the video amplifier and d-c restorer connections.

At the upper left in Fig. 15 is an 8-pin cable plug which does not show on the photograph, because it is on the far end of a group of cable conductors which pass out through a hole in one side of the main chassis. This cable plug looks exactly like the octal base for a tube. It fits into an octal socket on the power chassis.

The socket member of the cable connecting device is placed on the power chassis rather than on the cable for this reason. With the set turned on, all connections at the power chassis are alive, but even with the plug withdrawn from the socket, connections down inside the socket openings are inaccessible, and you are protected from shock. The pins exposed on the cable plug while it is out of the socket are dead, and cannot give a shock.

Leads from numbered pins of the cable plug can be followed on the layout of Fig. 15. They go to points which are similarly numbered on the service schematic of Fig. 14. Here is a listing of the cable leads according to plug pin numbers.

1. Not used.

2. From second plate of horizontal oscillator on main chassis to grid of the horizontal output amplifier on the power chassis.

3. A ground connection. One of the conductors in nearly all inter-chassis cables connects the metal (chassis ground) of one chassis to metal of the other chassis. Such a ground connection is necessary for completing the various B-voltage circuits and for completing all other circuits which are grounded at one point.

4. This lead brings a feedback pulse from horizontal deflecting circuits on the power chassis to the afc tube on the main chassis.

5, 6, 7, and 8. These leads furnish B+ voltages respectively of 175, 220, 300, and 360 from the power chassis to the main chassis.

Plate voltages for the sync amplifier and both sections of the sweep oscillator of Fig.

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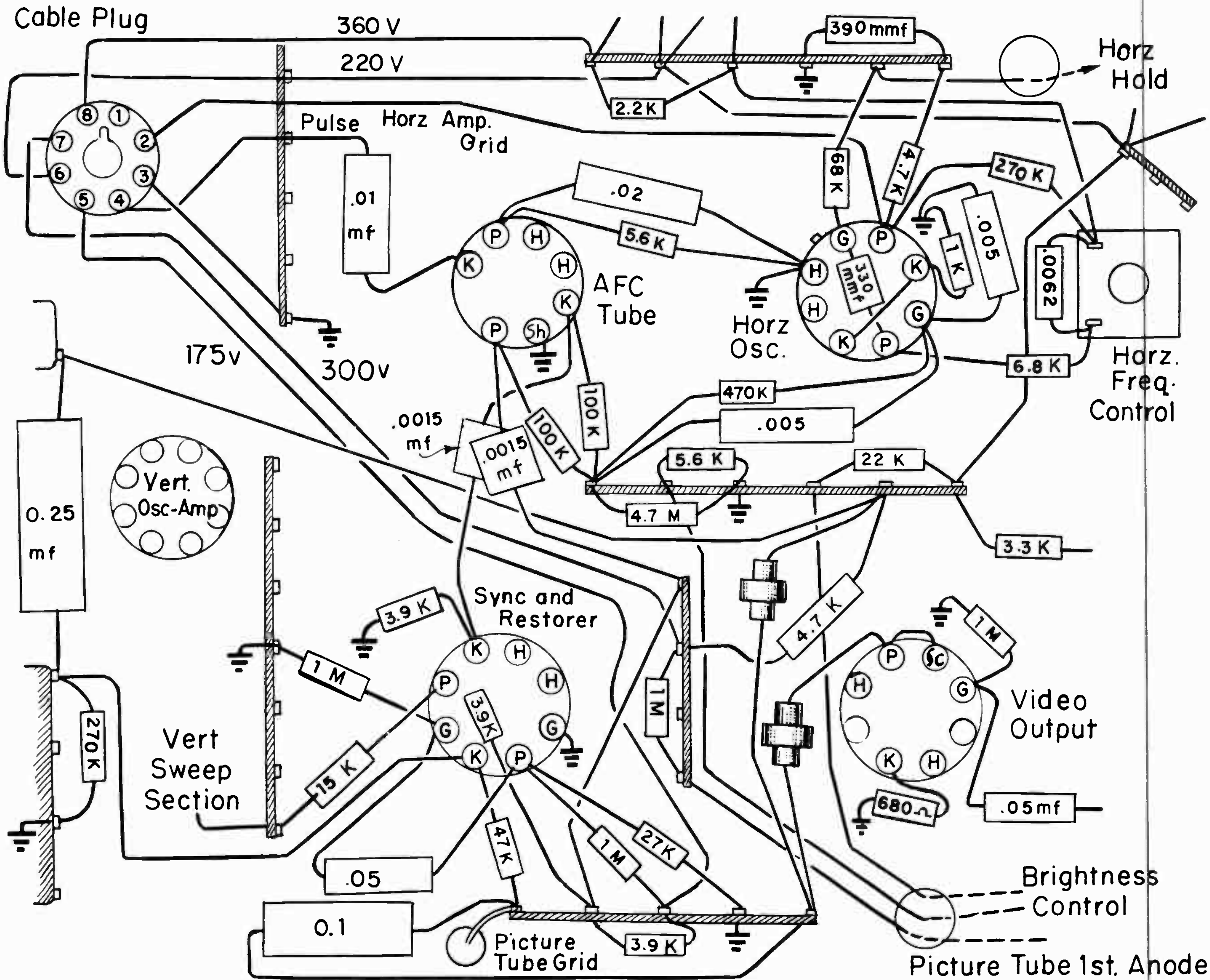

Fig. 15. This is the chassis layout corresponding to the picture of Fig. 13 and the service schematic of Fig. 14.

14 are secured from the low-voltage power supply. In Fig. 11 all these voltages are secured from the boosted-B circuit of the receiver.

Whenever you trace certain circuits through a chassis you will have to follow through numerous wires and parts which have no direct relation to these circuits. A few such unrelated wires and parts are shown on the layout of Fig. 15, but are not shown on the service schematic. The schematic was redrawn to include only circuits in which we are now interested. The unrelated lines are as follows.

From pin 6 of the cable plug a 220-volt line goes to a lug on the uppermost terminal strip, to which other unrelated circuits are connected. Then the 220-volt line goes to another terminal strip above the horizontal frequency control, where still other unrelated circuit wires are connected. From here the 220-volt line runs downward to still another terminal strip at which are connected resistors of 3.3K and of 22K. From the 22K resistor a lead runs down and through a hole in the chassis to the brightness control. Coming back from the brightness control is a lead running to a centrally located terminal strip, and through 5.6K to ground. None of this 220-volt feeder has anything to do with circuits which we are preparing to trace, it is put in merely to illustrate conditions which exist on all chasses.

Start tracing again from pin 5 of the cable plug. A 175-volt lead goes to a terminal strip at the left of the video output tube, where are connected 4.7K and 1M resistors. The 4.7K resistor carries current for circuits in which we are interested, but the 1M resistor connects only to a lead which passes through a chassis hole to the picture tube first anode.

While tracing circuits on the service schematic of Fig. 14 you should note the following features of this receiver. The video output amplifier is a beam power tube with plate and screen connected together to act as a power triode. In the plate circuit of this tube are peakers shunted with 47K and 1M resistors. These shunt resistors do not show separately on the chassis layout, because they are the winding forms for the peaker coils.

D-c restorer and sync amplifier functions are served by a twin triode. Sync pulses are taken from the restorer plate through 0.05 mf to the grid of the sync section. From here, all the way through the afc system and horizontal oscillator, the circuits are like those of Figs. 10 and 12. This is another chance to make sure that you recognize a given type of circuit no matter how it may be drawn on service schematics.

Earlier in this lesson you checked certain circuits of the schematic in Fig. 10 against the layout of Fig. 11, as follows:

1. From sync amplifier plate to first grid of the sweep oscillator.

2. From first plate of the oscillator to its B-voltage supply line, and from the second grid of the oscillator to the hold control lead.

Trace the equivalent connections on the schematic of Fig. 14 and on the chassis layout of Fig. 15. Before reading beyond this present paragraph, make a list of resistors and capacitors which serve equivalent purposes but which are of different values on Figs. 11 and 14.

You should have listed these differences.

	Fig. 11	Fig. 14
A. Two coupling capacitors from sync amplifier plate and cathode to afc tube.	.001	.0015
B. Capacitor from first grid of oscillator to ground.	.05	.005
C. Resistor from first plate of oscillator to horizontal frequency control.	5.6K	6.8K
D. Capacitor paralleling frequency control coil.	.0039	.0062

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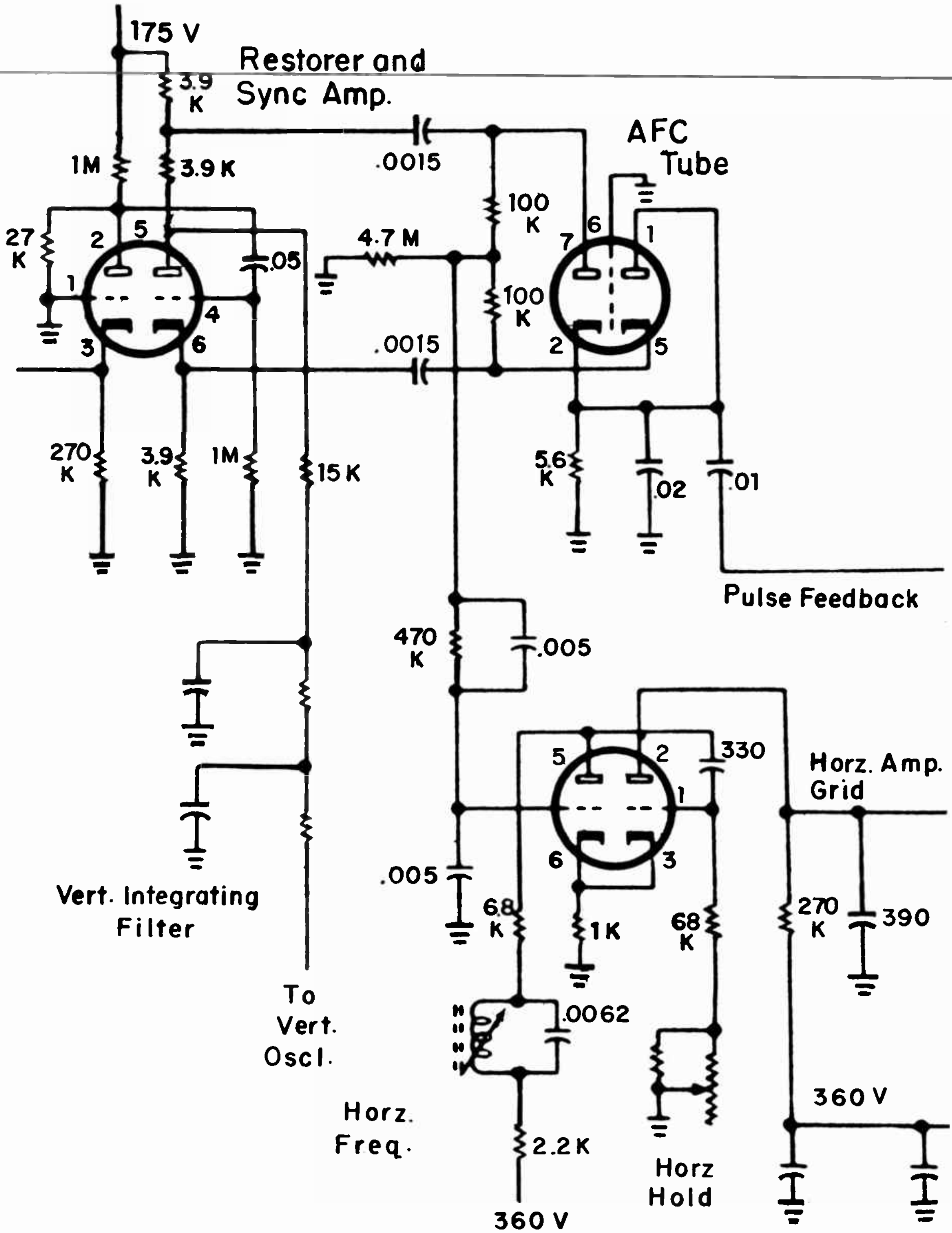

Fig. 16. Still another service schematic including the restorer, sync amplifier, afc phase detector, and multivibrator oscillator which appear in earlier diagrams.

	Fig.11	Fig.14
E. Resistor from frequency control to B-voltage.	22K	2.2K

Each receiver works satisfactorily with its own values of resistors and capacitors.

Differences in values are matters of original engineering design. Differences listed

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at A and C are not important; probably either value would be satisfactory in either receiver. There is a big difference listed at B; changing the values might cause trouble. Different capacitances listed at D are required in order to tune at 15,750 cycles with different inductances in the two frequency controls. Different resistances at E are necessary because of the different B-voltages, from the boosted-B circuit in one case and from the low-voltage power supply in the other case.

You may do a great deal of imaginary trouble shooting with our service schematics and corresponding chassis layouts. For example, with the circuits of Fig. 14, supposing that voltage at the restorer plate (pin 2) is within acceptable limits, but is badly out of line at the sync amplifier plate (pin 5). Since both these plate voltages come from the same 175-volt line, the fault might be in either of the 3.9K resistors leading to pin 5. Locate these two resistors on Fig. 15. Don't get them confused with the 3.9K resistor to ground from pin 6 of this tube. Incidentally, were this latter resistor open the plate voltage would go up, and were the resistor shorted out the plate voltage would go down.

There is virtually no end to the number of ways in which a given basic circuit may be drawn on a service schematic, and built into a chassis. As a case in point, look at the schematic of Fig. 16. It is exactly the same as the schematic of Fig. 14 except for omission of the video amplifier and its plate circuit, the inclusion of a vertical integrating filter beyond the 15K resistor, and a really important difference in the sawtooth capacitor circuit on the oscillator - what is it?

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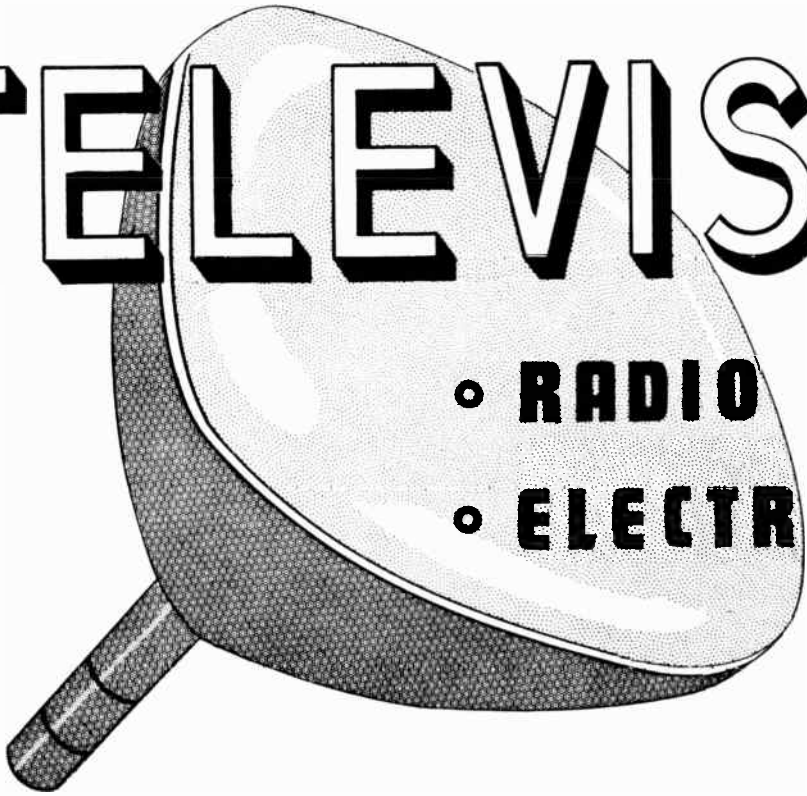

• RADIO
• ELECTRONICS

LESSON 74—B-SUPPLY CIRCUITS AND BAND SWITCHING

Coyne School

practical home training

Chicago, Illinois

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Lesson 74

B-SUPPLY CIRCUITS AND BAND SWITCHING

A d-c power supply of the type with which we have become familiar is shown in a schematic at A of Fig. 2. The load, here represented by only a single triode tube, actually would consist of plate and screen circuits for many tubes. For those circuits requiring less than maximum B-voltage there would be dropping and decoupling resistors at many points in the chassis wiring.

The power supply itself furnishes only a single positive B-voltage and a single negative B-voltage. The negative voltage is that at the center tap of the transformer secondary, which, we must not forget, always is the most negative point in any power supply employing a full-wave rectifier. This negative center tap is connected directly to chassis ground, thus making all ground connections throughout the receiver of the same potential as the transformer center tap.

There are several possible ways of providing negative grid bias voltages with this type of power supply. We may use cathode-bias resistors, which make the cathode of a tube more positive than ground, and may connect the grids through isolating resistors to ground. We may use the grid-leak method of biasing, which makes the grid more negative than ground, and may connect the cathode to ground. Negative bias may be furnished also by an automatic gain control system. Such a system developes a grid biasing voltage more negative than ground, to which cathodes are connected directly or indirectly.

Recently we looked at a modification of the power supply, as shown by diagram B. Here a negative biasing voltage is produced by drop in resistor Rb, which is bypassed by capacitor Cb. The transformer secondary center tap connects to the B-minus line, and to this line are brought grid returns of tubes biased from the power supply. Chassis ground is more positive than the B-minus line.

Tubes whose grid returns are not connected to B-minus in this modification of a power supply may be biased by cathode resistors, by the grid-leak method, or by an agc system. Plates and screens requiring less than maximum B+ potential would be supplied through voltage dropping or decoupling resistors.

Fig. 3 shows the principle of still another modification of our original power supply. Now we have two full-wave rectifiers. One rectifier operates at a high B+ voltage, usually at something around 350 volts. The other rectifier operates at a relatively low B+ voltage, say around 200 volts. All plate and screen circuits requiring high positive voltages are connected to the filter on the first rectifier, while all those requiring relatively low voltages are connected to the filter on the second rectifier.

The plates of both rectifiers are connected to the same secondary on the power transformer. Plates of the high-voltage rectifier are connected to the outer ends of the secondary, between which is the full number of turns on the entire winding. This provides maximum secondary voltage for the high-voltage rectifier.

Plates of the low-voltage rectifier are connected to secondary taps between which are only part of the total turns of this winding. Fewer active secondary turns mean a lesser step-up ratio from primary to secondary, and we have the lower voltage needed for plates of the second rectifier. A single secondary center tap, shown connected to chassis ground, serves for both rectifier systems.

There must be separate transformer windings for the filament-cathodes of the two rectifiers, because each filament-cathode winding will be at the positive d-c output potential of its respective rectifier, and these potentials are very different. Each rectifier feeds into its own filter system. Filters for either or both rectifiers may use either chokes or resistors, or one filter may have a

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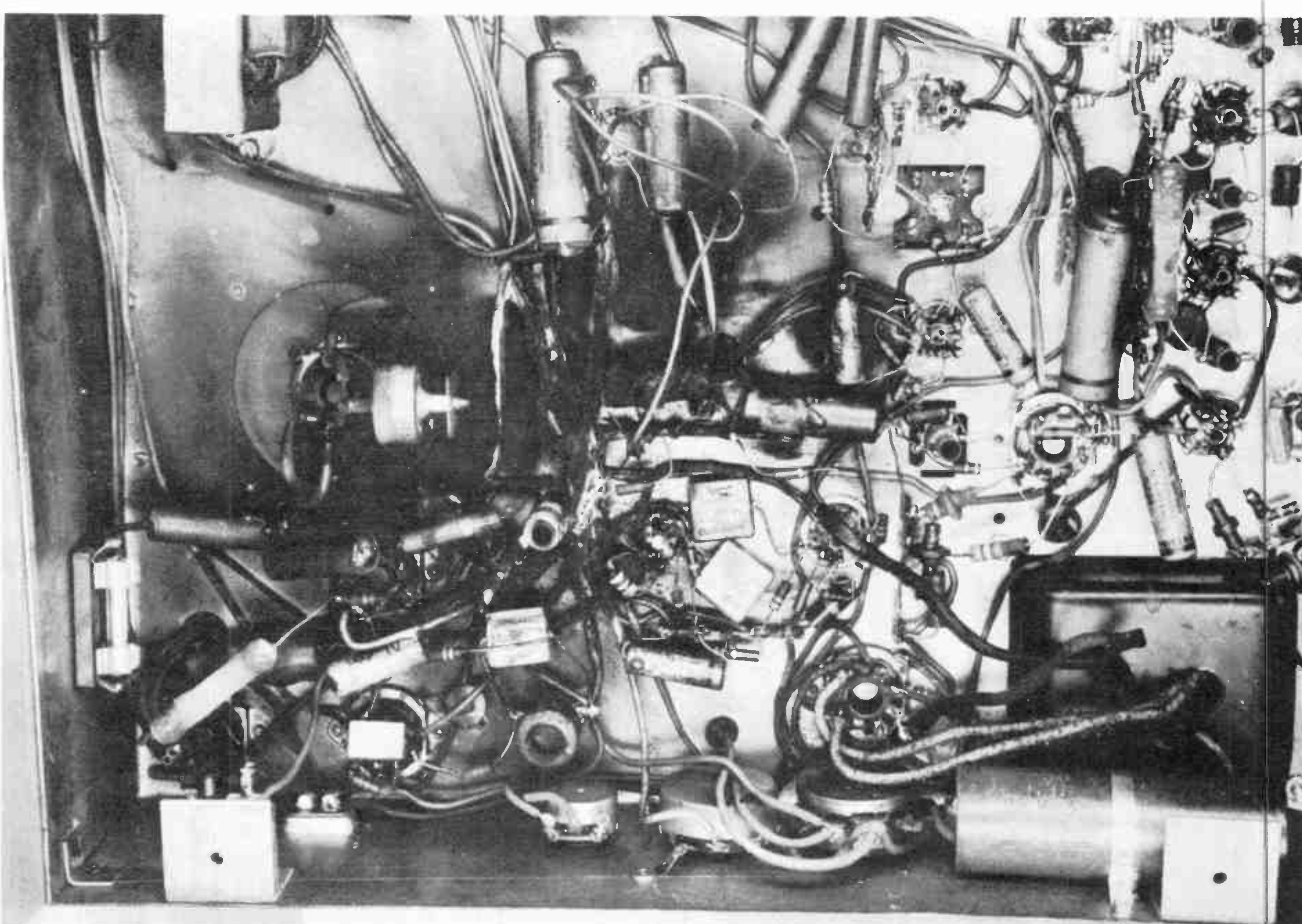

Fig. 1. This is the result of a short circuit. The owner squirted the contents of a fire extinguisher through the back of the cabinet, but it did no good - the fire was under the chassis.

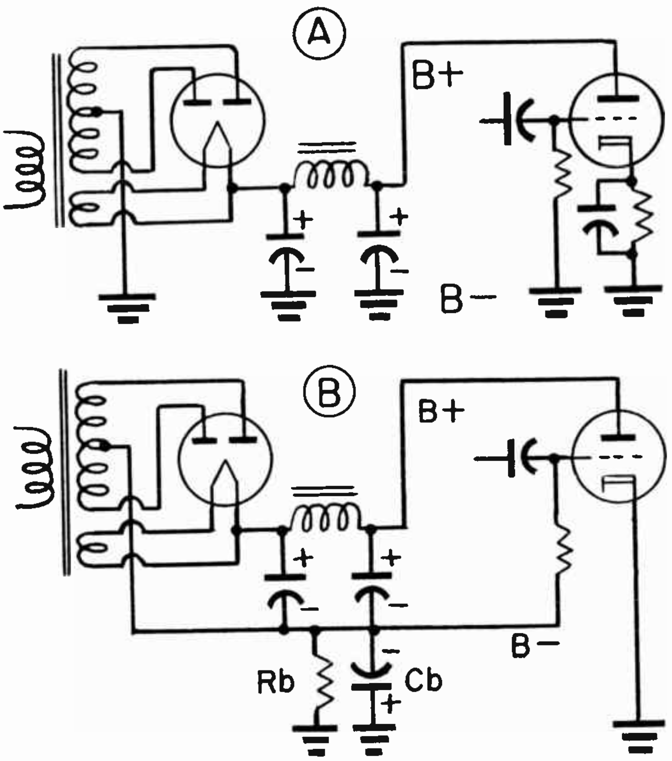

Fig. 2. Power supplies with chassis ground at B-minus potential or only slightly more positive than B-minus.

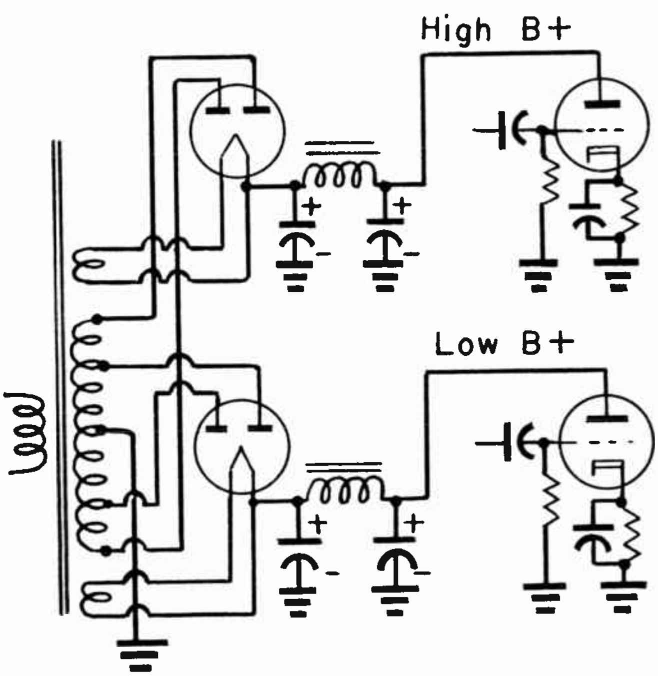

Fig. 3. A power supply employing two rectifiers operating at different voltages.

choke and the other a resistor, or there may be any combination of chokes and resistors.

Grid biasing methods for tubes connected to each rectifier system of Fig. 3 may be any of those which would be used with the single-rectifier power supplies of Fig. 2. One rectifier-filter system of Fig. 3, or both of them for that matter, might provide a negative biasing voltage such as shown at B in Fig. 2.

SERIES PLATE-CATHODE SYSTEMS. With all the power supplies which we have just examined, cathodes and grids of amplifiers and other tubes are at chassis ground potential, or normally at no more than ten to twenty volts either positive or negative with reference to ground.

Supposing, while checking B-voltages in a receiver which operates normally, you find cathodes and grids at potentials of a hundred and more volts positive with reference to chassis ground. This means that you are working on a set having plates and cathodes in series.

The elementary principle of operating tubes with plates and cathodes in series is illustrated by Fig. 4. Looking only at the power supply and triode tube 1, the arrangement is exactly the same as at A of Fig. 2, with the single triode representing any number of triodes, pentodes, and other loads.

Merely for illustration we shall assume that potential to ground at the output of the power supply filter is 350 volts. Then all loads represented by tube 1 would operate at a maximum of 350 positive volts, with dropping and decoupling resistors where needed to reduce this voltage.

But tubes requiring maximum B-potential differences of 200 volts or less would be connected with their plates and cathodes in series, as are tubes 2 and 3 of Fig. 4. Say, for example, that tube 2 is a type in which voltage drop from plate to cathode is 150 volts when operated with some certain grid bias. With the plate of this tube at 350 volts positive to ground, its cathode will be 150 volts less positive, and will be 200 volts positive to ground.

The 200-volt positive potential at the cathode of tube 2 becomes plate supply vol-

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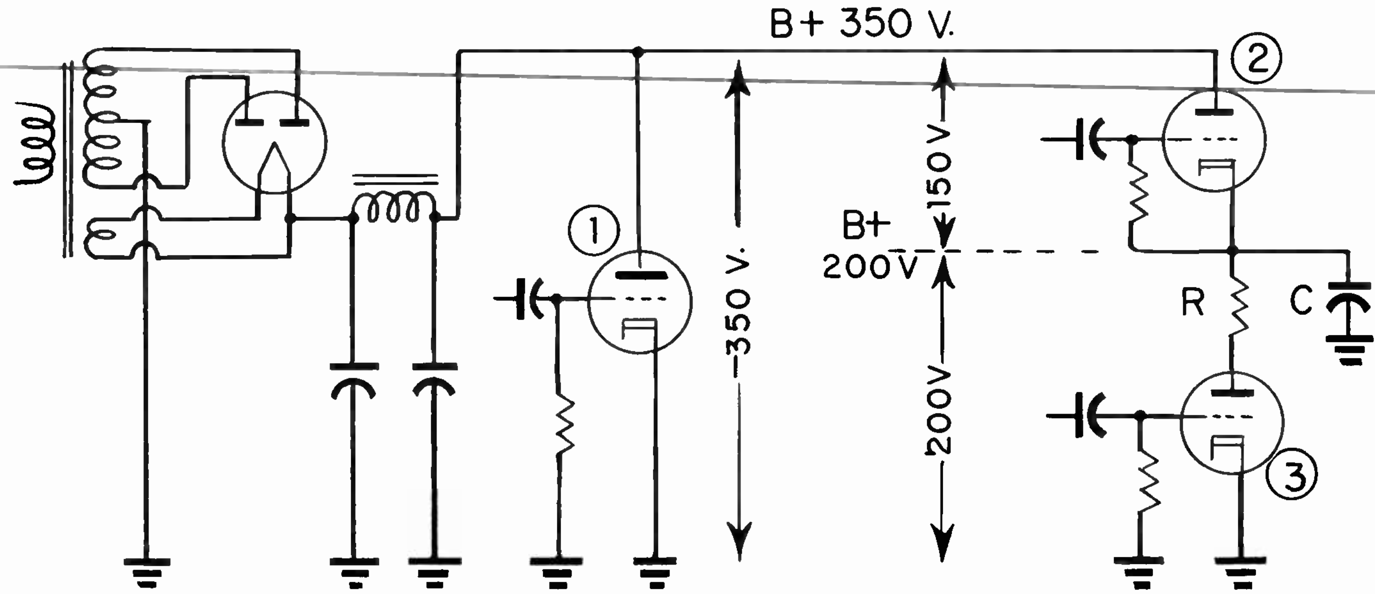

Fig. 4. A d-c power supply system with which plates and cathodes of some receiver tubes are in series.

tage for tube 3. This plate supply voltage must be filtered to get rid of all signal variations existing at the cathode of tube 2. For filtering, or decoupling, we connect a large capacitance at C. To complete the filtering action it is necessary that a dropping resistor or some other impedance be used at R, between the cathode of tube 2 and the plate of tube 3.

The grid of tube 2 must be biased with reference to its cathode, which means that the grid will be somewhat more negative than the cathode. But because the cathode of this tube is highly positive with reference to ground, its grid will be highly positive to ground, although not so positive as the cathode. The grid of tube 3 may be biased with reference to its cathode and ground in any of the usual ways.

Now let's look at a practical application of the series plate-cathode principle, as shown for a particular receiver by Fig. 5. Only B-plus and B-minus connections are on this diagram. Signal circuits and most of the grid biasing connections are omitted for the sake of simplicity. The power supply, at the lower left, is similar to that in diagram A of Fig. 2, with chassis grounds at B-minus potential. Leads carrying maximum B+ potential, 350 volts are drawn with single lines. The intermediate B+ potential, assumed to be 200 volts, is carried by leads drawn with double lines.

The 350-volt lead goes to the following tube elements:

Second i-f amplifier plate.
Horizontal sweep amplifier screen.
4.5-mc sound amplifier plate and screen.
A-f voltage amplifier plate.
A-f output amplifier plate and screen.

In addition, at the right-hand end of the lower 350-volt lead there is a connection to horizontal deflecting circuits which include the yoke coils, damper circuit, and secondary of the horizontal output transformer. Part of the current through this connection is that which flows in the boosted-B circuit of the flyback power supply. Current in the boosted-B circuit comes through the vertical oscillator and amplifier, both plates of the horizontal multivibrator oscillator, and the plate of the horizontal sweep amplifier.

Now look at the cathode connections of tubes in the sound section, at the top of the diagram. All three cathodes are connected to the 200-volt lead. The drop through the circuits of the three tubes in this section, from plates and screens to cathodes, is the difference between 350 volts and 200 volts.

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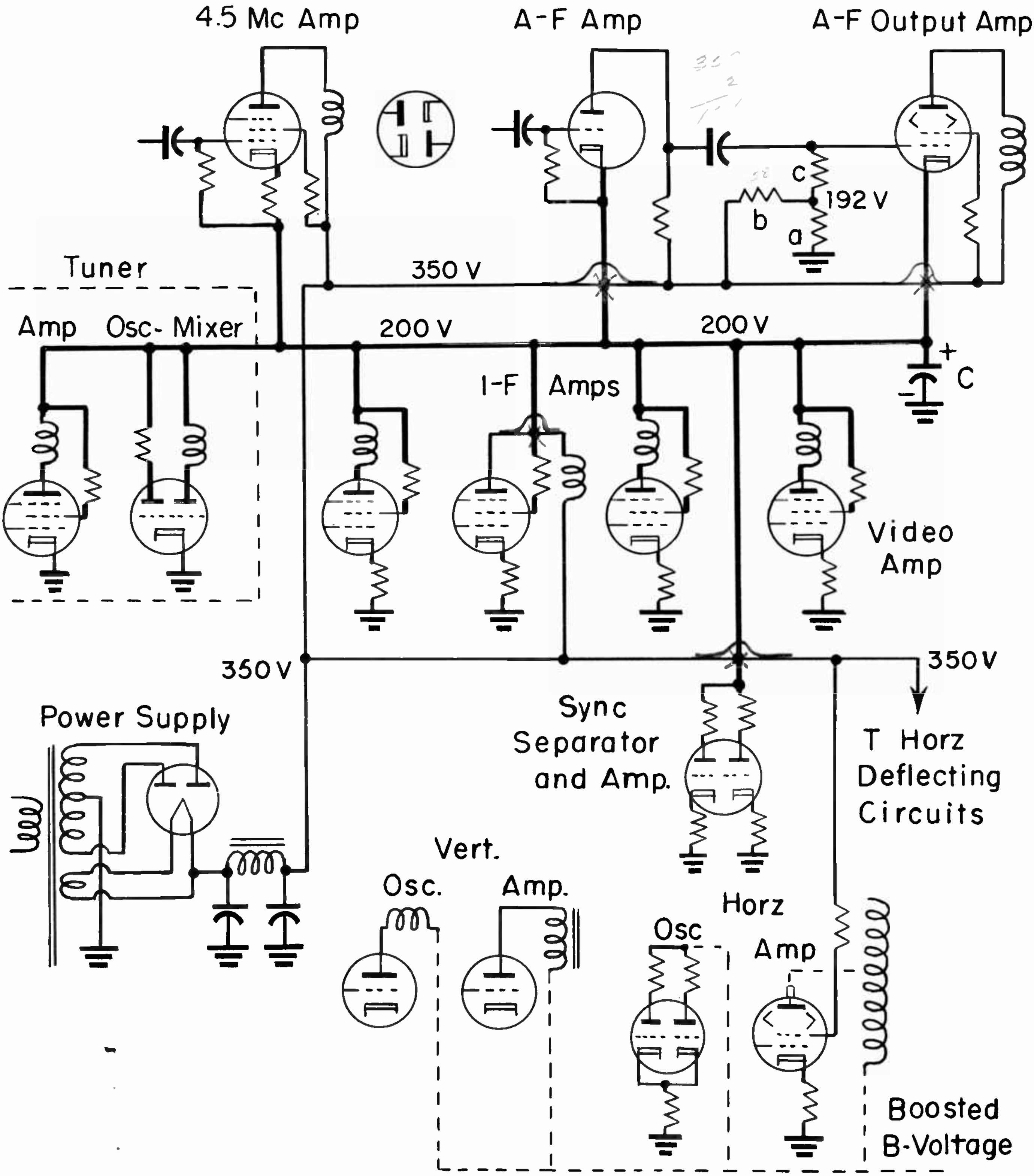

Fig. 5. A practical application of the series plate-cathode system to a television receiver.

All current flowing to the three cathodes must come from the 200-volt lead.

From where does the 200-volt lead obtain the current flowing to the three cathodes of the sound section tubes? Here are the sources of this current:

Plate and screen of r-f amplifier, in tuner.

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Plates of dual-triode oscillator and mixer in the tuner.
Plate and screen of first i-f amplifier.
Screen of second i-f amplifier.
Screen of second i-f amplifier.
Plate and screen of third i-f amplifier.
Plate and screen of video amplifier.

The sum of all plate and screen currents flowing into the 200-volt lead from tubes just listed must equal the sum of all currents flowing from this lead to the cathodes of tubes in the sound section.

Currents from i-f and r-f amplifiers do not remain absolutely constant, because of agc action on different channels or signals. Under certain operating conditions these currents were measured as follows:

R-f amplifier, oscillator, and mixer. The tuner section of the receiver.	17.0 ma
I-f amplifiers, with only screen current from one of them.	16.5 ma
Video amplifier	9.5ma
Total current into 200-volt lead.	43.0 ma

Cathode currents flowing out of the 200 volt lead measured very close to these values:

To a-f output tube, a beam power type.	34 ma
To a-f voltage amplifier triode	1 ma
To 4.5-mc sound amplifier pentode.	8 ma
Total current out of 200-volt lead.	43.0 ma

The same current, of 43 ma, flows in both groups of tubes. Had these groups of tubes not been connected in series, the power supply would have had to deliver 43 ma to each of the groups, with voltage reductions obtained by means of dropping and decoupling resistors. The series arrangement allows using a power supply capable of delivering 43 ma less current than would be needed for the same receiver with all tubes across the maximum B-voltage. It is this reduction of direct current, and the accompanying reduction of watts of power lost in heat, that is the chief reason for using the series connection.

It is quite evident that any groups of tubes might be connected in series provided the totals of plate and screen currents and of cathode currents are equal or nearly equal in the two groups. When currents for the two series groups of tubes are not exactly equal, the group requiring the smaller total current is paralleled with a fixed resistor. The parallel resistance is of such value as to carry the difference between total currents for the groups of tubes, or to carry the extra current which must flow through the group of tubes requiring the greater of the two total currents.

Fig. 6 shows B-voltage and current connections for another receiver in which some of the plates and cathodes are in series. Again the leads for maximum B+ potential, this time 275 volts, are drawn with single lines, while those for the lower or intermediate B+ potential, 150 volts, are drawn with double lines. The 275-volt lead may be traced to plates and screens of various tubes, as in the preceding diagram.

In this new layout only two cathodes are connected to the 150-volt lead, the cathode of the a-f output amplifier and the cathode of the sync separator. Since the plate of the sync amplifier is connected to the same B+ lead, the effect of this twin-triode tube on total current distribution is so small as to be neglected for our present purposes. The a-f output amplifier is a beam power tube, type 6W4-GT, which draws more than 50 ma cathode current even when operated at only about 110 volts on plate and screen.

Tube elements which feed current into the 150-volt lead include plates of the 4.5-mc amplifier, of the oscillator, the mixer, and the first i-f amplifier, also screens of the 4.5-mc amplifier and of all the i-f amplifiers. The total of all these incoming currents must equal the current which flows to the cathode of the a-f output amplifier.

On both diagrams, Figs. 5 and 6, there is a large filter capacitor, C, connected from the lower B-voltage lead to ground. One or more of these filter capacitors are essential

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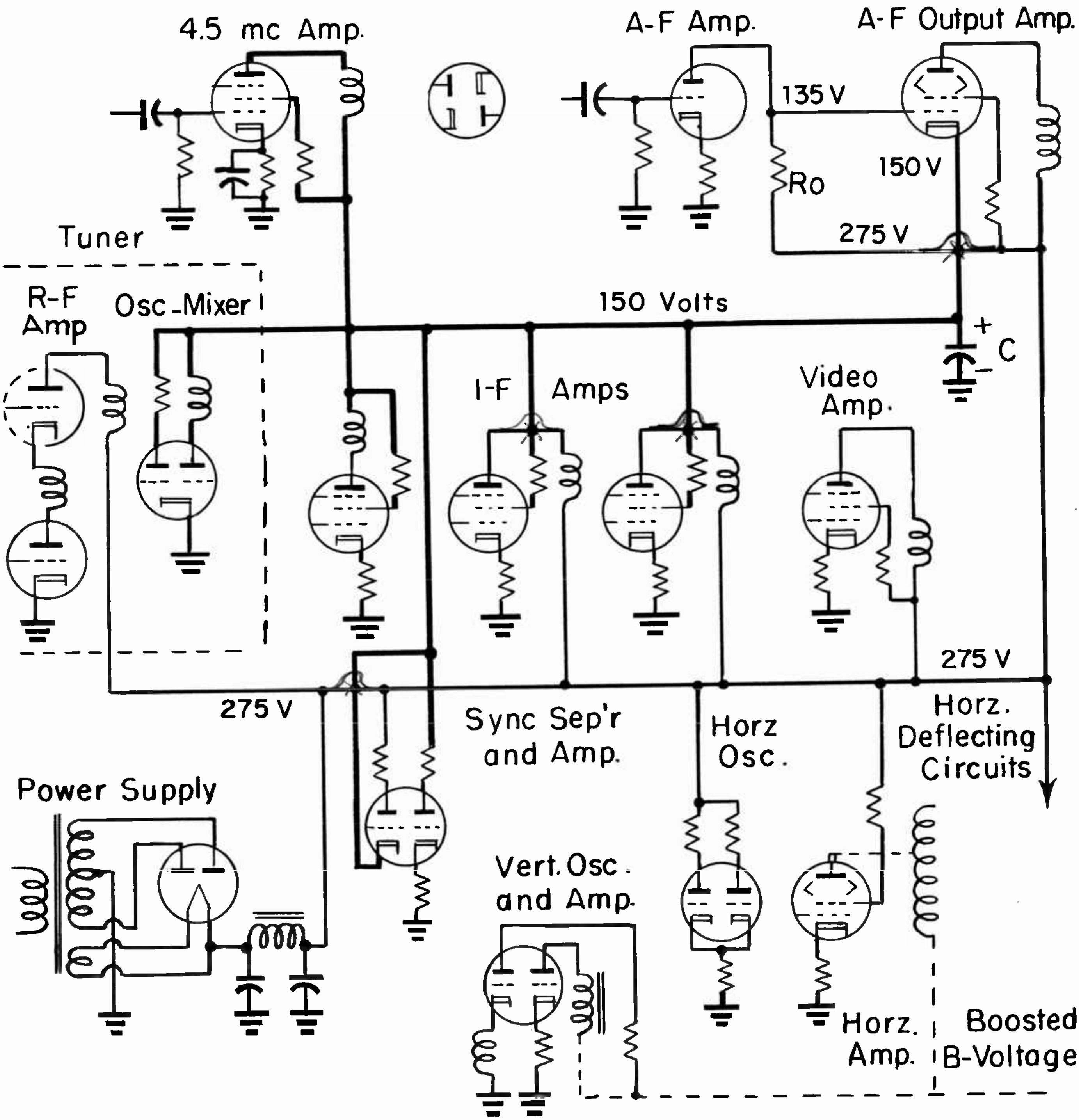

Fig. 6. A series plate-cathode system in which nearly all current for intermediate voltage lines is carried by the audio output amplifier tube.

on the lower or intermediate B-voltage lead of any series plate-cathode system.

Note, on Fig. 6, that two sections of the r-f amplifier are in series, with plate current from the lower section flowing to the cathode of the upper section. In other receivers you may find still other sections or other complete tubes in series. For example, plate current from the first i-f amplifier may flow to the cathode of the second i-f amplifier. Pairs of tubes or sections of twin tubes in series usually are connected between maximum B+ voltage and ground.

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Because cathodes and grids are highly positive to ground in tubes whose cathodes take current from the intermediate B+ lead, we find some unusual methods of biasing. In Fig. 5 the bias connections for the a-f output amplifier include resistors a, b, and c. Current from ground flows through a and b to the 350-volt lead. The drop in resistor b is such that potential to ground at the junction of a and b is 192 volts. That is, the drop across resistor b is the difference between 350 volts and 192 volts, or is 158 volts.

The grid of the a-f output amplifier is connected through resistor c to the junction between resistors a and b, where potential to ground is 192 volts. The cathode of this tube is directly connected to the 200-volt lead, making the cathode potential to ground 200 volts. Thus we find that the grid return and the grid itself are connected to a point which is 8 volts less positive than the cathode, which is the equivalent of an 8-volt negative bias for the grid, with reference to the cathode.

A different method is used for biasing the grid of the a-f output amplifier in Fig. 6. The grid of the output amplifier is directly connected to the plate of the a-f voltage amplifier, and these two elements are connected through load resistor Ro to the 275-volt lead. Drop in resistor Ro is 140 volts. This brings potential to ground down to 135 volts at the plate of the a-f voltage amplifier and the grid of the output amplifier. The cathode of the output amplifier is directly connected to the 150-volt lead. Thus the grid of the output amplifier is 15 volts less positive than the cathode of this tube, and there is the equivalent of a 15-volt negative bias on the grid.

In both Fig. 5 and Fig. 6 the 4-5 mc sound amplifiers operate with cathode bias, while the a-f voltage amplifiers operate with grid-leak bias.

In any series plate-cathode system a large total current passes from plates and screens of many tubes into the intermediate B+ lead, which is the 200-volt lead in Fig. 5 and the 150-volt lead in Fig. 6. This large total current must flow from the intermediate B+ lead to cathodes of other tubes. One of these other tubes taking its cathode current from the intermediate B+ lead practically always is the a-f output amplifier, and it may be the only such tube. This is because the a-f output amplifier always is a type which requires and carries large currents in its cathode and plate circuits.

How many tubes in addition to the a-f output amplifier take their cathode currents from the intermediate B+ lead depends on the total current to be thus handled. This total current depends, in turn, on what tubes feed their plate and screen currents into the lead. In Fig. 5 the intermediate B+ lead receives plate and screen currents from a total of six tubes in the tuner, i-f amplifier, and video amplifier sections. This total current goes to the cathodes of three tubes in the sound section.

In Fig. 6 the intermediate B+ lead receives current from four tubes in the tuner and i-f amplifier sections, and from one tube in the sound section. The total current goes to the cathode of only the a-f output amplifier. In different receivers employing the series plate-cathode system you will find great variety in combinations of tubes which feed current into, and take current out of the intermediate B+ lead.

Because the a-f output amplifier in any series plate-cathode system carries most of the current from all tubes feeding onto the intermediate B+ lead, any serious trouble in this amplifier or its circuits is almost certain to affect performance of circuits from which plate or screen currents feed into the lead. Pictures might be absent due to lack of gain in the tuner, the i-f amplifier section, or the video amplifier. The lack of gain might be due to incorrect voltages for plates and screens in these sections. The real trouble might be a faulty a-f output amplifier, and replacement of this audio tube would restore picture reproduction.

INTERMEDIATE GROUNDS. While checking B-voltages in a television set it might seem somewhat puzzling, at first, to find plates and screens connected to chassis ground, and at zero voltage with reference to the chassis. In the same receiver you would find cathodes which are negative to chassis

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ground by 50 to 100 volts or more. There would be resistors positive at one end and negative at the other end, with reference to ground. All these things would be entirely normal in a set employing an intermediate ground on its low-voltage d-c power supply.

Fig. 7 illustrates the principle of a B-voltage system having an intermediate ground. We are assuming here a total d-c potential difference of 350 volts between the positive output of the power filter and the negative secondary center tap of the power transformer. Across this total potential difference are resistors Ra and Rb in series, with a connection from their junction to chassis ground.

The chassis ground connection must be at some potential intermediate between maximum positive and maximum negative potentials. For purposes of illustration we are assuming a drop of 200 volts across resistor Ra and a drop of 150 volts across Rb. Then, in this particular case, chassis ground will be 200 volts less positive than potential at the filter output, and will be 150 volts less negative than potential at the transformer center tap.

Since it is customary to consider chassis ground as of zero potential we have, with reference to ground, 200 positive volts at the filter output and on all leads connected to this output. Such leads are marked B+ 200v. With reference to ground we have 150 negative volts at the transformer center tap and on all leads connected to this tap. These leads are marked B- 150v.

The plate circuit of tube 1 in Fig. 7 is connected to B+ 200v, and its cathode circuit is connected to B- 150v. Therefore, the circuits for this tube operate from a total potential difference, positive to negative, of 350 volts. This single tube on our diagram represents any number of tubes and loads which are to operate on 350 volts.

The plate circuit of tube 2 is connected to B+ 200v, and its cathode circuit is connected to chassis ground. Therefore, the circuits for this tube operate from a potential difference of 200 volts. This one tube represents all loads which are to operate from 200 volts.

The plate circuit of tube 3 is connected to chassis ground, while its cathode circuit is connected to B- 150 volts. Since ground is 150 volts less negative than the B- 150v lead, ground is effectively 150 volts more positive than this lead. Then tube 3 is supplied with plate potential 150 volts more positive than its cathode potential, and operates on a

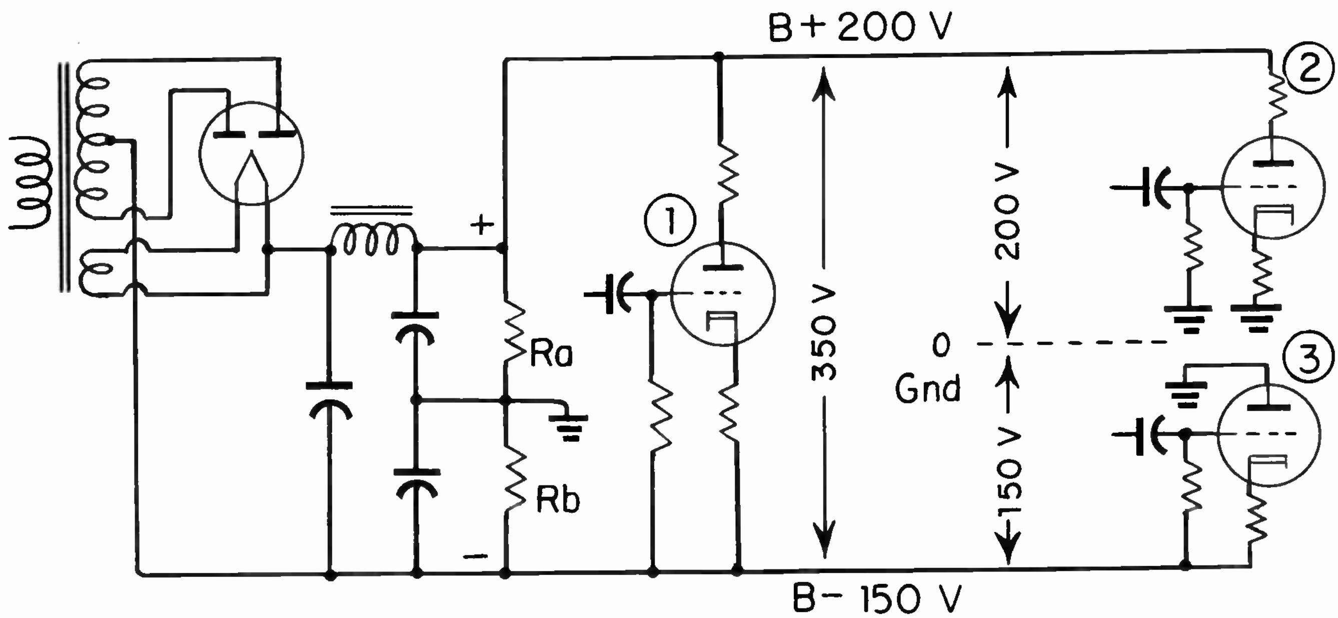

Fig. 7. The principle of a d-c power supply having chassis ground at a potential about half way between maximum positive and negative potentials.

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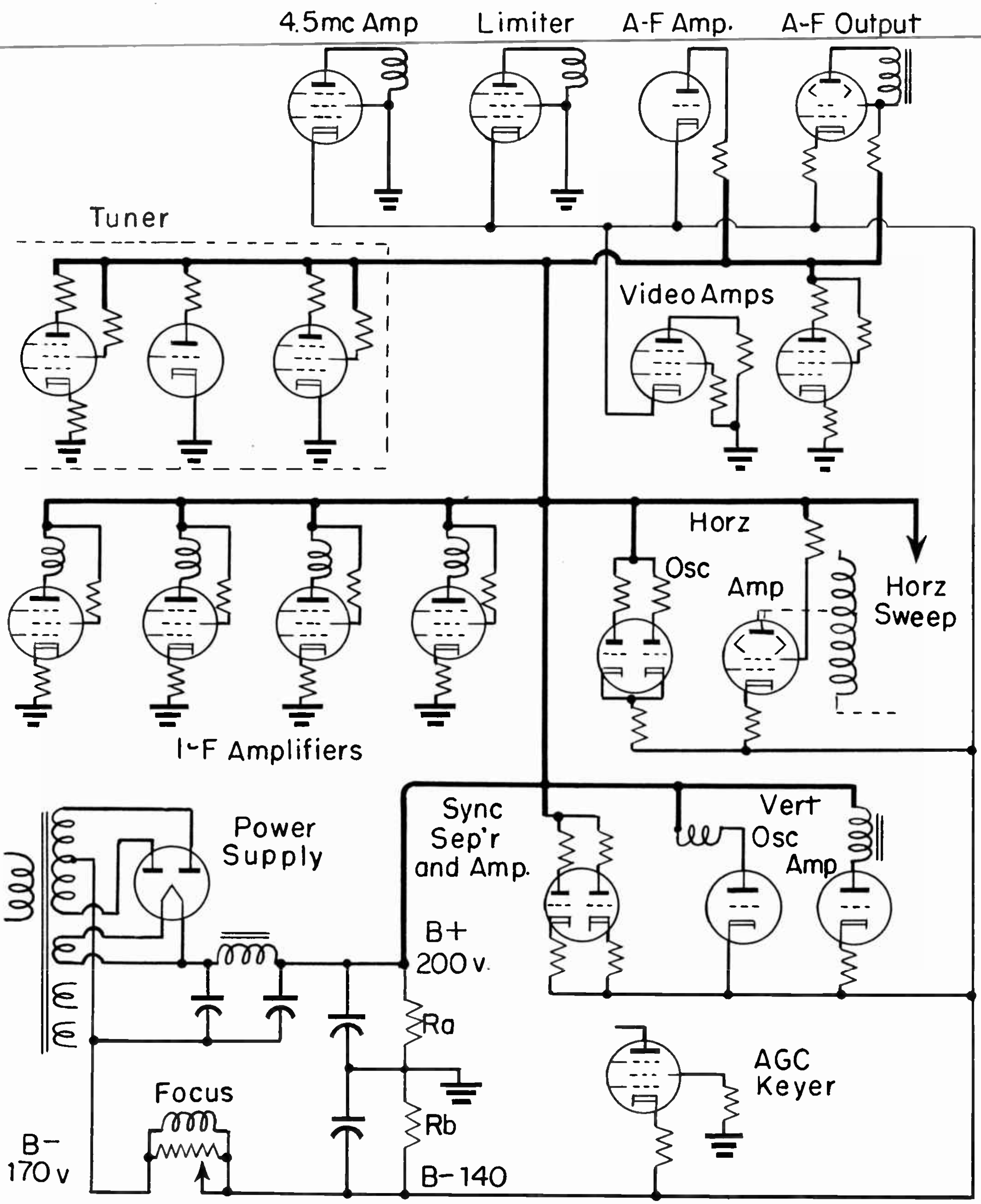

Fig. 8. A practical application of the intermediate ground on a d-c power supply as used with a television receiver.

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potential difference of 150 volts, plate to cathode.

Fig. 8 shows B-voltage connections for a practical application of the intermediate ground principle in a television set. The power supply furnishes a total d-c potential difference of 370 volts. There is a drop of 30 volts in the focus coil and control, leaving a difference of 340 volts for tube circuits. This difference is divided into 200 volts positive with reference to ground, and 140 volts negative with reference to ground.

You may trace the B+ 200v lead from the power supply to plate and screen circuits of various tubes whose cathode circuits connect either to the B- 140v lead or to chassis ground. Plate and screen circuits of some tubes connect to ground, with their cathodes to B- 140v. Make lists of tubes which operate from a B-supply of 340 volts, of tubes which operate from 200 volts, and of those which operate from 140 volts. Your lists should be as follows:

340 volts.
- A-f amplifier
- A-f output
- Horizontal oscillator
- Horizontal amplifier
- Sync separator and amplifier
- Vertical oscillator
- Vertical amplifier

200 volts.
- Three tubes in tuner
- Four i-f amplifiers
- Second video amplifier

140 volts
- 4.5-mc amplifier
- Limiter, in sound section
- First video amplifier
- Agc keyer tube

With power supply systems having intermediate grounds it is advisable and customary to run separate heater circuit wiring for all tubes whose cathodes connect directly or through biasing resistors to B-minus leads. As illustrated at the bottom of Fig. 9, this separate heater circuit has both sides run with insulated wires, neither side is grounded. The more common heater circuit, with one side grounded, is shown in the upper part of Fig. 9. Here the cathodes are connected directly or through biasing resistors to ground.

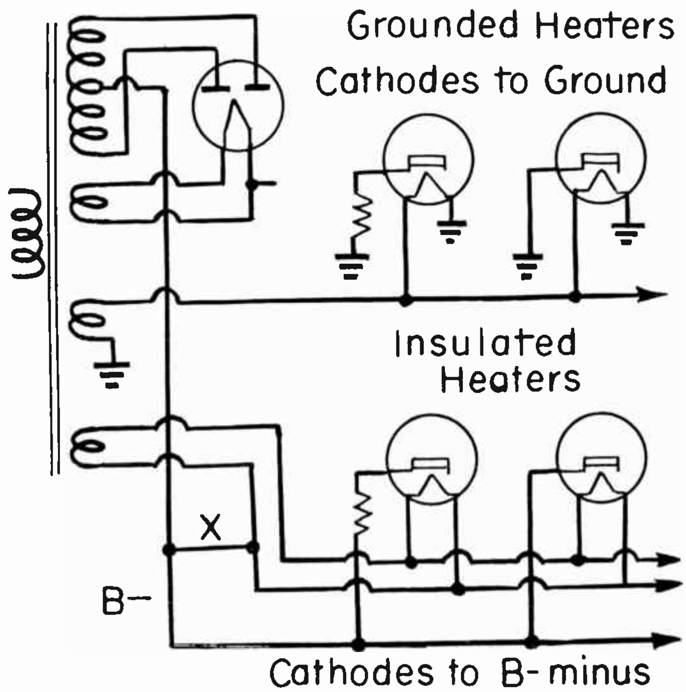

Fig. 9. An insulated heater circuit, with neither side grounded, ordinarily is used for some tubes connected to a power supply having an intermediate ground.

Were we to use a grounded heater circuit with cathodes connected to B-minus, the potential difference between cathodes and heaters would be practically the full B-minus voltage to ground. In the majority of cases this cathode-to-heater voltage would exceed the limits specified in tube ratings, and leakage might result. Furthermore, there would be increased tendency for cathode signal voltages to get into the heater circuit which is common to several tubes.

One side of the separate insulated heater circuit is connected to a B-minus lead, as shown at X of Fig. 9. Then the greatest potential difference between heater and cathode of any tube on this heater circuit will be the drop across a biasing resistor used between the cathode and the B-minus line.

Fig. 10 illustrates another general type of intermediate-ground power supply which has been used in many television receivers.

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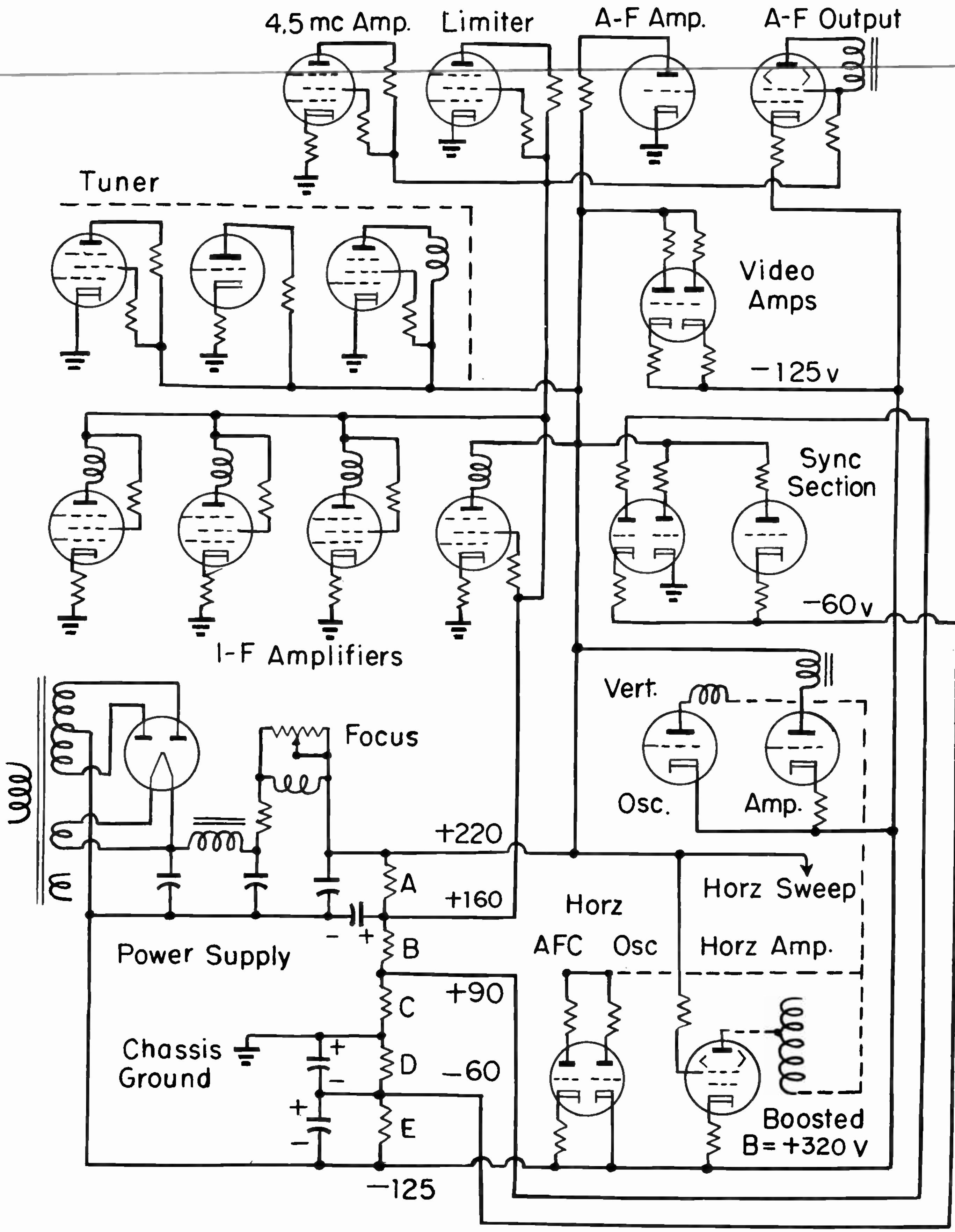

Fig. 10. A power supply of the intermediate ground type across whose output is a resistance voltage divider having many taps.

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Total d-c potential difference is 345 volts, from maximum positive at the output of the filter choke and focus coil to maximum negative at the secondary center tap of the power transformer. Between the maximum positive and negative potentials is connected a resistance type voltage divider consisting of resistors marked from A to E. The junction of resistors C and D is connected to chassis ground.

Chassis ground is considered to be at zero potential. Working from ground toward the maximum positive potential, we have first a drop of 90 volts across resistor C, and 90 volts positive to ground for the tap at the top of C. Across resistor B the drop is 70 volts, which, added to the drop across C, gives 160 positive volts to ground for the tap at the top of B. There is a drop of 60 volts across resistor A, which brings potential at the top of A to the maximum of 220 positive volts with reference to ground.

Proceeding from chassis ground toward maximum negative potential, there is first a drop of 60 volts across resistor D. Accordingly, there is potential of 60 negative volts at the tap just below D. Across resistor E the drop is 65 volts, which brings negative potential at the bottom of E to the maximum of 125 volts.

At the several taps or connections on the voltage divider we have available, with reference to ground, positive potentials of 220, 160, and 90 volts, and negative potentials of 60 and 125 volts. Leads from these taps and connections go to plate, screen, and cathode circuits of various tubes. In addition, there is a boosted-B potential of 320 positive volts with reference to ground.

Total potential difference applied to the circuits for any tube is, of course, the difference between positive potential applied to its plate and screen connections and a negative potential or the ground potential at its cathode connection. The receiver represented by Fig. 10 employs combinations of positive, negative, and ground potentials which provide seven different voltages for tube circuits. You should check all these voltages by tracing the leads on Fig. 10. Here is a list.

445 volts, boosted-B 320 volts to -125v
- Vertical oscillator
- Horizontal afc and oscillator tube

345 volts, +220v to -125v
- First and second sections of video amplifier.
- Vertical sweep amplifier
- Screen of horizontal sweep amplifier.

285 volts, +160v to -125v
- A-f output tube

280 volts, +220v to -60v
- Second tube in sync section

220 volts, +220v to ground
- A-f voltage amplifier
- Each of three tubes in tuner
- Plate of fourth i-f amplifier
- Second section of first sync tube

160 volts, +160v to ground
- 4.5-mc sound amplifier
- Sound limiter tube
- Each of first three i-f amplifiers
- Screen of fourth i-f amplifier

150 volts, +90v to -60v
- First section of first sync tube

Positive and negative potentials to ground from the voltage divider of Fig. 10 are fairly typical of common practice, but in other receivers you will find many other combinations which suit the tubes or their manner of operation. The sum of maximum positive and negative potentials always is the total d-c output potential from the power supply, neglecting any boosted B-voltage. Relative values of maximum positive and negative potentials depend on where the chassis ground connection is located in the voltage divider system.

When measuring B-supply voltages to plate and screen circuits where there is an intermediate ground, values may be misleading if you check with reference to chassis ground. For example, the plate supply for the video amplifiers of Fig. 10 would measure only 220 volts to ground, whereas total supply voltage from plates to cathodes is 345 volts.

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If you are in doubt as to the method of B-voltage distribution and its effects on potentials at tube elements, measure plate, screen, and grid voltages with reference to the cathode of the same tube. Should there be a great difference between these voltages and those measured from plate, screen, and grid to ground, you probably are working with a B-supply system having an intermediate ground or with one having series plate-cathode connections.

You should be able to determine the method of d-c power supply voltage distribution by measuring a few cathode potentials to ground, especially at cathodes of tubes in the sound and audio sections.

A. If cathode potentials are no more than 10 to 20 volts to ground, the power supply probably operates with negative ground or with a small biasing voltage, as in Figs. 2 and 3.

B. If some cathode potentials are 50 to 100 or more volts positive to ground, the power supply probably operates with the series plate-cathode method, as in Fig. 4.

C. If some cathodes are 50 to 100 or more volts negative to ground, the power supply probably has an intermediate ground, as in Figs. 7 and 10.

SELECTOR SWITCHES. In receivers which provide a choice between television, a-m radio, f-m radio, or phonograph reproduction the various "bands" are selected in nearly all cases by some form of rotary switch. Similar switches are used for channel selection in many TV tuners, also in service testing instruments for selection of functions and ranges. Connections through terminals and contacts of selector switches provide some of the problems in circuit tracing.

One style of rotary selector switch is pictured by Fig. 11. The three parts which carry terminals and contacts may be called sections, gangs, decks, or wafers. There may be anywhere from one to as many as twenty sections on a single switch. The large discs carrying terminals and contacts of the switch illustrated are made of steatite insulation. Consequently, this switch would be suitable for use in high-frequency circuits.

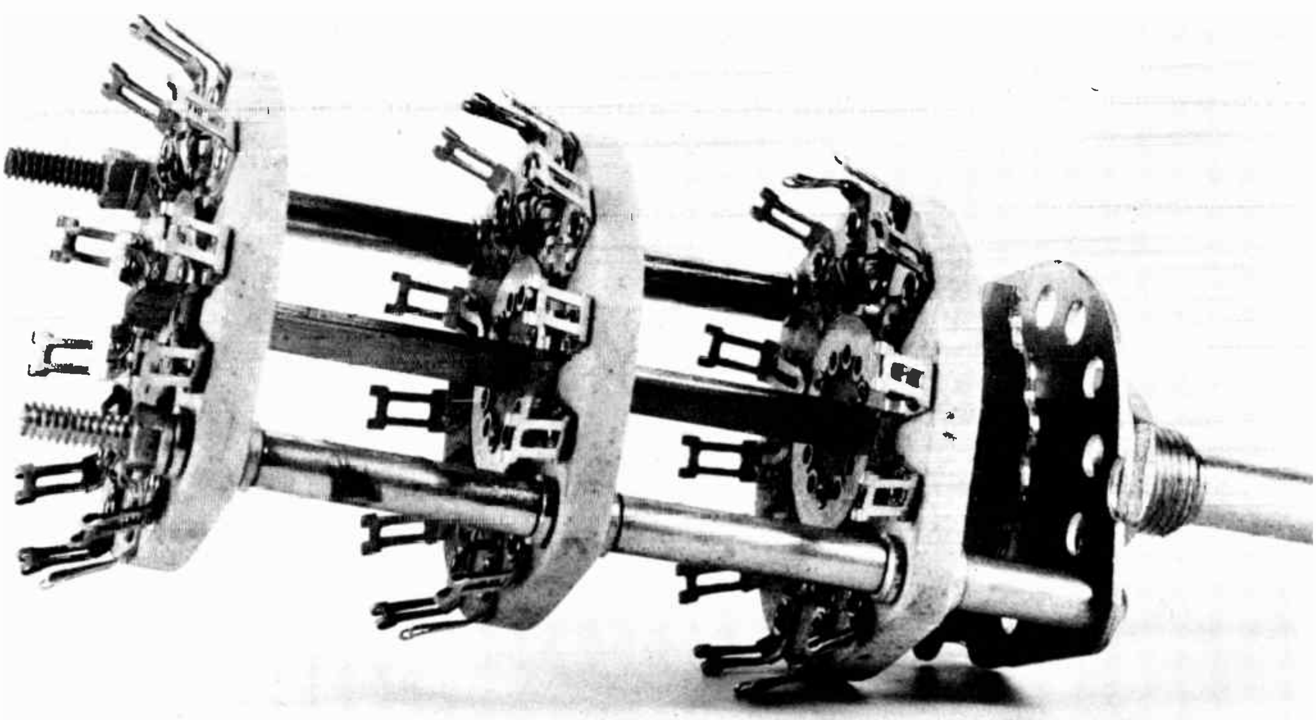

Fig. 11. A three-section rotary selector switch.

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A single-section rotary switch is shown by Fig. 12. This unit has a disc or wafer of phenolic composition, suitable for frequencies up to several megacycles.

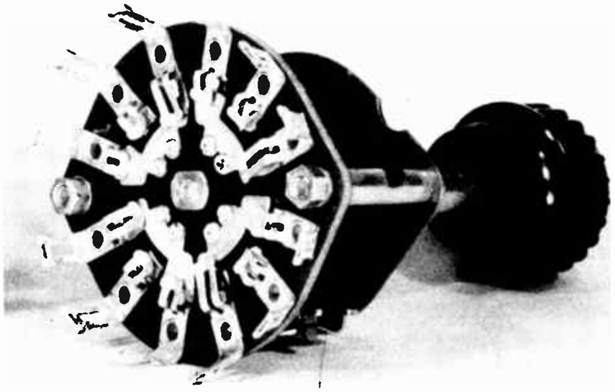

Fig. 12. A single-section rotary selector switch.

Solder lugs around the edge of each section in any rotary switch connect to or are in one piece with stationary contact points mounted on the disc or wafer and extending inward. Contacts usually are of silver-plated brass or bronze. Inside the contacts is a rotor on which are mounted one or more pieces of metal called segments. The segments, or tongues which extend outward from the segments, make electrical connections with the stationary contacts, singly or in various combinations.

All rotors of any one switch are turned together by a single shaft. This shaft passes through the center of each rotor and extends through the mounting at one end of the switch. On the outer end of the shaft is placed the knob or pointer which is turned by the operator.

Regular stock types of rotary selector switches often have sections such as shown by Fig. 13. In diagram A the rotor carries a single segment in the form of a continuous ring, at one point on which is an outward extension or tongue. All except one of the stationary contacts are short enough to clear the rotor segment, but long enough to be engaged by the extended tongue. The remaining contact, called the common, is long enough to engage the ring-shaped segment at all times, no matter how the rotor may be turned.

In diagram A the rotor is turned to a position at which there is electrical connection between the common terminal and terminal 3. The rotor might be turned to make connection between the common and any one of the other terminals. The switch section illustrated would be described as having one pole or one circuit, because there is only one rotor segment and one common terminal. This section is said to have eleven positions or throws, because the common may make connection through the rotor tongue with any one of eleven other terminals.

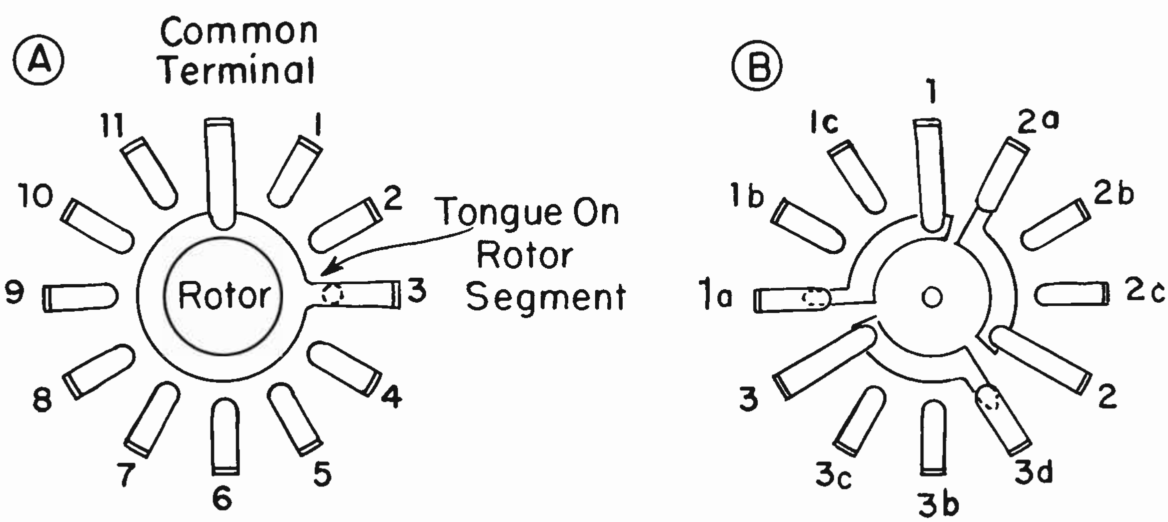

Fig. 13. How rotary switches make connections from common terminals to other terminals on any one section.

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In diagram B the rotor carries three separate segments, on each of which is an extended tongue. On each rotor segment rests a long contact from one of three common terminals marked 1, 2, and 3. With the rotor in the position shown, common 1 connects through one of the segments to terminal 1a, common 2 connects through another segment to terminal 2a, and common 3 connects through the third segment to terminal 3a.

Turning the rotor of diagram B one position or one-twelfth of the full circle would make connections from 1 to 1b, from 2 to 2b, and from 3 to 3b. Turning the rotor one more position clockwise would complete connections from 1 to 1c, from 2 to 2c, from 3 to 3c. By means of suitable mechanical stops the rotor movement is limited to these three positions. This is a three-pole or three-circuit section, because there are three rotor segments and three common terminals. It is also a three-position or three-throw section because each common may make connection with any one of three other terminals.

With the same total of twelve terminals around the switch section the rotor might carry two segments and there might be two commons, each of which would make connection with any of five other terminals. Then we would have a 2-pole 5-position section. There could be four rotor segments and four commons, each making connection with either of two other terminals. This would be a 4-pole 2-position section.

The sections or switches of Fig. 13 have rotor segment tongues and contacts so narrow that the tongues break contact at one terminal before engaging the next one. Because adjacent contacts never are short circuited on each other by the rotor segment tongue, these are called non-shorting sections or switches. In another general style of switch, called a shorting type, tongues on rotor segments are wide enough to remain on one contact while engaging an adjacent one. Which style of switch is used depends on requirements of controlled circuits.

Shafts of rotary switches nearly always are 1/4-inch in diameter. The shafts pass through mounting bushings with outside threads that pass through 3/8-inch diameter holes in panels or chasses. The mounting method is the same as described for potentiometers in the lesson on "Adjustable Resistors". Shafts are insulated from rotor segments, so switches may be mounted without insulating washers around the threaded bushings. Small pins or lips which extend from the bushing are intended to fit through small holes in panel or chassis metal to keep the entire switch from turning.

When the shaft and rotor or rotors are turned to a selected position they are held there by some form of ball or roller "detent" device which rides over and drops into notches or openings on the switch base. Sometimes the ball engages corrugations around the edge of a "star wheel" attached to the shaft. Pins or keys of various forms act as stops on switches whose rotor travel is to be limited.

Special rotary switches designed for particular receivers may have segments of many forms, and contacts only at some of the possible positions, as required for certain circuit connections. Such segments are shown by Fig. 14.

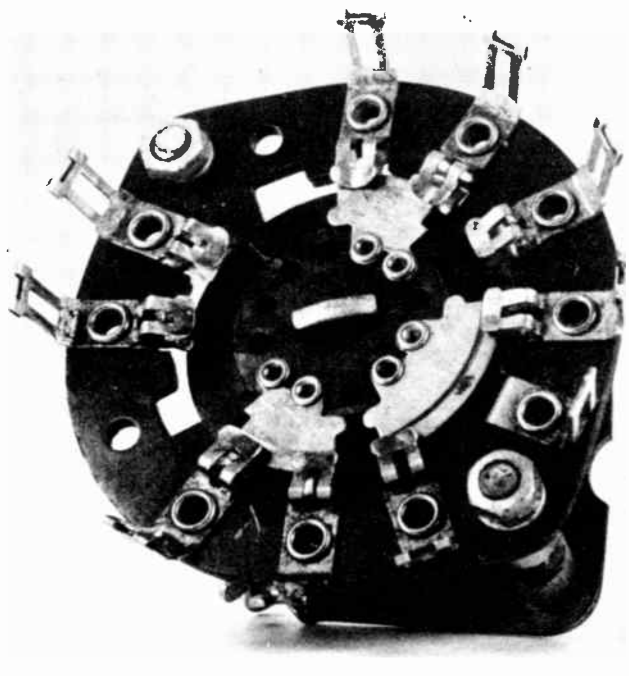

Fig. 14. A selector switch having segments of forms that suit one particular application. This is not a standard or stock type of switch.

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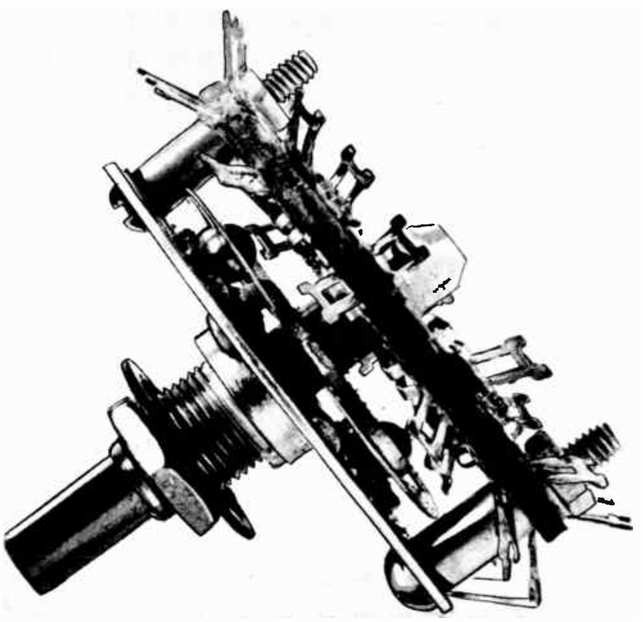

Fig. 15. The single rotor of this switch carries segments on both sides. Contacts are on both sides of the wafer.

Another kind of switch often used for special applications is shown by Fig. 15. Terminal lugs with attached contacts are on both sides of the insulating wafer. Segments are on both sides of the single rotor. Consequently, this switch or a similar section with only a single disc of insulation, may serve may of the purposes for which a two-section switch or one with two insulating discs and rotors otherwise might be used. Incidentally, the rotor segment and contacts toward the mounting end and supporting panel are referred to as the front of this switch or section, while the segment and contacts farther from the panel are referred to as the back.

Fig. 16 shows one method of using a 3-pole 2-position rotary switch for changing between television and phonograph reproduction. There are three rotor segments, also three common terminals and contacts, marked A, B, C. The tongue on each segment can engage only one or the other of two short contacts. Rotor travel is limited to two positions. At a third possible position there are no terminals or contacts. It is customary on service diagrams to show rotary switch contacts as arrows, and rotor segments in outline, as on this diagram.

The switch rotor and segments are shown in the television position. Trace the following connections and note how circuits are completed.

Common A to terminal A1. The grid of the a-f amplifier is connected through the

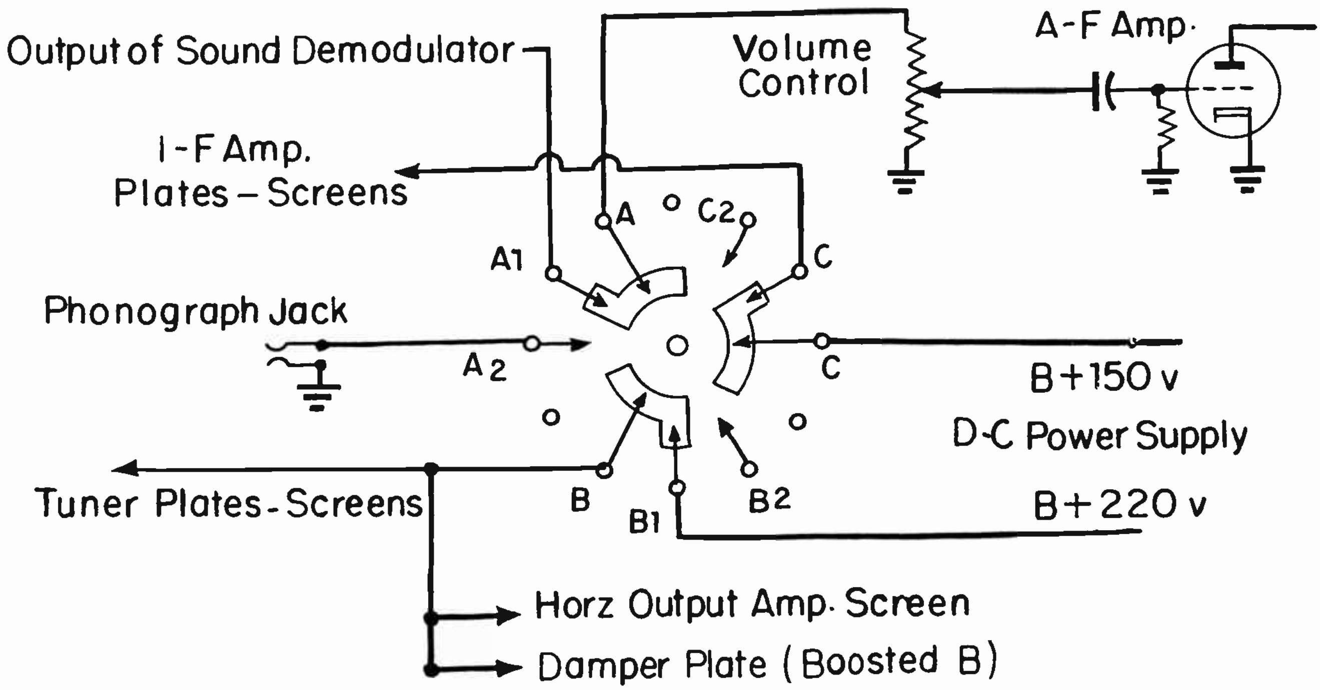

Fig. 16. Circuits for a television-phonograph selector switch.

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volume control to the output of the sound demodulator.

Common B to terminal B1. The B+ 220v line from the d-c power supply is connected to plates and screens of tubes in the tuner, also to the screen of the horizontal output amplifier and to the plate of the damper tube. This connection to the damper tube allows production of boosted B-voltage for vertical and horizontal sweep sections.

Common C to terminal C1. The B+ 150v line from the d-c power supply is connected to plates and screens of the i-f amplifier tubes.

With the switch in this position, all tubes necessary for television reproduction are in operation and the sound demodulator is connected to the a-f amplifier. Rotating the switch one-twelfth turn counter-clockwise brings it to the position for phonograph reproduction. Trace the following connections.

Common A to terminal A2. The grid of the a-f amplifier now is connected through the volume control to the phonograph jack. Into this jack fits a shielded lead from the pickup of a record player. The TV sound demodulator is disconnected.

Common B to terminal B2. Terminal B2 is open, no wire is connected to it. Consequently, B+ voltage and current are cut off from plates and screens of tubes in the tuner, from the screen of the horizontal output amplifier, and from the plate of the damper. Now there can be no television reception through the tuner. The horizontal output amplifier is dead, which means no horizontal sweep, and no high-voltage for the second anode of the picture tube. The damper circuit is dead, which stops boosted B-voltage to cut off the horizontal and vertical sweep oscillators and amplifiers.

Common C to terminal C2. Terminal C2 is open. B+ voltage and current are cut off from tubes in the i-f amplifier.

Fig. 17 shows band switching connections for a receiver providing a choice between television, phonograph, f-m radio, and a-m radio. The fm-am radio portion of the set includes its own separate tuner, combination fm-am i-f amplifier, f-m ratio detector, and a-m diode detector. The a-m diode detector consists of the cathode and grid (acting as a diode plate) in a pentode from which plate voltage may be removed.

The television sound section includes the usual 4.5-mc amplifier followed by a ratio detector. The a-f voltage amplifier and a-f output amplifier are used for all sources of audio signals.

The selector switch consists of two sections. Terminals are numbered 1 to 7 on one section, and lettered a to g on the other section. This unit might be a two-section switch with separate rotors on one shaft, or it might be the front and back of a single disc or wafer. Fig. 17 shows the switch segments in their positions for television reproduction. The segments are of special shapes designed for this particular application.

So far as the selector switch connections are concerned we have three sources of audio signals: (1) Output from the television sound ratio detector. (2) A phonograph pickup which here is built into the combination receiver. (3) Output from either the f-m ratio detector or from the a-m diode detector. These radio outputs are selected by a separate switch, which would be part of another selector switch controlling the fm-am tuner and i-f circuits.

Any one of the three sources of audio signals may be connected through the switch of Fig. 17 to the a-f amplifier.

Certain of our selector switch connections control B+ voltage and current for the 4.5-mc TV sound amplifier and the tubes in the TV tuner, also B+ voltage and current for the combined a-m detector and f-m i-f amplifier tube.

Trace the following circuit connections for television reproduction.

1. TV sound detector. To TV volume control. From control slider to terminal d, through a segment to terminal g and to grid of a-f amplifier. Note that line from terminal

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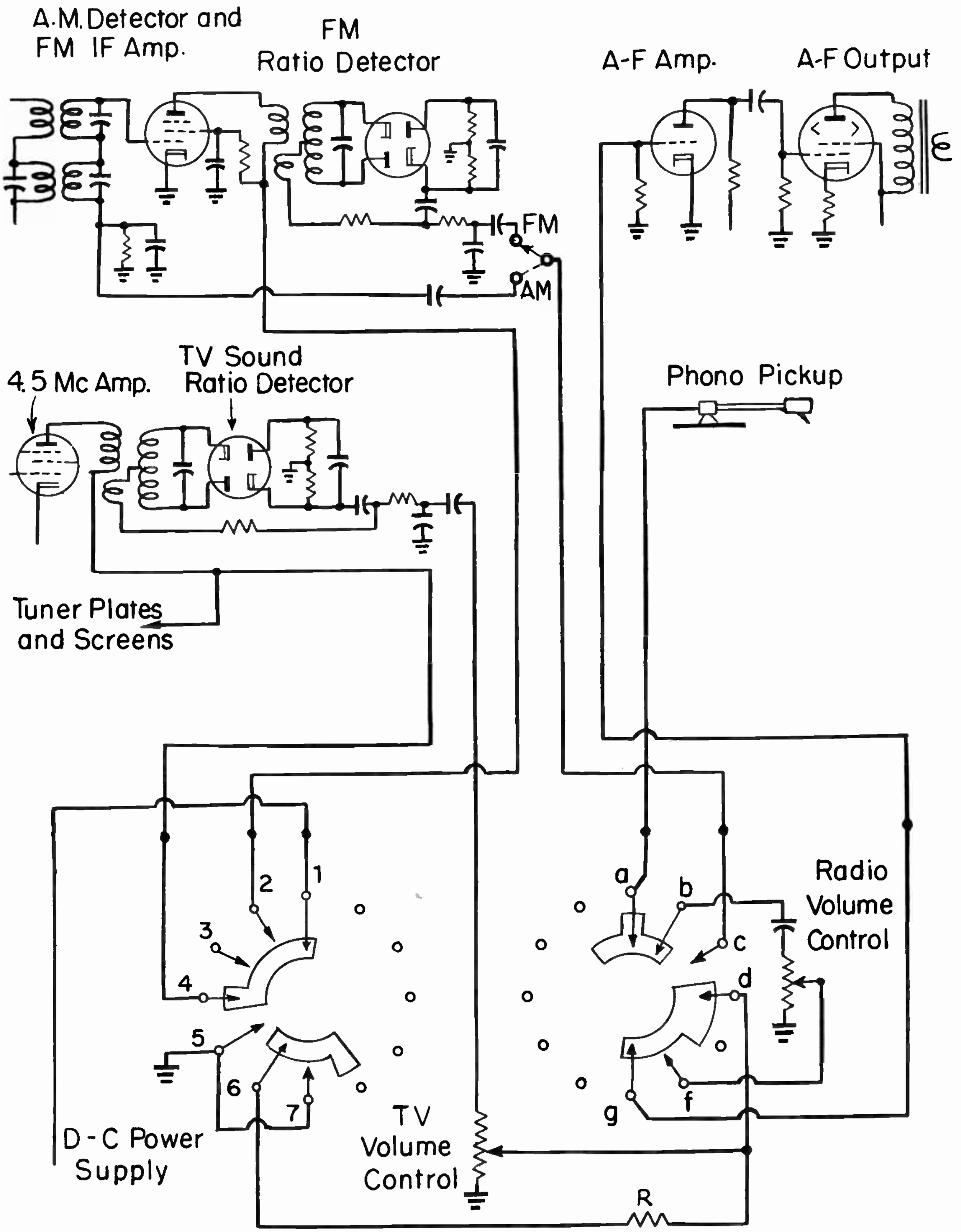

Fig. 17. Selector switch connections in the television positions for a combination receiver providing TV-Phono-AM-FM reproduction.

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d through resistor at R to terminal 6 is open from the segment in contact with 6.

2. Phono pickup. To terminal a, through segment to terminal b and radio volume control. Volume control slider connection is open at terminal f.

3. FM-AM detectors. Open circuited at terminal c.

4. TV tuner and 4.5-mc sound amplifier. To terminal 4, through segment to terminal 1, thence to d-c power supply for B+ voltage and current for plates and screens of these tubes.

5. FM amplifier plate-screen. Open circuited at terminal 2.

These connections place the TV sound section in operation, feed its output to the a-f amplifier, and prevent audio signal production reaching the a-f amplifier from either the radio sound section or the phonograph pickup.

For phonograph reproduction the selector switch is rotated one-twelfth turn clockwise, bringing rotor segments to positions shown by Fig. 18. Except for changed positions and connections from the segments this diagram is like the lower part of Fig. 17, and might be put in place of the lower part of that earlier diagram.

Trace the following circuit connections for phonograph reproduction.

1. TV sound detector. To TV volume control. The slider connection of this control is open circuited at terminal d and is grounded through high resistance at R and through terminal 6, a segment, and terminal 5.

2. Phono pickup. To terminal a, through a segment to terminal b and radio volume control. From slider of this control to terminal f, through a segment to terminal g and to grid of a-f amplifier.

3. FM-AM detectors. Open circuited at terminal c.

4. TV tuner and 4.5-mc sound amplifier. Plate and screen lines for these tubes are open circuited at terminal 4.

5. FM amplifier plate-screen. Open circuited at terminal 2.

Now we have the phono pickup connected to the audio volume control and grid of the

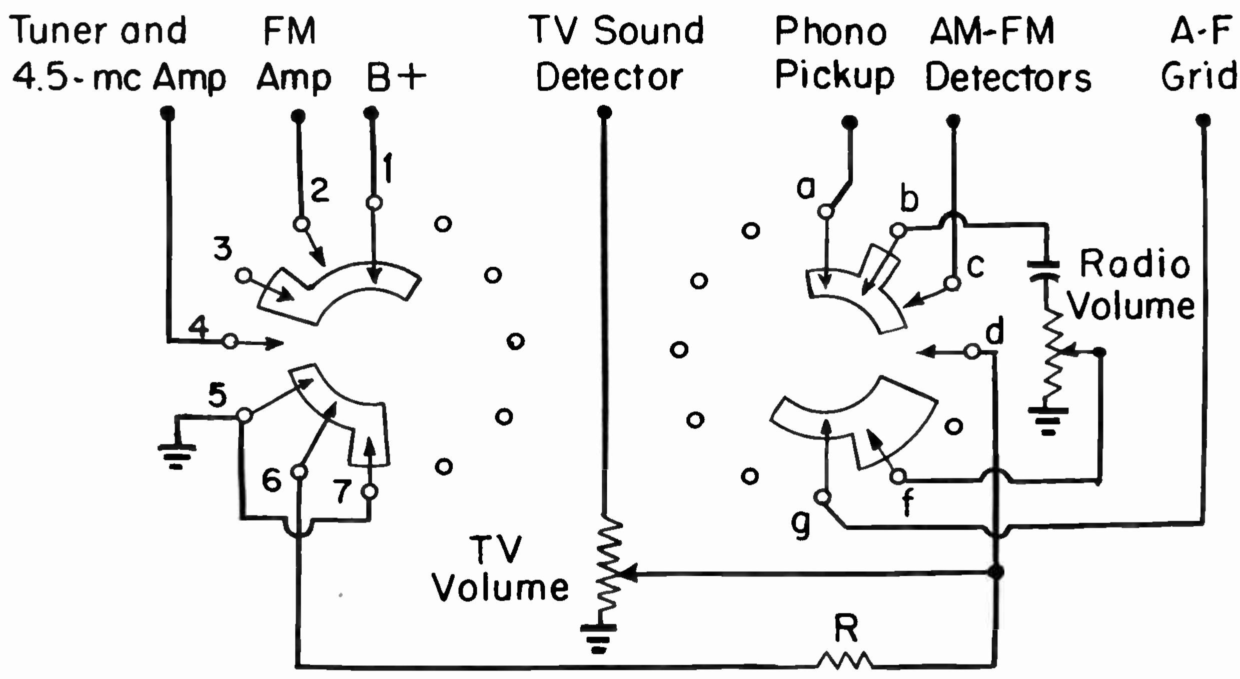

Fig. 18. Switch segments are here in their positions for phonograph reproduction.

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a-f amplifier. No other audio signals reach the a-f amplifier grid because both TV sound output and FM-AM sound output are open circuited.

Rotating the switch another twelfth turn brings the segments to the positions of Fig. 19 and completes circuit connections for a-m or f-m radio reproduction by means of the a-f amplifier. This diagram might be put in place of the lower part of Fig. 17, since only the segment positions are changed.

Trace the following circuits for radio reproduction.

1. TV sound detector. To TV volume control. From slider of this control to an open circuit at terminal d, also through high resistance at R to ground through terminal 6, a segment, and terminal 5.

2. Phono pickup. Open circuited at terminal a.

3. FM-AM detectors. To terminal c, through segment and terminal b to radio volume control. From slider of this control to terminal f, through a segment to terminal g, and to grid of a-f amplifier.

4. TV tuner and 4.5-mc amplifier. Open circuited at terminal 4.

5. FM amplifier plate-screen. To terminal 2, through segment to terminal 1 and to d-c power supply for B+ voltage and current. This places the f-m amplifier in operation for reception of f-m sound broadcast.

In this last position of the selector switch we have the output of the fm-am detectors feeding to the audio volume control and grid of the a-f amplifier. No audio signals come to the a-f amplifier from the phono pickup, which is open circuited, nor from the output of the TV sound detector, which is open circuited and grounded.

The accompanying table summarizes circuit connections for each of the three positions of the selector switch.

In the diagrams of Figs. 17, 18, and 19 both sections of the switch turn in the same direction, clockwise, in going from television to phono to radio reproduction. On a regular service diagram this probably would indicate that the switch has two separate rotors, each carrying its own segments and contacts. It indicates two separate rotors because, when looking at either the front or back of two ro-

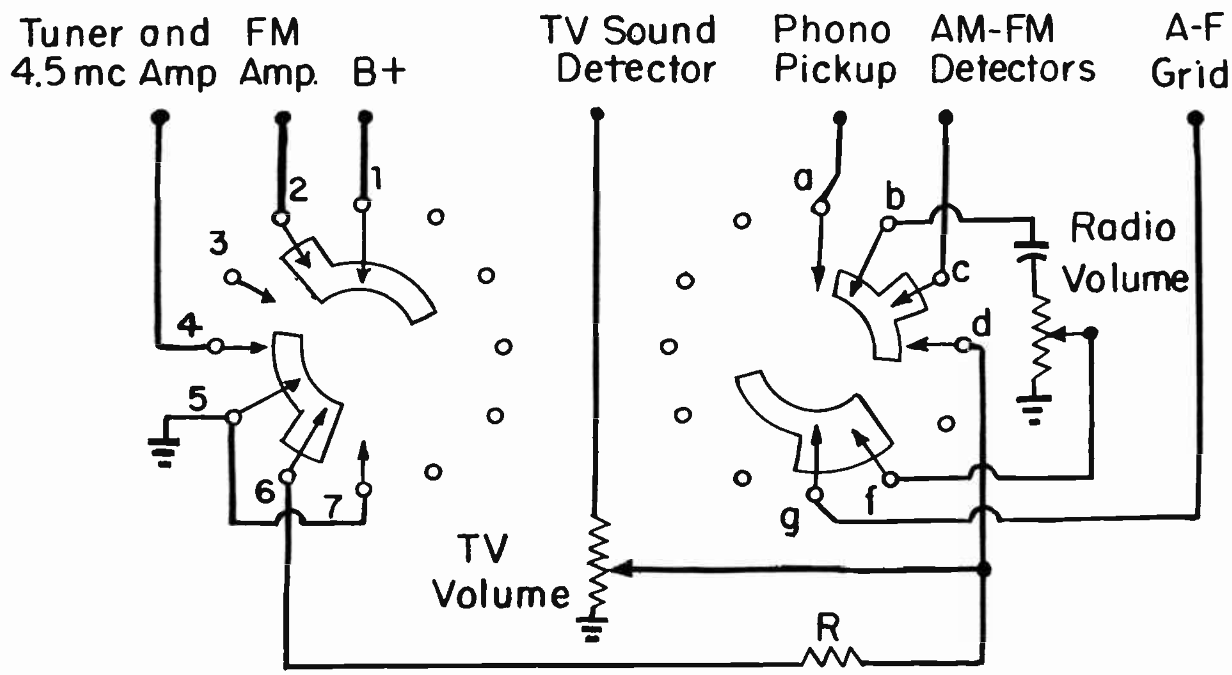

Fig. 19. Switch segments are now in their positions for radio reproduction.

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SWITCH POSITION	SOURCES OF AUDIO SIGNALS			PLATES AND SCREENS	
	TV Sound Detector	FM-AM Detectors	Phono Pickup	TV Tuner And 4.5-mc Amp	FM I-f Amplifier
TELEVISION	A-f grid	Open	Open	B+ power	Open
PHONOGRAPH	Open and grounded	Open	A-f grid	Open	Open
FM-AM RADIO	Open and grounded	A-f grid	Open	Open	B+ power

tors they appear to turn and actually do turn the same direction.

But consider what happens when you look first at the front and then at the back of a single rotor carrying segments on opposite sides. If you turn such a rotor clockwise while looking at the front, anyone looking at the back would see it turn counter-clockwise. If the back turns clockwise, the front turns counter-clockwise. Try this with a coin turned the same direction while looking at opposite sides.

Segments on opposite sides of a single rotor may be shown on service diagrams as turning opposite directions. Curved arrows sometimes indicate directions of rotation. On other diagrams both segments or both sets of segments may be shown as turning the same direction, as though you were looking right through the rotor from front to back or back to front. All this must be watched while tracing circuits and referring to service diagrams.

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TELEVISION

• RADIO
• ELECTRONICS

LESSON 75 — VOLTAGE REGULATORS

Coyne School

practical home training

Chicago, Illinois

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Lesson 75

VOLTAGE REGULATORS

It is, of course, desirable that d-c voltages supplied to plate, screen, and grid circuits remain constant. But fluctuations of a-c power line voltage cause erratic changes of d-c output voltage from a d-c supply system operating on line power. It is true also, that large variations of signal currents in a-f amplifiers and other heavy-duty tubes can cause changes of plate and screen voltage supplied to other circuits.

These undesirable variations of d-c voltage are tolerated in most television and radio receivers because of added cost of preventing them. But in test instruments containing calibrated oscillators, in high-fidelity audio amplifiers, and in other apparatus where best possible performance is wanted, the cost of maintaining practically constant d-c supply voltage is warranted. Nearly constant d-c voltage may be insured by using one or voltage regulator tubes.

Fig. 1. A glow tube used for automatic voltage regulation.

The most common method of d-c voltage regulation employs "glow tubes" whose envelopes contain small quantities of argon and other gases, and in which there are only two elements, a cathode and an anode. No heater is needed. One such tube is pictured by Fig. 1. These glow tube regulators often are called VR tubes, the letters VR being an abbreviation of voltage regulator. The usual method of connection is illustrated by Fig. 2.

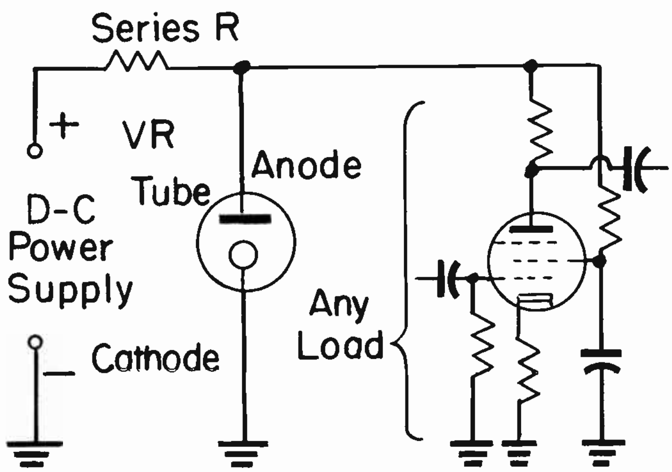

Fig. 2. Glow tube voltage regulators are connected in parallel with the load.

When voltage of suitable value is applied between anode and cathode of a VR tube there is ionization of gas within the tube. You will see a blue-violet glow on the elements and in the space between them. Ionization is explained in the lesson on "Service Oscilloscopes," in connection with the subject of Gaseous Tube Oscillators.

Once ionization has commenced, the least additional increase of voltage causes a great increase in the quantity of ions. This becomes evident as a more intense glow. The additional ions allow the tube to conduct much more current, although there is but a slight increase of voltage between anode and cathode. Every additional small increase of voltage causes the formation of still more ions, there is a brighter glow, and still more current flows through the tube.

A particular VR tube of the OD3 type, subjected to 149 anode-to-cathode volts while in a state of ionization, might allow current of 5 ma. Computed from these values of voltage and current, the effective internal resistance of this tube figures out as 29,800 ohms. At 151 volts the ionization increases

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so greatly as to allow current of 30 ma. Again computing from values of voltage and current, we find that effective internal resistance has dropped to about 5,000 ohms, yet potential difference across the tube has changed by only 2 volts.

REGULATION WHEN LINE VOLTAGE VARIES. To see how changes of effective internal resistance in the VR tube serve to regulate voltage to a load when there are large changes of power supply d-c voltage we shall use the circuit at A of Fig. 3. The load, Ro, is shown as a resistor which represents any tube circuit or circuits which act like resistance when drawing normal plate and screen currents. In parallel with the load is a type OD3 tube, which will carry a wide range of currents while potential difference across the tube remains close to 150 volts. A resistor, Rs, is in series between the power supply and the paralleled VR tube and load. It will help to understand the operation of this regulator circuit if we keep three facts in mind.

First: D-c output voltage from a power supply varies with current. When current is small there is but little loss of voltage in internal resistance of the rectifier, transformer windings, and filter circuits of the power supply, and remaining output voltage is high. As current increases, there is greater internal voltage loss, and output voltage drops proportionately.

Second: Voltage drop across the series resistor, Rs in our diagram, is proportional to current. Increase of current is accompanied by greater voltage drop.

Third: As is plainly evident from the diagram, the sum of voltage across the series resistor and of voltage across the paralleled VR tube and load must become equal to output voltage from the d-c power supply when the circuit reaches a stable operating condition.

Now for the performance. We shall assume, as at B of Fig. 3, a value of 2,000 ohms for the series resistor and of 15,000 ohms for the load. When power is turned on there is a quick rise of d-c voltage from the power supply. Current commences to flow and increases in the series resistor, the VR tube, and the load. The increase of current causes a decrease of voltage from the power supply. Don't forget, power supply output voltage now is coming down.

The increase of current is accompanied by rise of voltage across the series resistor, the load, and the VR tube. After current has increased to such value that there is potential difference of 150 volts across the VR tube and load, voltage across this portion of the circuit is held close to 150 volts by the VR tube while current continues to increase.

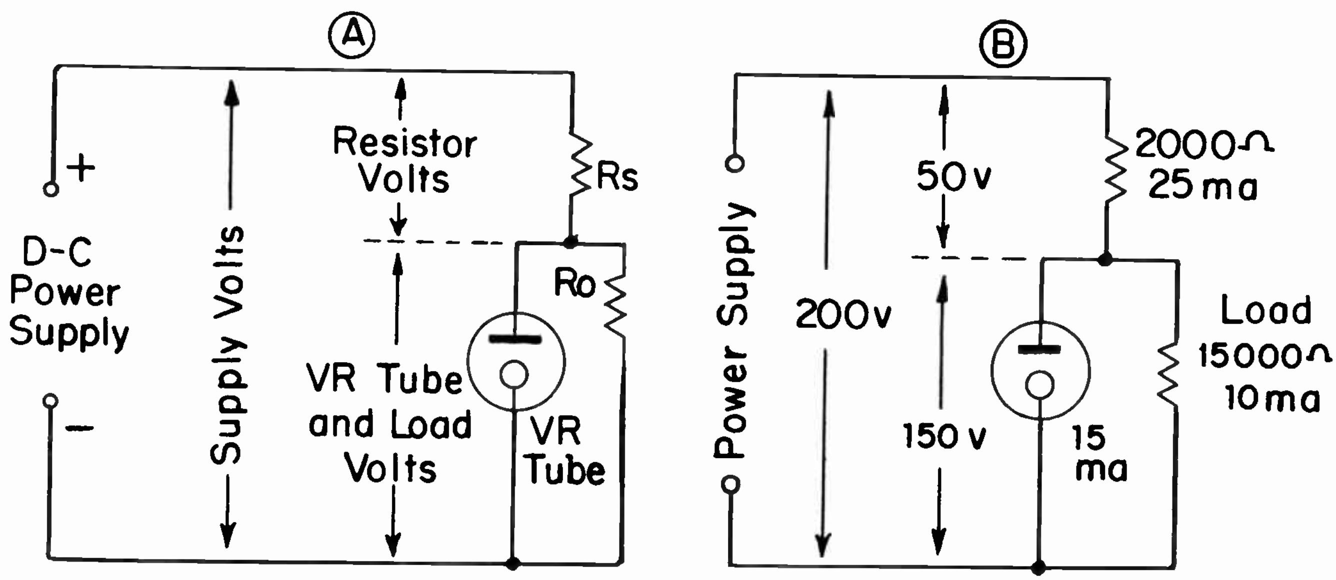

Fig. 3. Distribution of voltages in a system employing a VR regulator tube.

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But continued increase of current in the series resistor continues to increase the voltage drop across this resistor. Therefore, total voltage across the series resistor and the parallel combination of VR tube and load continues to go up - while power supply voltage is coming down.

When rising voltage across the series resistor, VR tube, and load becomes equal to voltage from the power supply, which is falling, there can be no further change of current. That is, when voltage stabilizes, so does current. In diagram B of Fig. 3 this stable condition has been reached. The 200 volts from the power supply is balanced by the sum of 50 volts across the series resistor plus 150 volts across the VR tube and paralleled load.

With 50 volts across 2,000 ohms in the series resistor, current in this resistor must be 25 ma. The sum of currents in the load and VR tube must be equal to series resistor current, or 25 ma. With 150 volts across 15,000 ohms of the load the load current must be 10 ma. This leaves 15 ma flowing in the VR tube.

Now look at diagram A of Fig. 4. Power supply output has risen to 210 volts, which might result from a rise of a-c power line voltage. This higher voltage causes more current in the series resistor, load, and VR tube. The VR tube is capable of carrying a lot more current with hardly any rise of voltage across this tube, and the load. Assuming that VR tube voltage goes up to 151 we have these conditions:

210 power supply volts minus 151 volts across the VR tube leaves 59 volts across the series resistor.

59 volts across 2,000 ohms in the series resistor causes resistor current of 29.50 ma, which must equal the sum of currents in the VR tube and load.

151 volts across 15,000 ohms in the load, causes load current of about 10.07 ma.

A total of 29.50 ma in VR tube and load together, minus 10.07 ma in the load, leaves 19.43 ma in the VR tube.

There has been almost no change of voltage across the load in spite of a 10-volt rise of d-c voltage from the power supply.

In diagram B of Fig. 4 the power supply output voltage has dropped to 180. This allows voltage across the VR tube to drop to 149. All other changes of voltages and currents are shown on the diagram. You might figure them out for yourself, as was done for conditions in diagram A.

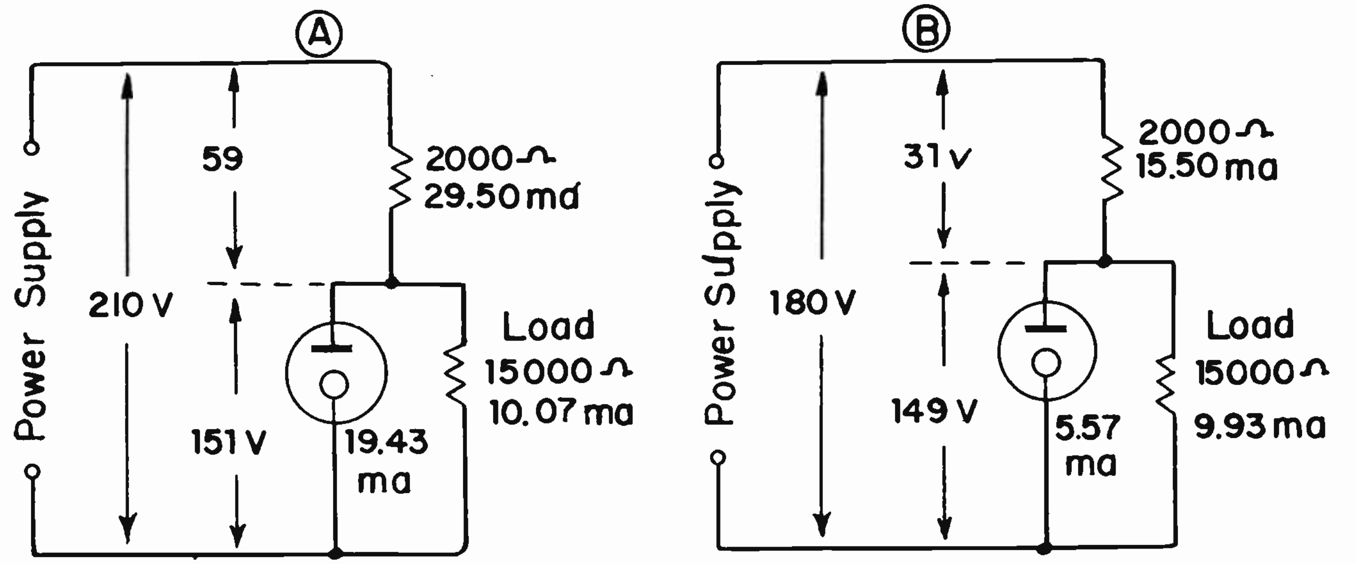

Fig. 4. What happens to voltages and currents in regulated circuits when there is variation of output voltage from the d-c power supply.

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REGULATION WITH VARYING LOADS. The VR tube is as effective in holding constant d-c voltage on a changing load as in holding constant voltage with changes of power line voltage. As an example of how changes of load current are handled we may commence with diagram B of Fig. 3, then change the load current instead of d-c supply voltage. To change the load current in our experimental setup we shall change the load resistance.

At A of Fig. 5 the load has been made 10,000 ohms instead of 15,000 ohms as in earlier diagrams. Total current from the power supply will change hardly at all, and power supply output voltage will remain practically constant at 200 volts. The lesser load resistance will take more current, and a little more current will flow in the series resistor. This means slightly more voltage drop across the series resistor, and somewhat less voltage will remain for the parallel combination of VR tube and load. We may assume that voltage across the VR tube and load drops from the former 150 volts to 149.5 volts, which leaves 50.5 volts across the series resistor.

It is easy to compute remaining voltages and currents. With 50.5 volts across 2,000 ohms in the series resistor this unit will carry current of 25.25 ma, which must divide between paralleled VR tube and load. Across the 10,000-ohm load is 149.5 volts, so load current must be 14.95 ma. Subtracting load current from series resistor current leaves 10.30 ma flowing in the VR tube.

Earlier we had 5.57 ma in the VR tube with 149 volts. Now, with 149.5 volts, we have current of 10.30 ma in the VR tube. Such a large change of current with such small change of voltage is just what enables the VR tube to do its appointed work.

In diagram B of Fig. 5 the load has been increased to 30,000 ohms. This higher resistance causes decrease of current in the load. There is slightly less current and less voltage drop in the series resistor. Somewhat more voltage, assumed to be 150.5 volts, remains across the VR tubes and load. From here on you can figure out the remaining values for current and voltage, as shown on the diagram.

The action is simply this. More load current takes current away from the VR tube, and less current flows in this tube. Total current in VR tube and load remains very nearly constant in spite of large variations of current in the load itself. This nearly constant current from the d-c power supply allows using a supply having high internal resistances and poor voltage regulation within itself, while maintaining excellent operating voltage on a connected load.

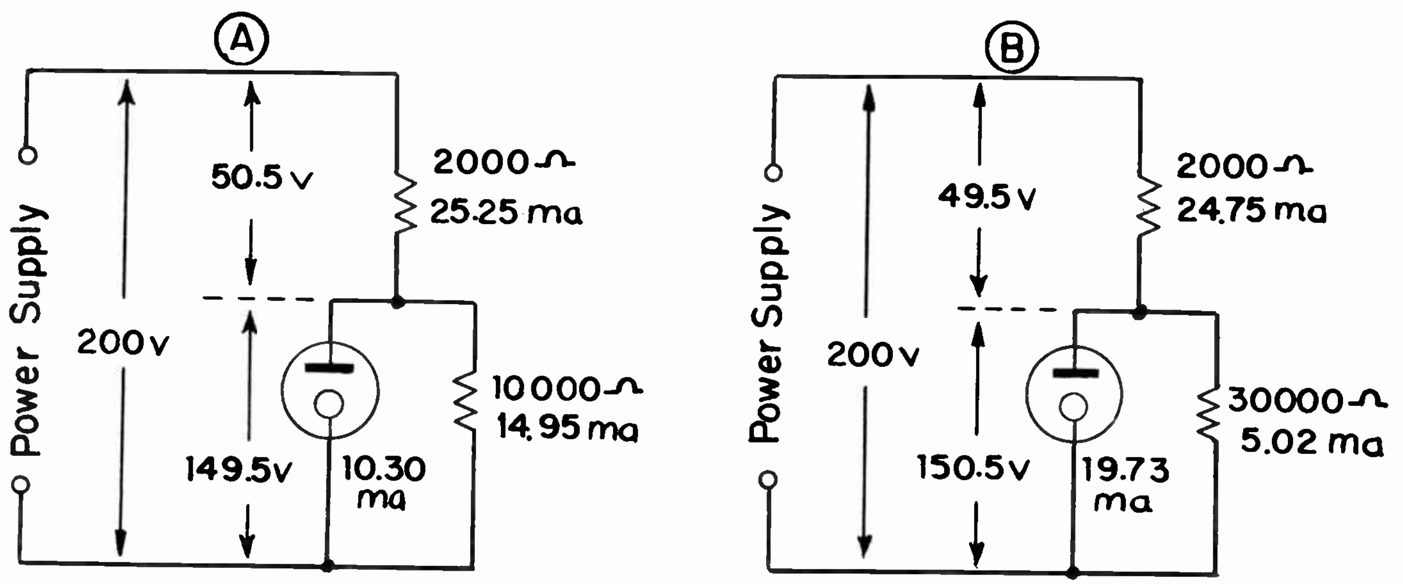

Fig. 5. Changes of voltages and currents in the regulation system when the load draws more or less current.

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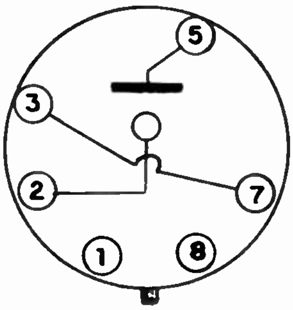
LESSON 75 – VOLTAGE REGULATORS

REGULATOR TUBE CHARACTERISTICS. The accompanying table lists the more important characteristics of VR tubes in general use. Types OA3, OB3, OC3, and OD3 have 6-pin octal bases with element connections shown at the left in Fig. 6. The glass envelope or bulb of these types is of the shape illustrated by Fig. 1. Types OA2 and OB2 are miniatures with the regular 7-pin miniature base. Older designations of the octal types included the letters VR and the value of operating voltage. Some tubes still are marked with double identifications, thus: OA3/VR75, OB3/VR90, OC3/VR105, and OD3/VR150.

VOLTAGE REGULATOR TUBES

TYPE	Operating Voltage	Voltage Range	Starting Volts, max.	Current, ma Min.	Max.
OA3	75 75	3 5	105 105	5 5	30 40
OB3	90	6	125	10	30
OC3	105 105	1 2	133 133	5 5	30 40
OD3	150 150	2 4	185 185	5 5	30 40
OA2	150	2	185	5	30
OB2	108	5	133	5	30



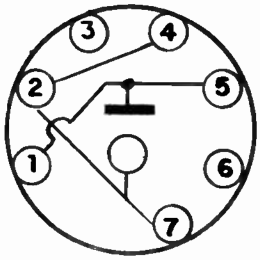


Fig. 6. Connections of base pins and internal elements for the two principal styles of VR tubes.

Operating voltages listed in the table are nominal or approximate. A particular tube might maintain d-c potential a couple of volts higher or lower than listed. There is no way of changing the appriximate operating voltage other than by using a tube of different type.

Voltage range, called also regulation, refers to total change of operating voltage or regulated voltage when current through the tube changes between limits of values listed as minimum and maximum. For example, an OC3 so operated that current can vary only within limits of 5 and 30 ma will allow voltage drop across the tube to vary by a total of 1 volt. If current in the same tube is allowed to vary between limits of 5 and 40 ma, the drop across this tube may vary as much as 2 volts. At currents less than 5 ma any of the VR tubes may allow regulated voltage to be erratic or unstable.

Any kind of glow tube requires higher voltage to start ionization than to maintain ionization after once started. Starting voltages listed in the table are the highest which should be needed during normal life of a tube. New tubes and those which have had little use ordinarily start or "fire" on voltages lower than listed for starting.

The power supply must be capable of furnishing d-c output voltage higher than listed starting voltages, in order to overcome drop in the series resistor and still apply necessary starting voltage to the VR tube. If the load happens to be temporarily disconnected, or for any reason there is temporarily more than rated maximum current forced through the VR tube, it may take 15 to 20 minutes of operation at normal current values before the tube will regulate correctly.

REGULATOR CIRCUITS. Across the series resistor of our diagrams appears a voltage which is the difference between power supply output voltage and regulated voltage across the paralleled VR tube and load. This resistor must be of such value as to prevent excessive current through the VR tube should the load be disconnected. Minimum value for the series resistance is determined in accordance with highest probable d-c output voltage from the power supply, rated operating voltage for the VR tube, and maximum rated current for the VR tube, thus:

1. From maximum d-c power supply voltage at total normal load current subtract rated operating voltage of the VR tube.

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2. Multiply the voltage difference by 1,000, then divide the result by maximum intended current for the VR tube, in ma. This gives the number of ohms for the series resistor. Resistor wattage rating must be ample for current and resistance.

Example: An OC3 tube, rated for 105 operating volts, is to be used at no more than 30 ma current. The power supply is capable of furnishing a maximum of 150 volts at 30 ma.

1. 150v - 105v = 45v

2. $\frac{45 \times 1000}{30} = \frac{45000}{30} = 1500$ ohms

Minimum series resistance which will protect the VR tube may be too great to allow starting or ionization when supply voltage falls to its minimum probable value, due usually to power line voltage fluctuation. This is to say, drop of voltage in the series resistor, resulting from load current before the VR tube fires, may reduce voltage across the VR tube and load below the value required for starting. Then it is necessary to change the load so it takes less current, or to divide the load between two or more regulated circuits.

Between pins 3 and 7 in the bases of octal-based regulator tubes is a jumper connection. Socket lugs for these two pins may be wired in series with one of the a-c line power leads to the primary of the power transformer, as at A of Fig. 7. When the VR tube is removed from its socket the jumper connection opens the line power circuit, and no d-c voltage can be produced. This protects load circuits from unregulated d-c voltage.

In the miniature regulator tubes the cathodes are connected to pins 2, 4, and 7. Socket lugs for two of these pins may be wired in series with the negative lead from the d-c output of the power supply, as at B of Fig. 7. Removing the regulator tube from its socket then opens the d-c supply circuit and prevents unregulated voltage from reaching load circuits. The jumper on an octal-based regulator tube might be similarly connected in series with the negative d-c line.

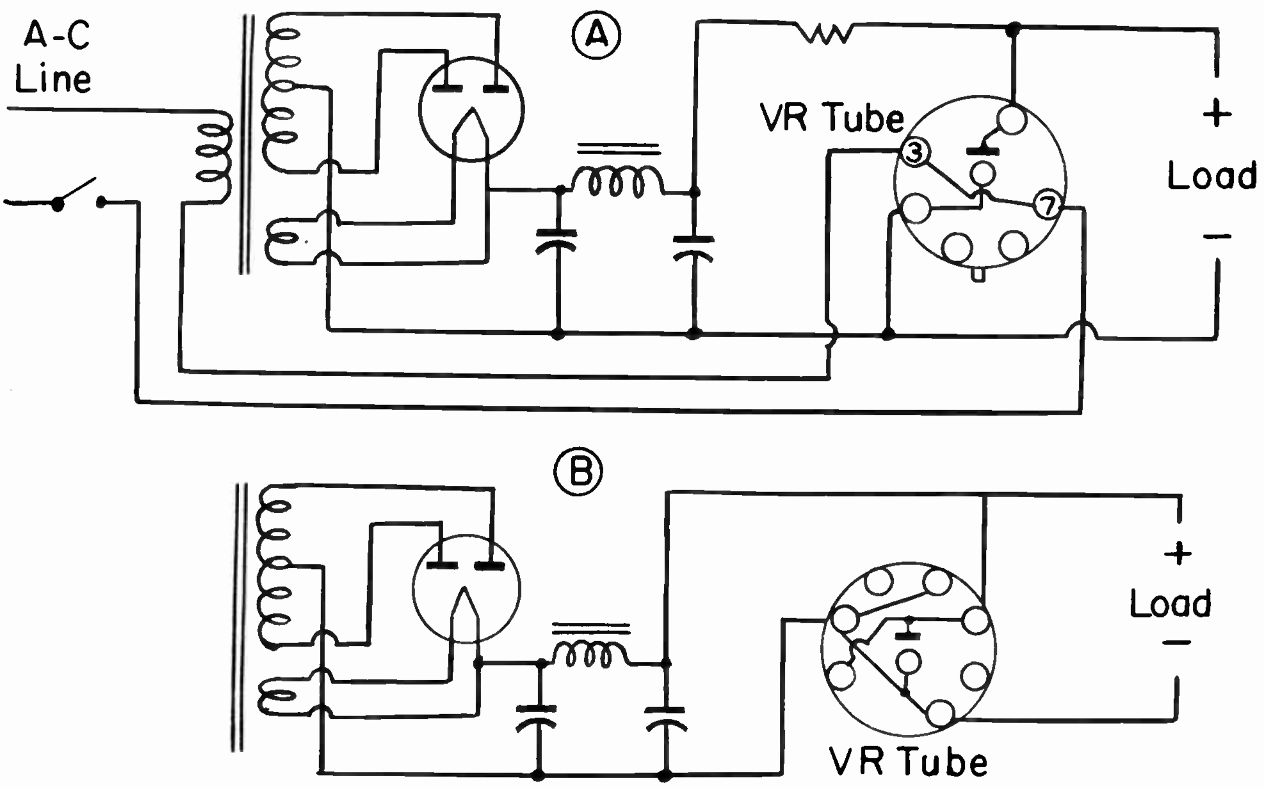

Fig. 7. How jumpers in bases of VR tubes may be connected to prevent unregulated voltage going to a load.

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To provide regulated voltage higher than can be had from a single VR tube, two tubes of the same type may be connected in series; as at 1 of Fig. 8. Regulated voltage across the load then will be twice the operating voltage of one VR tube. Two 105-volt tubes would provide 210 regulated volts on a load, two 150-volt tubes would provide regulation at 300 volts on a load, and so on. Starting voltage from the d-c power supply must be approximately twice that for a single similar VR tube.

Two different regulated voltages may be furnished to two loads with two VR tubes of the same type in series with each other and connected to the loads as at 2 of Fig. 8. Regulated voltage across load A will be the operating voltage for one VR tube. Regulated voltage across load B will be twice the operating voltage for a single VR tube. Starting voltage across the two tubes must be approximately equal to the sum of starting voltages for the two tubes.

Series regulator tubes of different types and different voltage ratings usually operate satisfactorily in the circuit at 1 of Fig. 8. The regulated voltage will equal the sum of operating voltages of the two tubes. VR tubes of different operating voltages seldom work well in the circuit shown at 2. One tube may start and the other remain inactive, which results in no regulation for either load, and there may be starting difficulties. Too little load current at B, or a disconnected load, may cause excessive current in VR tube B, which then carries total current for tube A and load A.

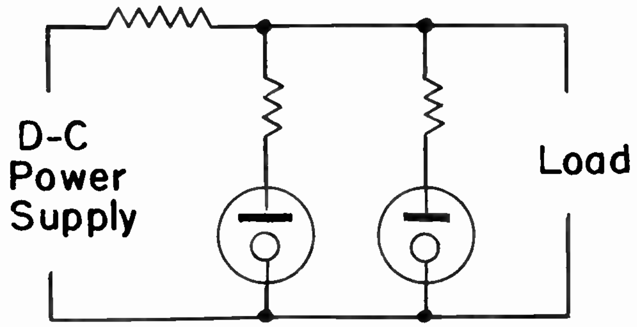

Fig. 9. It is possible, but seldom satisfactory, to use VR tubes in parallel.

For regulation where variations of load current may be greater than can be compensated for by a single regulator tube, two VR tubes of the same type may be connected in parallel as in Fig. 9. Resistors of 100 to 300 ohms must be connected in series with each VR tube. Otherwise, one tube will fire before the other, and the first tube will hold voltage lower than required for starting the second tube. The resistors in series with each tube increase the range of regulated voltage. Consequently, this arrangement seldom is entirely satisfactory.

VACUUM TUBE VOLTAGE REGULATORS. Systems of regulation which maintain nearly constant d-c voltage at their output, and across a load, also maintain nearly constant current from the power supply. Glow tube regulators do this by varying their own current. When current in a connected load

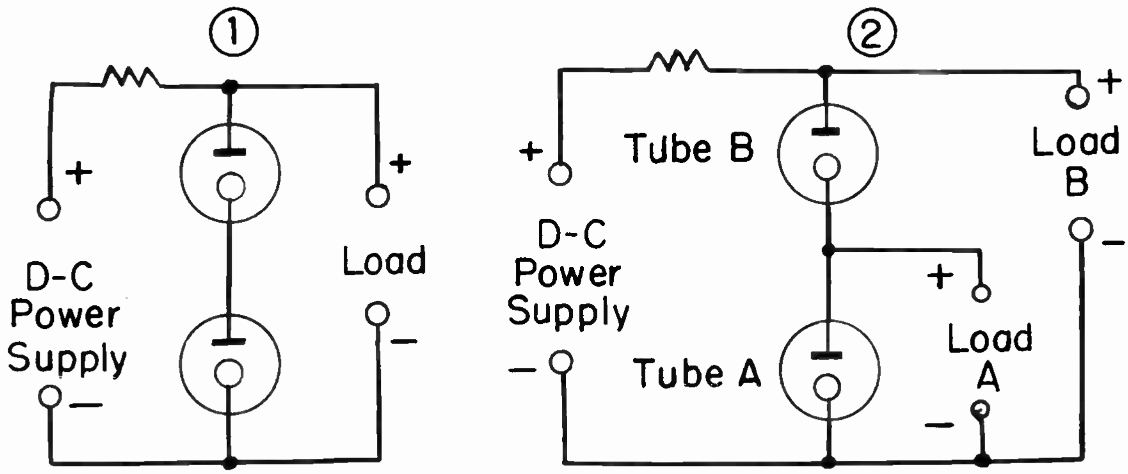

Fig. 8. VR tubes may be used in series to regulate voltages higher than can be handled by a single tube.

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increases, current in the VR tube decreases. When load current goes up, current in the VR tube goes down. As a result of these actions, total current from the power supply changes very little.

It would be possible to maintain constant current from a d-c supply, and constant voltage across a connected load, by varying a resistance connected in series between supply and load. If supply voltage, supply current, and load voltage tended to go up, as at A of Fig. 10, the series resistance could be increased. More series resistance would oppose rise of current and would absorb extra voltage in its own increased voltage drop. If supply current and load voltage tended to drop, as at B, less series resistance would compensate for these changes.

In practice, a tube having plate, cathode, and control grid may be used as a variable series resistance for automatic voltage regulation. Making the grid of such a tube more negative with reference to its cathode increases effective plate-cathode resistance and reduces plate-cathode current through the tube. When the grid is made less negative there is less plate resistance, and more plate current flows with any given applied voltage.

Diagram C of Fig. 10 illustrates an elementary circuit for voltage regulation by means of a heavy duty triode acting as a variable resistance in series between a d-c power supply and a load. Grid voltage and internal plate-cathode resistance of the regulator tube are controlled by another triode whose grid is connected to a shunt resistance across the load circuit. Any change of voltage across the load alters grid voltage of the control tube. This alters plate voltage of the control tube. The plate of the control tube is connected to the grid of the regulator tube, so every change of plate voltage at the control tube is also a change of grid voltage at the regulator tube.

Assume, with reference to diagram C, that there is an increase of power supply voltage. This causes greater current in the load and regulator tube, and greater voltage across the load. Increased voltage appears also across resistor Rg, which is shunted across the load. The portion of the voltage increase in Rg between the main negative conductor and grid of the control tube makes this grid more positive, or actually less negative. Electron flows in the control circuit are shown by broken line arrows.

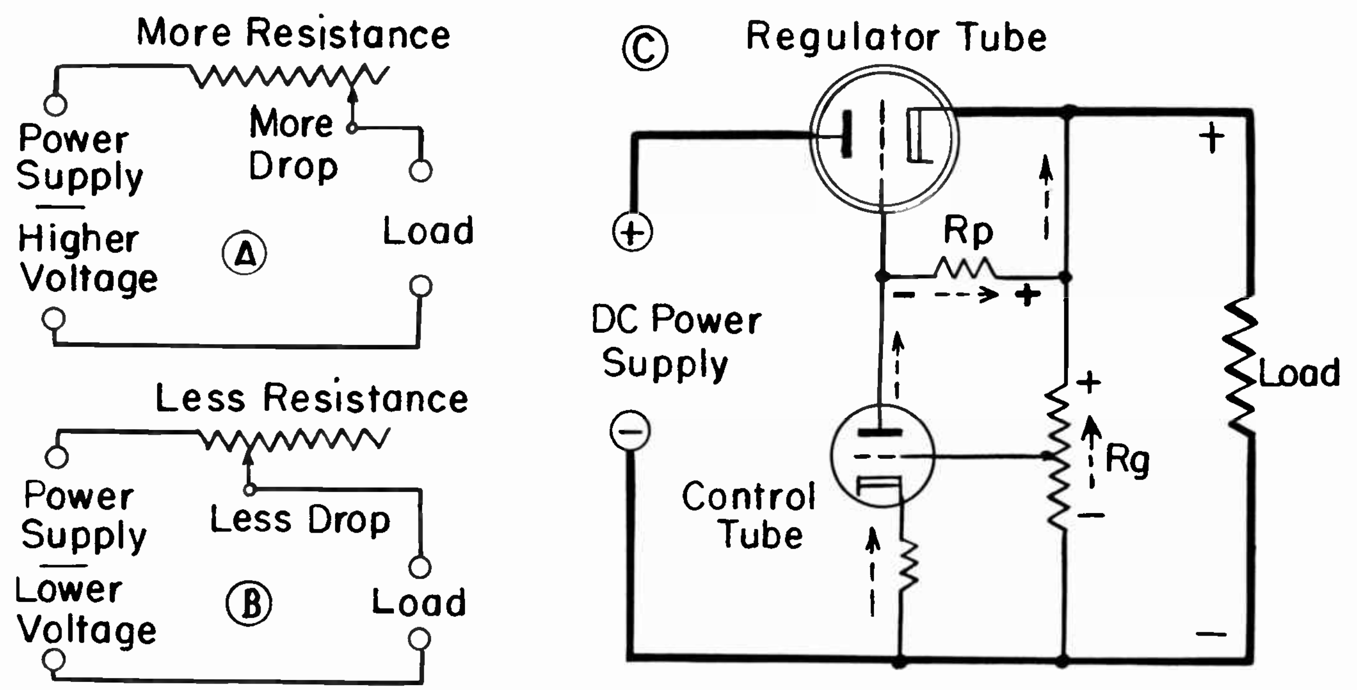

Fig. 10. The principle of voltage regulation with vacuum tubes, and an elementary circuit employing this method.

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LESSON 75 – VOLTAGE REGULATORS

As you know, plate voltage on a tube containing a control grid always changes oppositely to grid voltage. Therefore, when the grid of the control tube swings less negative its plate voltage must swing more negative. When the plate of the control tube becomes more negative, the grid of the regulator tube must become more negative, because the two elements in the two tubes are directly connected.

When the grid of the regulator tube becomes more negative there is increase of internal resistance in this tube. This increased resistance between power supply and load opposes the increase of current from the power supply. The increase of power supply voltage, which started this whole action, is absorbed by greater voltage drop across the greater internal resistance of the regulator tube.

Were there to be a drop of power supply voltage there would be less current and less voltage across the load and across resistor Rg. The control tube grid would become less positive, or actually more negative. The control tube plate and regulator tube grid would become less negative. This would decrease internal resistance of the control tube, there would be less voltage drop across this tube, and the lesser voltage from the power supply would be compensated for by less drop across the regulator tube.

The simple regulator circuit at C of Fig. 10 lacks some features which improve the action in practical applications. These features have been added in Fig. 11. The control tube has been changed to a voltage amplifier pentode of the sharp cutoff type. This is done to obtain greater voltage gain from grid to plate of this tube, so that very small changes of load voltage will cause large changes of voltage at control plate and regulator grid. This improves the sensitivity of the system and allows less variation of regulated voltage.

The control tube sometimes is a high-mu twin triode used as a two-stage voltage amplifier in a circuit designed for highest possible gain. With very high gain in the control section of the regulator system it may be necessary to have a separate heater winding or separate heater transformer for these tubes to prevent 60-cycle hum from affecting regulated voltage.

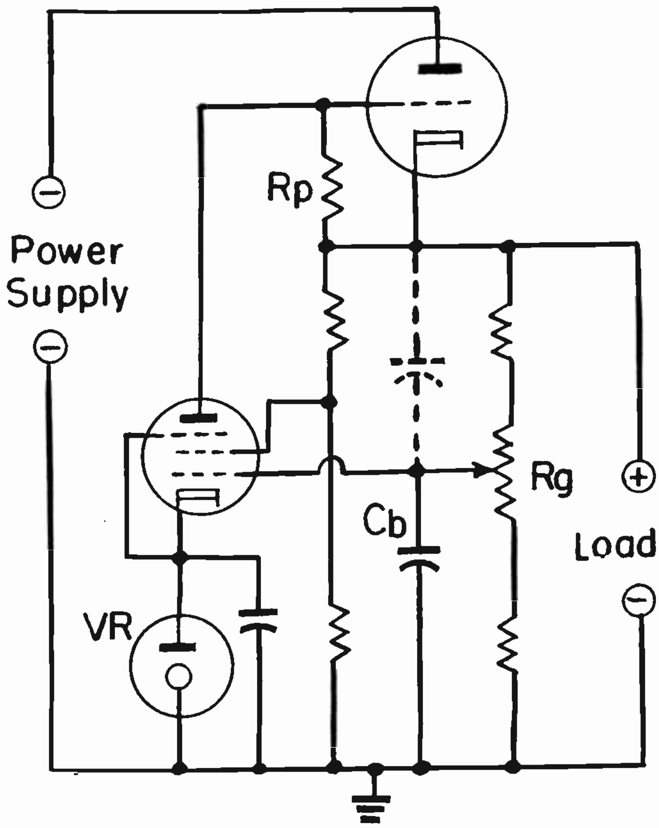

Fig. 11. A practical voltage regulator circuit in which are two vacuum tubes and one glow tube.

In Fig. 11 the grid of the control tube connects to the slider of a potentiometer in a string of resistances across the load. Adjustable control grid voltage allows making moderate changes in value of regulated voltage. Other resistances in the string are of values which insure that control voltage always will be at least somewhat negative with reference to the control tube cathode.

A bypass capacitor Cb may be connected as shown by full lines from control grid to ground, or as in broken lines from control grid to the positive side of the load. Capacitance of about 0.1 mf in this position helps prevent power supply ripple voltage from affecting regulated voltage.

An important addition in Fig. 11 is the glow type VR tube between cathode of the control tube and ground. Constant voltage drop across this VR tube holds the cathode of

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the control tube at constant potential with reference to the negative side of the load. Then voltage between cathode and grid of the control tube remains strictly proportional to changes of load voltage, as such changes appear between negative of the load and the slider on potentiometer Rg in the control grid circuit. The VR tube is chosen to have operating voltage suited to normal load voltage, using low-voltage VR tubes for smaller load voltages, and high-voltage VR tubes for higher load voltages.

The regulator tube must be of a type rated to safely carry maximum current for the load on the regulator system when there is maximum voltage drop across this tube. This means a tube rated for high dissipation in watts. The regulator tube should be rated for maximum plate voltage somewhat higher than maximum voltage from the power supply. Unless this tube will withstand a high voltage between heater and cathode it is advisable to have a separate heater winding or separate heater transformer for this one tube.

Large load currents may be handled by two or more regulator tubes with their plates, cathodes, and grids connected in parallel. Two or more triode-connected beam power tubes may be used. A type 6AS7-G twin power triode with elements paralleled often is used as the regulator tube. With elements paralleled this tube will handle a maximum of 250 ma with a drop up to 250 volts and total plate resistance less than 150 ohms. Transconductance is high, about 7,000 micromhos, to allow good regulation of plate-cathode current and load current.

Earlier it was explained that voltage on the regulator tube grid is varied by changes of voltage at the plate of the control tube. Before reading beyond this paragraph, examine the diagrams of Fig. 11 and at C in Fig. 10 to see whether you can see another reason why regulator grid voltage is altered by changes of control tube action due to variation of grid voltage on the control tube. This will be good practice in analyzing the operation of tube circuits.

Here is the explanation. Plate current from the control tube flows through resistor Rp from grid to cathode of the regulator tube. This flow is in such direction as to make the regulator grid negative with reference to its cathode. More plate current from the control tube, flowing in resistor Rp, will increase the drop across this resistor and make the grid of the regulator more negative to its cathode. This increases internal resistance of the regulator tube.

When load voltage increases, the grid of the control tube becomes more positive, or actually less negative, to its cathode. This change of grid voltage increases plate current in the control tube and current in resistor Rp. Then more drop across Rp makes the regulator grid more negative to its cathode. Did you figure it out?

VOLTAGE REGULATION WITH NEON LAMPS. Fairly effective voltage regulation for small and moderate load currents may be had with neon lamps designed primarily for use as night lamps, pilot lamps, signals, and generally similar purposes. Lamps of this type sometimes are used instead of the VR tube in Fig, 11. They are used also to stabilize plate voltages on oscillators in some service instruments and in a few radio and television receivers. Fig. 12 is a picture of three neon lamps rated at 1/25 watt, 1/4 watt, and 1 watt of normal power consumption. Also available are larger sizes rated at 2 watts and at 3 watts.

Neon lamps designed for general purposes, such as night lights, have screw bases of the large size used for ordinary electric light bulbs or else of the smaller candelabra size used for Christmas tree lamps and other decorative purposes. Into the bases of these screw-base neons are built resistors which limit current to values safe for the lamp when used on a-c or d-c power and light lines at 110 to 120 volts. These resistors seldom are of values suitable for voltage regulating circuits.

Neon lamps with bayonet bases, like those of Fig. 12, have no built-in resistors and may be used in voltage regulating circuits having series current limiting resistance or other limiting elements suited to each application. A small 1/25-watt neon with wire leads, but no base, has no built-in resistors. All these types without built-in

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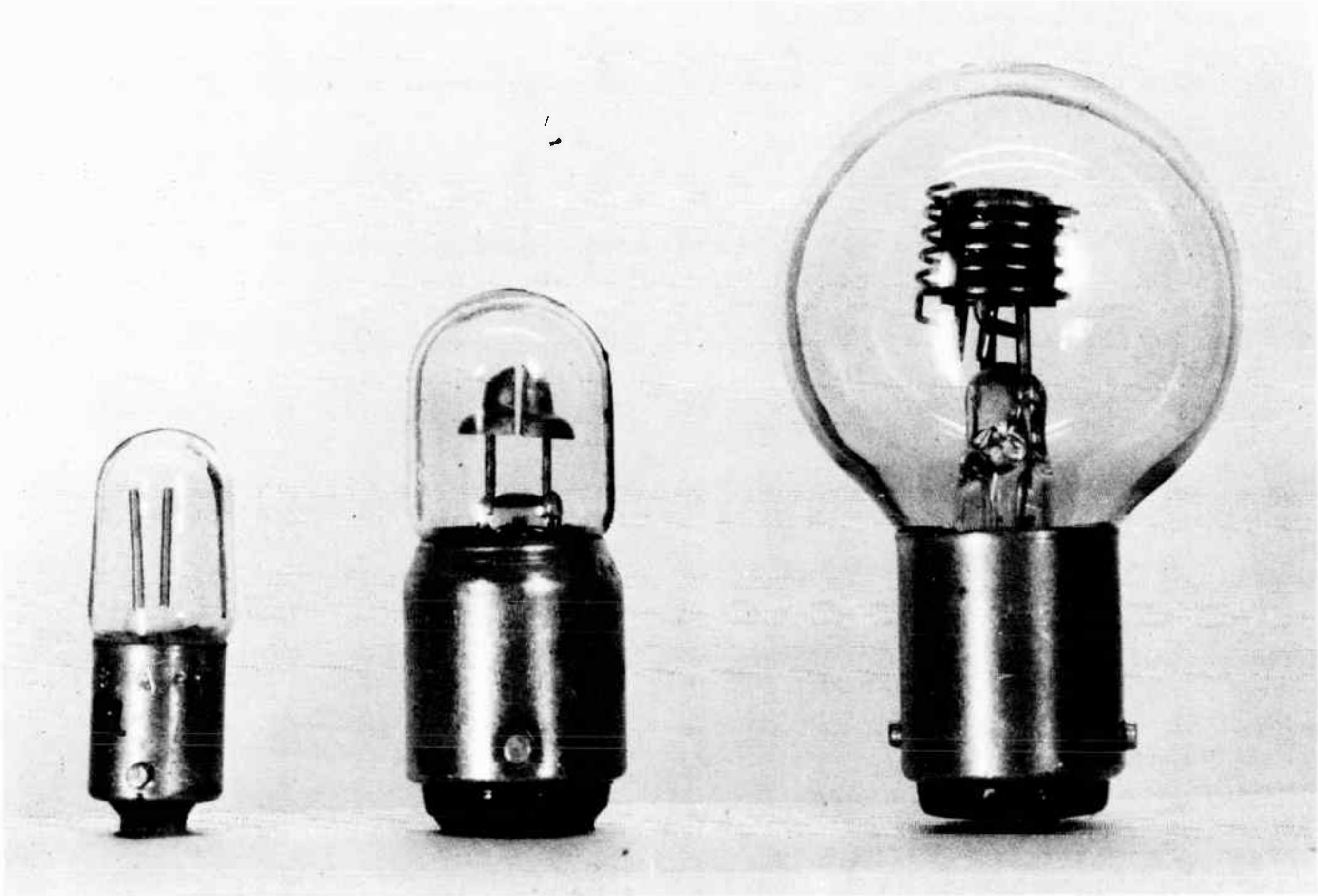

Fig. 12. A few of the many types of neon lamps which may be used as d-c voltage regulators.

resistors may be had from radio and television supply houses.

Neon lamps of the 1/25 watt size are designed for maximum current of 0.5 ma. Sizes of 1/4-watt and larger are designed for maximum currents of 20 ma per watt of rating. That is, a 1-watt lamp may carry up to 20 ma, while a 3-watt size may carry up to 60 ma, but a 1/4-watt size must not carry more than 5 ma. All the neons start or ionize at less than 105 volts, with some types starting as low as 70 volts. The ionization glow is red, the color which is characteristic of neon gas.

The three curves of Fig. 13 show average relations between voltage drop and current in a number of neon lamps rated at 1/25 watt, 1/4 watt, and 1 watt. Individual lamps of any size may regulate at voltage somewhat higher or lower than the average. By using lamps of suitable sizes it is possible to have regulation of voltages from around 50 up to 75 or 80. Higher voltages may be regulated with lamps of the same type in series, just as with VR tubes.

<u>SELENIUM RECTIFIERS FOR VOLTAGE REGULATION.</u> A selenium rectifier such as used in d-c power supplies may be used for regulation of load voltage when connected as in Fig. 14. The rectifier anode, its negative terminal, is connected to the positive side of the load. The rectifier cathode, usually marked positive, is connected to the negative of the load and of the d-c power supply.

The usual current limiting series resistor must be connected between the d-c supply and the paralleled rectifier and load, just as in other regulator circuits. This resistor is of a value which limits rectifier current, with the load disconnected, to about 20 per cent less than rated maximum d-c current for the selenium unit when used as a power rectifier.

The two curves of Fig. 14 show relations between current and voltage drop in typical power-supply types of selenium rectifiers

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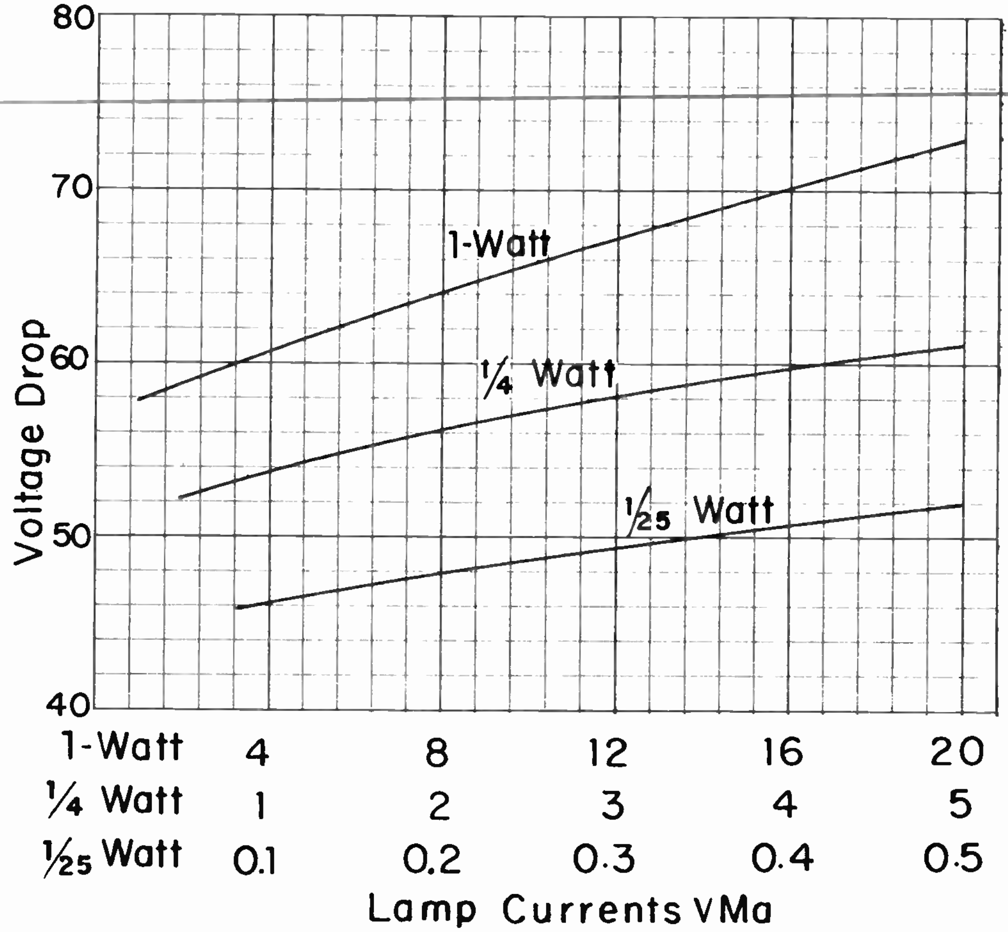

Fig. 13. Voltage drops and currents in small neon lamps of types used for voltage regulation.

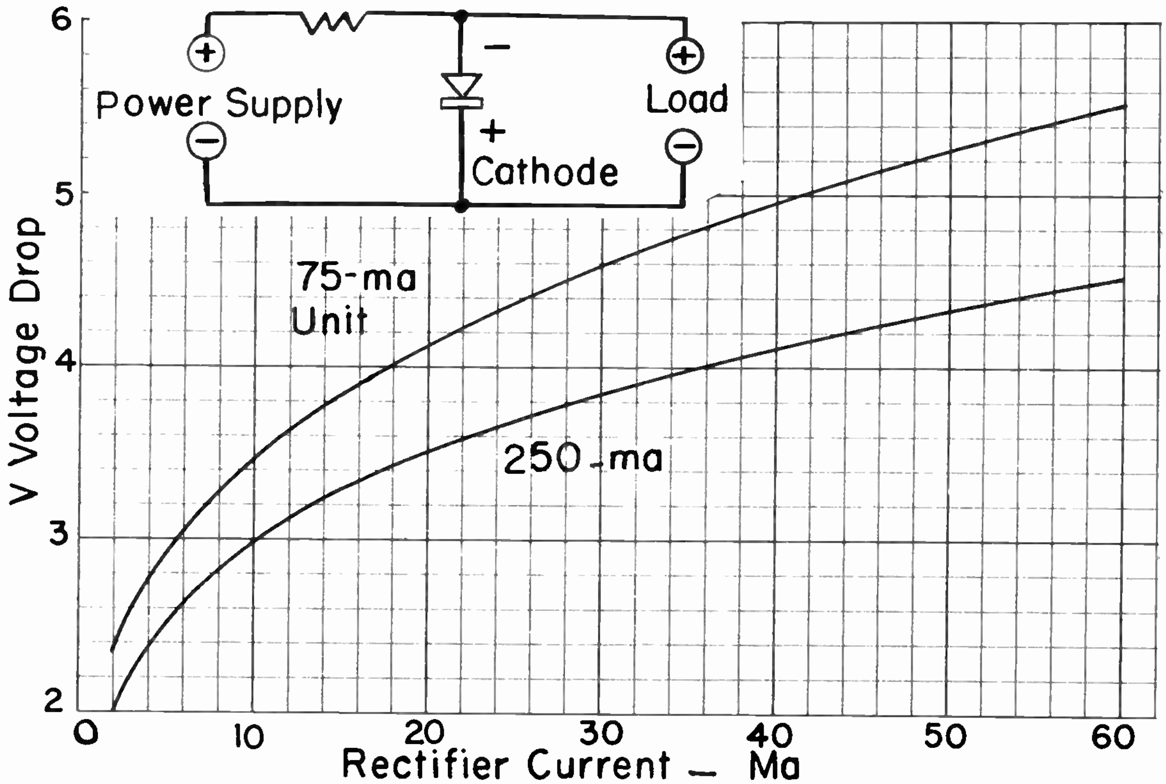

Fig. 14. Relations between current and voltage drop for two selenium rectifiers such as intended for use in d-c power supplies.

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rated at 75 and at 250 d-c ma, with currents up to 60 ma in each rectifier. Regulated voltages are low, but permissible currents are quite large. Higher load voltages may be regulated with two or more rectifier units in series with each other. Selenium units made especially for voltage regulator service give more uniform and dependable action than types intended for use as power rectifiers.

Regulated voltage varies with changes of rectifier temperature. When rectifier currents, or heat from nearby circuit elements, are great enough to cause appreciable heating of the selenium unit, the regulated voltage does not become stable until a steady temperature is reached. During tests of a particular rectifier, regulated voltage dropped by about 10 per cent when rectifier temperature increased from 75° to 130° F. Voltage did not rise by 10 per cent until the rectifier was cooled almost to freezing temperature, 32° F.

CONSTANT VOLTAGE POWER TRANSFORMERS. The simplest method of compensating for variation of a-c power line voltage, as it affects d-c voltage from a power supply, is to use a constant voltage power transformer. Such transformers will hold their secondary voltage, which goes to the power supply filter, within plus or minus 3 per cent of rated voltage when a-c power line voltage varies between 95 and 130 volts.

A constant voltage power transformer compensates for line voltage fluctuations, and does not cause the poor regulation which is due to resistance in secondary windings of ordinary transformers. The voltage regulating transformer furnishes constant voltage to the power supply rectifier and filter, but it cannot compensate for poor regulation due to internal resistance of the rectifier, to high resistance in filter chokes and resistors, nor to lack of adequate filter capacitance.

Constant voltage power transformers are available with the usual secondary voltages of other power transformers, and with d-c current ratings of 50 ma up to 250 ma. There are the usual heater windings, as on other power transformers for radio and television. The constant voltage transformers are larger than ordinary types with equivalent voltage and current ratings, they weigh about twice as much, and cost about twice as much.

NTC RESISTORS. The abbreviation NTC means negative temperature coefficient. A resistor having a negative temperature coefficient is one in which resistance drops when temperature rises. This is just the opposite of what happens in conductors made of copper, brass, aluminum, iron and other metals except those alloyed especially for ordinary wire-wound resistors. In all these conductors there is increase of resistance with rise of temperature, they have positive temperature coefficients.

When an NTC resistor is cold it has high resistance. Applying voltage across the resistor causes current to flow in it. This current heats the resistor, and its resistance drops. The decreased resistance allows still more current to flow, even with no increase of applied voltage, and the resistor gets still warmer. The increased current, flowing in other parts of the connected circuit, increases the voltage drops in those other parts. Soon we have the condition in which voltage, current, temperature, and resistance of the NTC unit become stable.

Now any small increase of voltage across the NTC resistor increases the current and temperature, and lowers the resistance of the unit. In effect, there is a decrease of resistance when there is an increase of voltage, and, of course, there is an increase of resistance with less applied voltage. This change of resistance with change of applied voltage is the really useful property of NTC resistors. The action is quite like that in a VR tube, whose effective internal resistance drops rapidly when there is only small increase of voltage across the tube.

Fig. 15 is a picture of a few NTC resistors. There are many other sizes, but most of them may be recognized by their black or slate-colored bodies, light-colored metal end caps, and radial rather than axial pigtails. The smallest of the units illustrated has cold resistance of about 1,400 ohms. When its temperature rises to about 200° F, resistance drops to about 550 ohms. At still higher temperature the resistance may drop as low as 200 ohms. Other NTC resistors have

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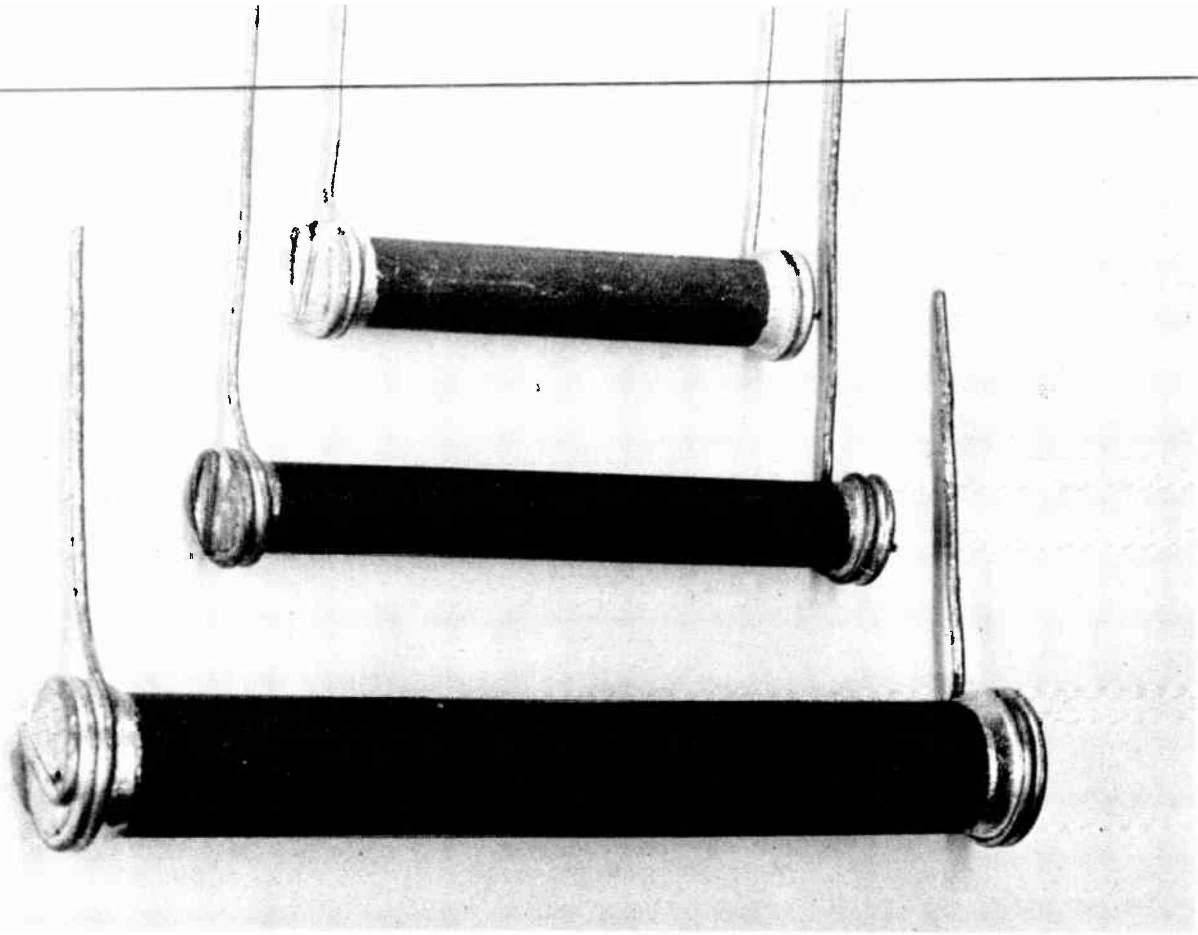

Fig. 15. Some negative temperature coefficient resistors.

cold resistances ranging from 200 to 1,000 ohms, and hot resistance of 20 to 125 ohms. Still others have cold resistance of several megohms, which drops rapidly to something like 15K to 20K ohms with currents of only a few milliamperes.

One common use of NTC resistors is for prevention of initial high voltages on plates and screens in receivers having selenium type power rectifiers. Selenium rectifiers do not have to warm up, as do vacuum tube rectifiers, before they pass rectified current and d-c voltage. When line power is first applied to a receiver of this class the power supply delivers maximum voltage to plates and screens before tube cathodes become hot enough to allow flow of d-c current. Once the plate and screen currents commence to flow, voltages come down to normal because of drops in various resistances of receiver circuits, but harm may be done before this happens.

With an NTC resistor in series with the power rectifier circuit, the initial voltage is opposed by high resistance of this unit. By the time the NTC resistor warms up, drops its resistance, and allows normal B-voltage to tube circuits, heaters and cathodes of receiver tubes have become hot enough to allow flow of normal currents. There is no period during which excessively high voltages appear in plate and screen circuits.

NTC resistors may be found in some plate or screen circuits whose average d-c voltages should remain nearly constant. An example is shown by Fig. 16. NTC resistor is between screen and cathode of a horizontal output amplifier tube, to regulate the screen voltage.

An increase of voltage from the d-c power supply or boosted-B circuit would raise the screen voltage. But the increase of voltage acts on the NTC unit to lower its resistance and allow more current in this re-

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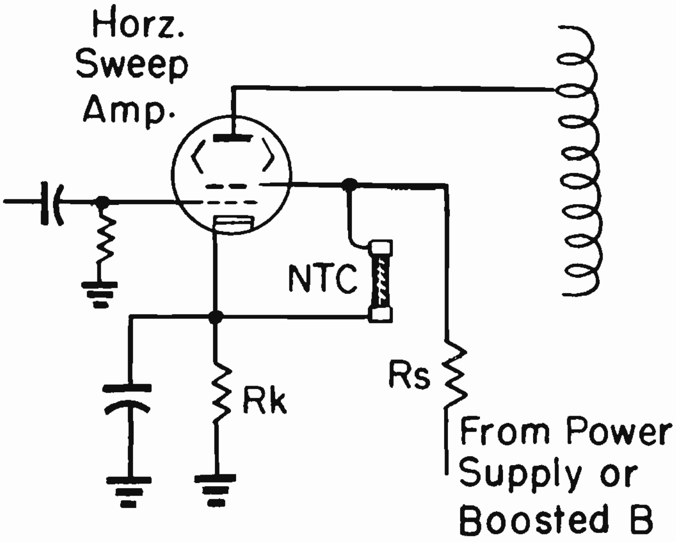

Fig. 16. An NTC resistor for regulation of d-c voltage to the screen of a horizontal output amplifier tube.

sistor. The greater current flows in screen dropping resistor Rs, and so increases voltage drop across Rs that voltage at the screen of the tube rises very little. Increased current in the NTC unit flows in cathode resistors Rk to slightly increase the negative grid bias on the amplifier and thus compensate for the slightly higher screen voltage.

You cannot measure hot resistance or operating resistance of an NTC unit with an ohmmeter, because the ohmmeter won't furnish enough current to heat the resistor. It is necessary to disconnect one end of the NTC resistor, connect a milliammeter in series and a d-c voltmeter is parallel with the unit, then operate the receiver while measuring current and voltage drop. A resistance formula or an alignment chart will allow determining the effective resistance.

You may observe in a general way how an NTC resistor behaves by connecting it to an ohmmeter. Hold a hot soldering iron close enough to heat the resistor while observing the resulting drop of resistance as indicated by the ohmmeter.

FUSES. Some television receivers are equipped with fuses which blow, like a fuse in a house lighting circuit, when there is excessive current due to overload. Types of fuses most often used are pictured by Fig. 17. All are glass enclosed, with metal end

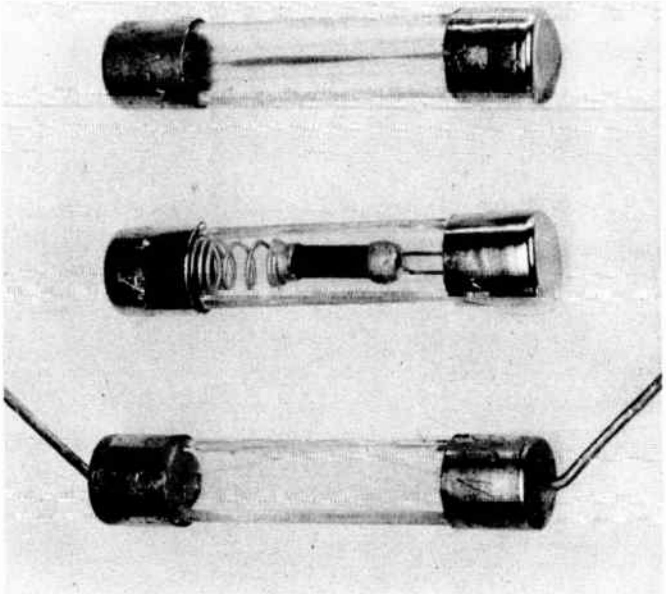

Fig. 17. Types of fuses which may be used in television receiver circuits.

caps for electrical connections. End caps of units at the top and center of the picture snap into fuse holder spring clips having solder lugs, or may fit into recesses of fuse holders made of insulation and containing spring contacts. The fuse at the bottom of the picture has pigtails attached to the end caps. It is soldered into a circuit in the same manner as a resistor or capacitor having pigtails.

All fuses in the picture are of the 3AG size and style, which means they are 1/4 inch in diameter, 1-1/4 inches long, glass enclosed, with metal end caps. The upper and lower units are ordinary quick break types which open or blow almost immediately when there is current much in excess of that for which the fuse is rated. Ratings commence at 1/16 ampere and increase by small fractions up to 1 ampere, then in jumps of a half-ampere or one ampere up to as much as 20 amperes.

The fuse at the center of Fig. 17 has a long time lag, a type often specified as a slow-blow fuse. These fuses open only after excessive current continues long enough to heat a part of the unit within the glass. They are especially useful in circuits containing large inductances or capacitances, which allow strong current surges when voltage is

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first applied. The slow-blow fuses are not affected by the momentary strong current, but will open should excessive current continue.

Television receiver fuses are found most often in the line to the low side of the primary winding of a flyback transformer, where they prevent excessive plate current in the horizontal output amplifier. Fuses in this position usually have 1/4-ampere ratings. Some sets have fuses in the line from ground or B-minus to the center tap of the power transformer secondary. A fuse in this position opens should there be continued overload in any of the B+ lines, thus protecting resistors and other circuit elements against burnout.

Fuses are quite generally used between the a-c power line terminals and the primary of the power transformer in separate d-c power supplies and in complete receivers. The fuse rating depends, of course, on current drawn when the receiver is in good order. Ratings of 2 amperes and of 3 amperes are quite common.

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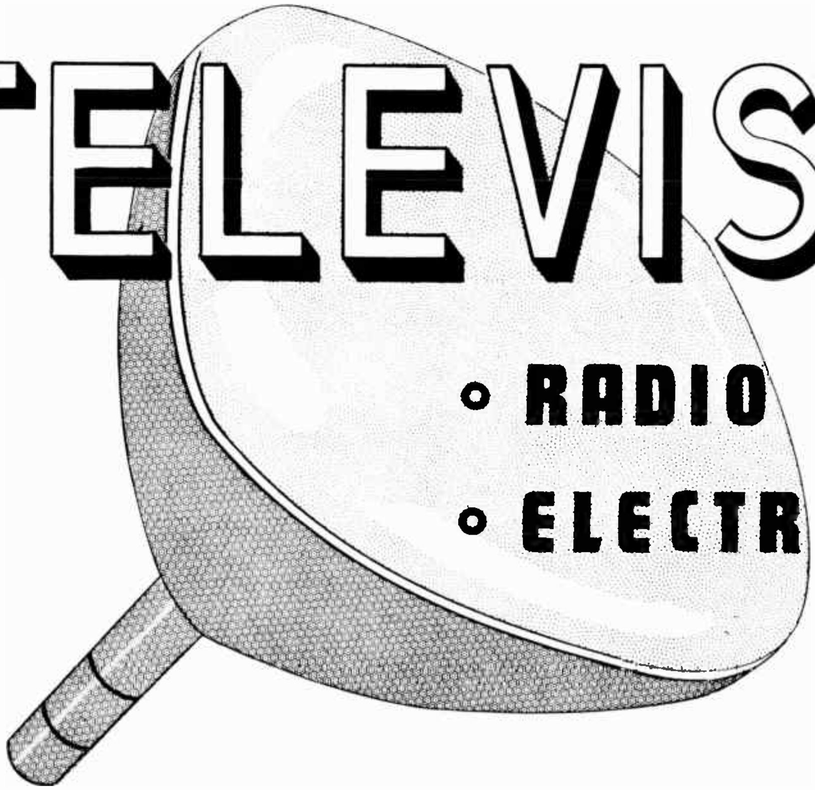

- RADIO
- ELECTRONICS

LESSON 76 — DRESSING OF LEADS AND PARTS

Coyne School

practical home training

Chicago, Illinois

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Lesson 76

DRESSING OF LEADS AND PARTS

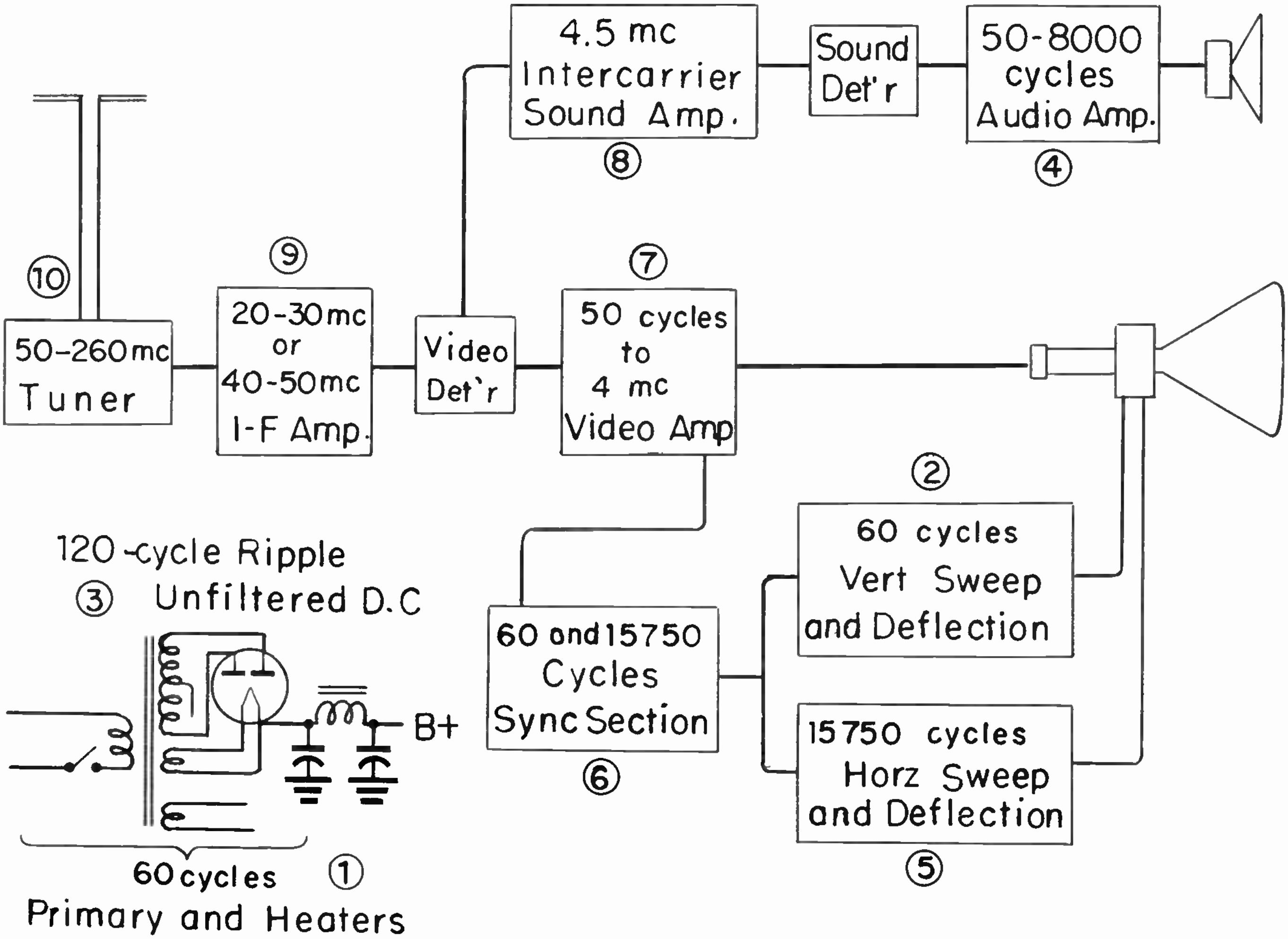

Fig. 1. When frequencies in one section are of the same general range as frequencies in another section, conductors for the two sections may require careful dressing to avoid trouble.

When wire conductors and parts which they connect are in such positions as to reduce unwanted couplings, stray capacitances, and stray inductances, the wires and parts are said to be correctly "dressed".

Unwanted couplings and feedbacks are reduced by suitable separation between elements of circuits in which are signal currents that should not get into other circuits. Couplings and feedbacks are reduced also by the shielding effect of running conductors close to grounded chassis metal, or running conductors for different signal circuits on opposite sides of grounded metal.

Stray capacitances are reduced by having maximum practicable separation between signal-carrying wires and other parts containing metal, by using parts having relatively small areas of metal, and by keeping signal-carrying conductors and parts well away from grounded chassis metal. In making alterations or additions the new parts should not be placed close to circuits carrying carrier, i-f, or intercarrier frequencies.

Stray inductances are reduced by using shortest possible wires or leads in the signal circuits. This applies especially to very-high and ultra-high frequency circuits, with

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which even short conductors have enough inductance to provide appreciable inductive reactances. These reactances exist whether the conductors are on the high sides or grounded sides of high-frequency circuits. Short leads are effective also in reducing stray capacitances and in reducing unwanted couplings and feedbacks.

It is necessary to pay more careful attention to dressing in high-impedance circuits than in circuits of low-impedance. A high-impedance circuit is a signal-carrying circuit in which there is high capacitive reactance, high inductive reactance, high resistance, or any combination of these things. The great majority of grid circuits and plate circuits are of the high-impedance type. Cathode circuits usually are in the low-impedance class. Screen circuits which do not carry signal currents are treated as low-impedance circuits.

There is more danger of undesired couplings from circuits carrying strong signal currents and voltages than from circuits carrying relatively weak signals at the same or approximately the same frequencies. As an example, there can be more signal transfer through stray capacitances from the final i-f amplifier circuits than from the first i-f amplifier circuits.

Often it is said that circuits carrying high-frequency signals require more careful dressing than low-frequency circuits. This is true to the extent that radiation takes place more easily through high-frequency magnetic and electric fields than through low-frequency fields. But in actual practice you are much more likely to have trouble with 60-cycle vertical deflection frequencies and with 15,750-cycle horizontal deflection frequencies than with intermediate and carries frequencies of 20 to 200 megacycles. Let's see how this comes about.

The all-important fact is this: Any circuit which is tuned to a certain frequency or range of frequencies, or which is constructed to carry certain frequencies or ranges of frequency, will be responsive not only to these frequencies but also to others somewhat lower and higher. Here is an example. An i-f coupler or transformer tuned to something like 24 mc is practically unaffected by audio frequencies of 50 to 8,000 cycles per second. On the other hand, an audio amplifier designed for 50- to 8,000-cycle response will pick up the horizontal sweep frequency of 15,750 cycles, which is only twice as high as the highest ordinary audio frequency.

The frequencies and frequency ranges with which we are concerned, and the sections where they are found, are shown by Fig. 1. In Fig. 2 these frequencies and fre-

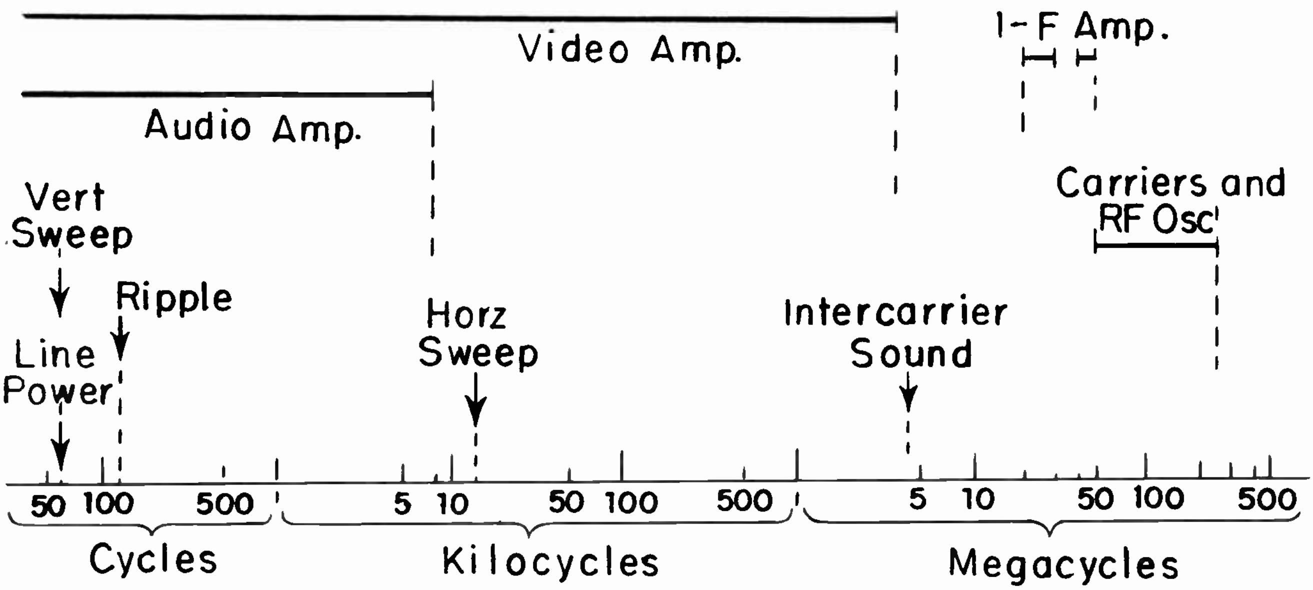

Fig. 2. Here we see which sections are likely to pick up frequencies from other sections.

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quency ranges are marked on a logarithmic scale running from 50 cycles per second to 500 megacycles. Here we see quite clearly which circuits and sections are designed for operation at frequencies making them responsive to frequencies in other circuits and sections, also which ones are so far separated in frequency characteristics as to allow little interaction.

Audio amplifier and video amplifier frequency ranges include line power, vertical sweep, and B+ ripple frequencies. The video amplifier frequency range includes also the horizontal sweep frequency. In all these circuits and sections it is necessary to watch the dressing of leads and parts.

Frequency ranges of i-f amplifiers are far removed from all other frequencies except those in the tuner, where we have carrier and r-f oscillator frequencies. This is the reason why an audio amplifier section may be mounted on a chassis right along side an i-f amplifier section with no danger of intercoupling. It is the reason why power transformers, rectifiers, and filters may be so close to i-f amplifiers, also to tuners, with no coupling troubles appearing.

The frequency graph shows why audio amplifier circuits must be kept as far as practicable from conductors and parts carrying power line frequency, or strong ripple frequencies in power rectifier and filter, or vertical sync and sweep frequency - the audio circuits are responsive to all these other frequencies.

Video amplifier circuits could pick up plenty of unwanted frequencies, because nothing else in television has such a wide range of frequency response as the video amplifier. Luckily, the one or two tubes and the circuit connections in a video amplifier section may be placed close together in a small area of the chassis. Dressing is not likely to cause trouble in parts and wires of any one section which is small and compact, and where there is only one frequency or a single range of frequencies.

A great deal of trouble may appear due to incorrect dressing where parts of a single section are widely distributed on the chassis, and where wires between these separated parts may come close to runs of wire connections carrying other frequencies to which the first section is responsive. This is the reason for shielding of wires extending from audio amplifiers to volume controls and tone controls on front panels.

It is necessary to recognize just what parts and leads are included in each of the circuits and sections operating at certain frequencies and frequency ranges, thus:

<u>1.</u> Power-line frequency, 60 cycles. Power cord. Power transformer. Off-on switch located on front panel. Wires connecting these parts, also wires running to tube heaters and pilot lamps. Keep all such wires tight against chassis metal.

<u>2.</u> Vertical sweep and deflection frequency, 60 cycles. Everything from output of the vertical sweep oscillator through to the vertical deflecting coils in the yoke. Keep wires close to chassis metal so far as this is possible.

<u>3.</u> Unfiltered ripple frequency, 120 cycles. Found only in power transformer, power rectifier or rectifiers, and leads to filter or to speaker field or focus coil when these are used as filter chokes. Such wiring can radiate strong fields because of the high peak-to-peak amplitude of the ripple component.

<u>4.</u> Audio amplifier section, 50 to 8,000 cycles as usual response. This section begins in the transformer which feeds the sound demodulator and extends all the way into the speaker. It includes the volume control, any tone control, and any switch for selecting television, phonograph, or a-m radio reproduction. Pickup of power-line frequency causes a soft hum. Unfiltered ripple frequency causes a higher pitch and a buzzing effect due to sawtooth waveform of the ripple. Vertical sweep frequency causes a buzz. If audio response goes high enough, horizontal sweep frequency causes a continual hissing sound.

<u>5.</u> Horizontal sweep and deflection frequency, 15,750 cycles. Everything from output of horizontal sweep oscillator through

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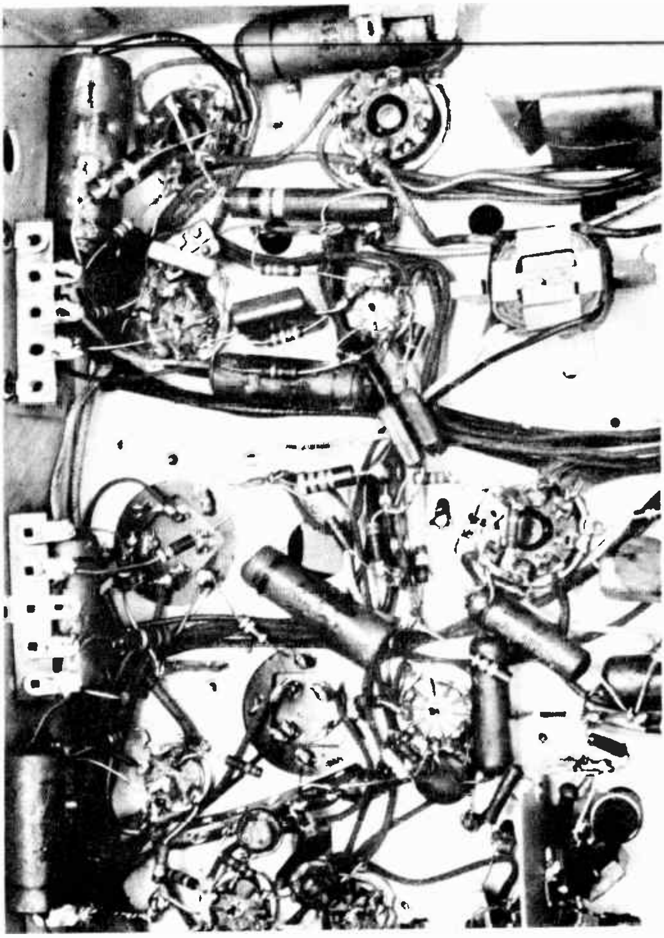

Fig. 3. Capacitors, resistors, and their connections to socket lugs are carefully arranged in this horizontal sweep and deflection section.

to the horizontal deflecting coils in the yoke. This includes drive or peaking controls, horizontal output amplifier tube, horizontal flyback transformer, damper tube, high-voltage rectifier and filter, and all their connections. Leads to the damper tube socket require careful dressing, because of strong pulse voltages.

6. Sync section. Here we have both vertical pulses (60 cycles) and horizontal pulses (15,750 cycles).

7. Video amplifier section, 50 cycles to 4 megacycles. Includes everything from output of the video detector through to the grid or cathode of the picture tube, whichever of these elements receives the video signals.

8. Intercarrier sound amplifier, 4.5 megacycles. Begins at the sound takeoff and includes everything to and including the sound demodulator. Like the video amplifier, this sound amplifier usually is quite compact and has few if any signal leads extending far away from the section.

9. I-f amplifier section. Operates at 20 to 30 mc in some receivers, at 40 to 50 mc in others. Includes everything from output of mixer tube in tuner to the input of the video detector. In this section are the agc circuits, but since these circuits carry only d-c voltage they cause little trouble.

10. Carrier and r-f oscillator frequencies, 50 to 260 mc for vhf receivers. These frequencies are confined to the antenna, the transmission line or lead-in, and the tuner. Dressing of parts within a tuner is very nearly an exact science in itself, and under no conditions may it be altered during service operations. Other than the transmission line, the only leads to the tuner are for B+, agc voltage, and heater current. None of these carry signals.

CAPACITOR, INDUCTOR, AND RESISTOR POSITIONS. The following practices and precautions should be observed when installing bypass or decoupling capacitors in circuits operating at frequencies above those in the a-m radio broadcast band.

1. Place capacitors to allow shortest possible leads, but not so short that you have to solder a pigtail closer than 1/4 inch to the capacitor body. Try to hold pliers on the pigtail, near the capacitor, to absorb heat.

2. Connect bypass ground leads to the same point as the ground for cathode or cathode resistor of the same tube.

3. Connect one side of plate and screen bypasses directly to a socket lug. When one pigtail must be longer than the other, connect the long one on the ground or low-impedance side of the circuit.

4. When bypasses from a screen or from a plate return to the cathode, keep pigtails on the cathode side separate from other cathode connections all the way, thus avoiding any lengths of wire common to screen or plate circuits and grid circuit.

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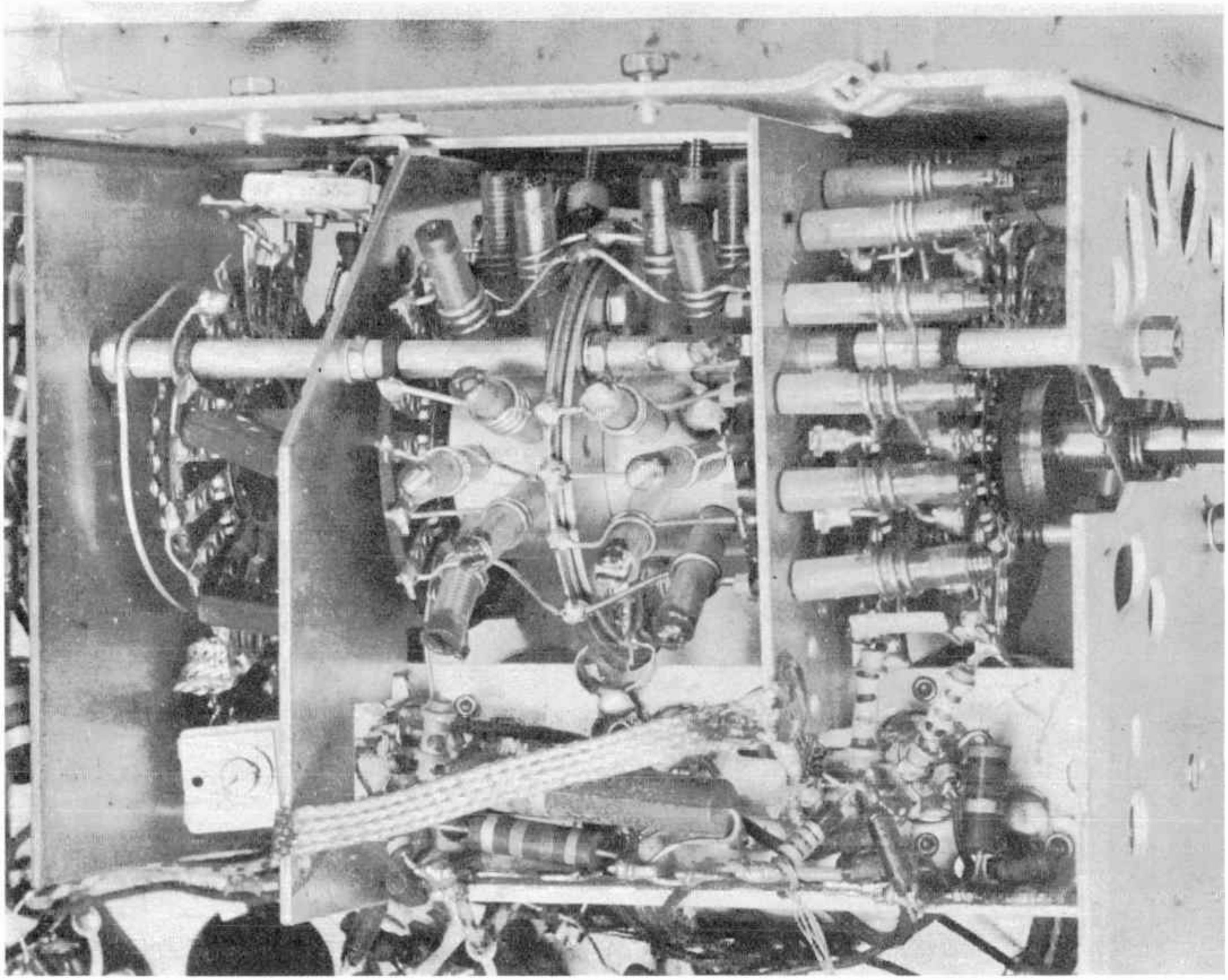

Fig. 4. High operating frequencies and the many small parts closely spaced in a tuner require precise dressing.

5. In vhf and uhf circuits make replacements with capacitors not only of the same capacitance, tolerance, and voltage rating, but also of the same type (ceramic, mica, or paper) and of the same dimensions, but not necessarily of the same make.

Observe the following precautions with coupling or blocking capacitors in circuits operating at frequencies above about 2 mc.

1. Dress these capacitors away from chassis metal, to avoid distributed capacitance to ground. Place new capacitors in the same positions as originals in new sets. All this applies to capacitors which couple to picture tube grids or cathodes, as well as to interstage coupling capacitors.

2. Place interstage coupling capacitors close to the grid of the following tube, with the longer pigtail toward the plate of the preceding tube. With paper tubulars marked as to the outside foil connection, place this connection toward the plate of the preceding tube.

Note: A coupling capacitor between a volume control and grid of an a-f amplifier, also the leads for this capacitor, are preferably dressed close to chassis metal. This helps avoid pickup of undesired frequencies by the audio amplifier.

Grid resistors, plate load resistors, and peakers in plate loads, should be kept as close as possible to the tube socket, so their high-side leads are very short. Extra lengths

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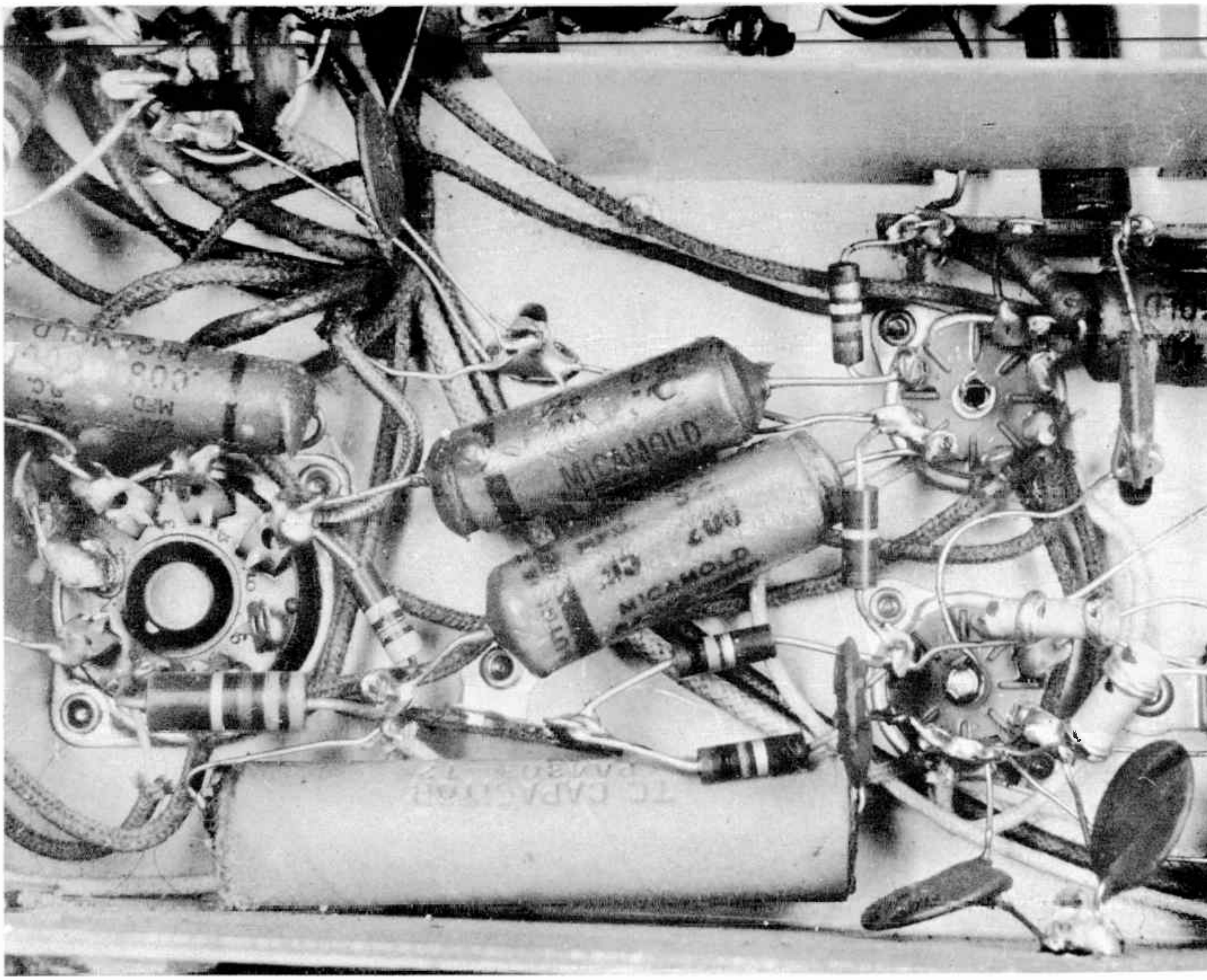

Fig. 5. Capacitors and resistors are placed close to tube sockets to allow shortest possible leads.

of leads or pigtails should be on the ground, B-minus, or B-plus sides.

Couplers or transformers in i-f, video, and sound intercarrier amplifiers should be close to grid lugs of sockets in these amplifier circuits, to allow short grid connections.

Peakers in video amplifier and video detector circuits should have short leads, but the leads should be long enough to keep peakers separated from chassis metal and from wiring leads. Do not attempt soldering close to peaker support forms unless you hold pliers on the pigtails between soldering iron and peaker. Ends of peaker windings usually are soldered to the pigtails, and will be loosened by excessive heat.

R-f chokes should be mounted close to chassis metal.

Coils, capacitors, and connections for oscillator circuits on converter tubes should be kept as far as possible from all other parts and wiring.

High-gain amplifier tubes operating at any frequency should not be located where they are close to, and are within strong magnetic fields of power transformers, power filter chokes, speaker field coils, or permanent magnets of PM speakers. Any or all of these fields can deflect electron streams in any tube, and cause peculiar troubles. Low-frequency amplifiers also will pick up hum or buzz at 60 or 120 cycles from such mag-

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netic fields when caused by currents at these frequencies.

When receivers have been altered, or poorly designed in the first place, it may be necessary to change positions of the parts mentioned as having strong magnetic fields. Sometimes it is sufficient merely to rotate a transformer or choke through part of a turn, without relocating it, to change the direction of field lines. The offending unit may be temporarily connected with flexible insulated leads while moving it to various positions and angles for trial.

DRESSING OF LEADS AND WIRES. Grid leads and plate leads for any one tube should be kept well separated from each other, at least as far as decoupling capacitors, in order to avoid feedbacks. Grid leads and plate leads for any one stage should be kept away from grid and plate leads for other stages. In general, it is desirable to keep grid leads well away from chassis metal, while plate leads may be run closer to chassis metal where necessary.

Where grid and plate leads of a signal transfer circuit are not of equal length, and both short, the grid leads should be as short as possible with necessary extra length on the plate side.

In vhf and uhf circuits the lengths, diameters, and positions of connecting leads often are major factors in fixing the value of stray capacitance for resonance at operating frequencies. If any of these factors are altered, tuning may become difficult or impossible.

All B+ leads from power supplies to decoupling resistors and capacitors should be dressed down close against chassis metal. Such leads include those to plates, screens, brightness controls, size controls, picture tube first anodes, and other elements. Leads which make up the agc bus are preferably dressed close to chassis metal. This applies also to avc buses in sound systems.

All low-frequency leads should be dressed close to chassis metal. This applies to line power and tube heater leads, to all leads in audio circuits, and to leads for both vertical and horizontal sweep and deflection sections.

When replacement parts have leads longer than required, as practically always is true, excess lengths should be cut off rather than tucked or coiled into any available spaces. If you do not wish to cut the leads, dress them back toward the part or circuit element operating nearer to ground and B-minus potentials, rather than toward parts operating at signal potentials. As mentioned before, make ground connections for replacement parts at the same points as original grounds.

High-voltage leads and connections require careful dressing, chiefly to prevent leakage, corona, and arcing, but also to reduce possibility of radiation of horizontal sweep frequency. The lead to the second anode of the picture tube should be kept clear of all grounded metal and of the grounded external conductive coating of a picture tube. This lead should have a heavy rubber or plastic insulating bushing where it passes through metal of the chassis or of a protective cage.

Leads from flyback transformer windings to plates of the output amplifier and the high-voltage rectifier should be well separated from each other, from all other wires, and from all grounded metal.

LOCATION OF TROUBLE DUE TO DRESSING. When frequencies which should not appear in certain parts or circuits actually do appear, it may be possible to locate the point at which trouble originates by using the oscilloscope. The first step is to connect the scope in the usual manner to the element showing the trouble, then try to tune the horizontal sweep frequency of the scope to bring onto the screen a waveform of the troublesome voltage.

Now the ground connection between chassis and scope should be left in place, but the high side tip or probe of the vertical input cable should be disconnected and left free. Increase the vertical gain, and move the vertical input probe or tip close to various points where the undesired pickup may be occuring. It is not necessary to touch the high side

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probe or tip to any conductors, but only to bring it close to points of suspected trouble.

When the vertical input lead of the scope is moved into a strong field caused by voltage or current at the troublesome frequency, there will be a decided increase of amplitude in the trace on the screen. Carefully check the dressing of leads and parts in areas where such pickup occurs. Reconnect the scope to the circuit or part affected by unwanted voltages while watching the effect of any changes in dressing.

REGENERATION AND OSCILLATION. The chief purpose of decoupling, shielding and dressing is to prevent passage of signal or other alternating voltages from one circuit into other circuits where these voltages may cause trouble. If voltages pass from output to input of the same tube, or from output to input of a single stage, or from output to input of an entire amplifying section, we have what is called feedback. If the feedback adds to the strength of voltages and currents at the input it is a regenerative feedback.

For a feedback to be regenerative three conditions are necessary. First, the circuits at which the feedback originates and those to which it returns must be capable of operating at the same frequency. Second, frequencies at the output and at the input must be alike or very nearly alike. Third, the feedback voltages and currents must be in phase or nearly in phase with voltages and currents at the input.

There is no objection to strengthening of signal voltages and currents by regenerative feedback when the action is under control. As an example, most oscillators depend on regenerative feedback for their operation. But now we are concerned with uncontrolled regeneration in amplifiers, where the most common result is irregular peaking at frequencies for which the circuits and parts of circuits may be resonant. If these circuits are of fairly low Q-factor they may commence to oscillate at any frequency within the band for which they are tuned. Then there is trouble.

It is quite easy to locate undesired oscillation when it occurs in a tube having a coupling or blocking capacitor between its grid and a preceding circuit, and having a resistor from grid to ground or B-minus. These are the elements required for grid-leak biasing.

Oscillation in a tube having a grid capacitor and grid resistor increases the alternating plate voltage enough to cause grid current in the grid resistor. This current makes the grid more negative than it should be. For a test it is necessary only to measure the grid bias voltage with a d-c VTVM. If this voltage appears to be much greater than bias for normal operation of the tube, oscillation probably is occuring.

Oscillation sometimes result from substituting a different type of tube for an original. The substitute tube might draw less plate current than the original type. Then there would be less drop in resistors in B+ lines feeding the plate, and plate voltage would become too high. The correction would be more dropping resistance or decoupling resistance.

In another case, plate and screen currents, and resulting cathode current in a substitute tube might be enough different than in the original to cause incorrect cathode bias. This would necessitate using a different cathode-bias resistance.

The usual reason for substituting a different type of tube in amplifying stages is to obtain greater gain. Transconductance and gain of the new tube may be so great, and signal voltages so increased, that the circuit oscillators. Also, the greater output from the substitute tube might cause oscillation in following stages. Internal shielding which was present in the original tube might be lacking in the substitute, or the internal shield might not be properly grounded through one of its base pins and the socket lugs.

Grids of amplifying tubes may receive not only signal frequencies at which the tubes are intended to operate, but other higher frequencies as well. These higher frequencies are amplified, and the action detracts from the ability of the tube to amplify intended frequencies.

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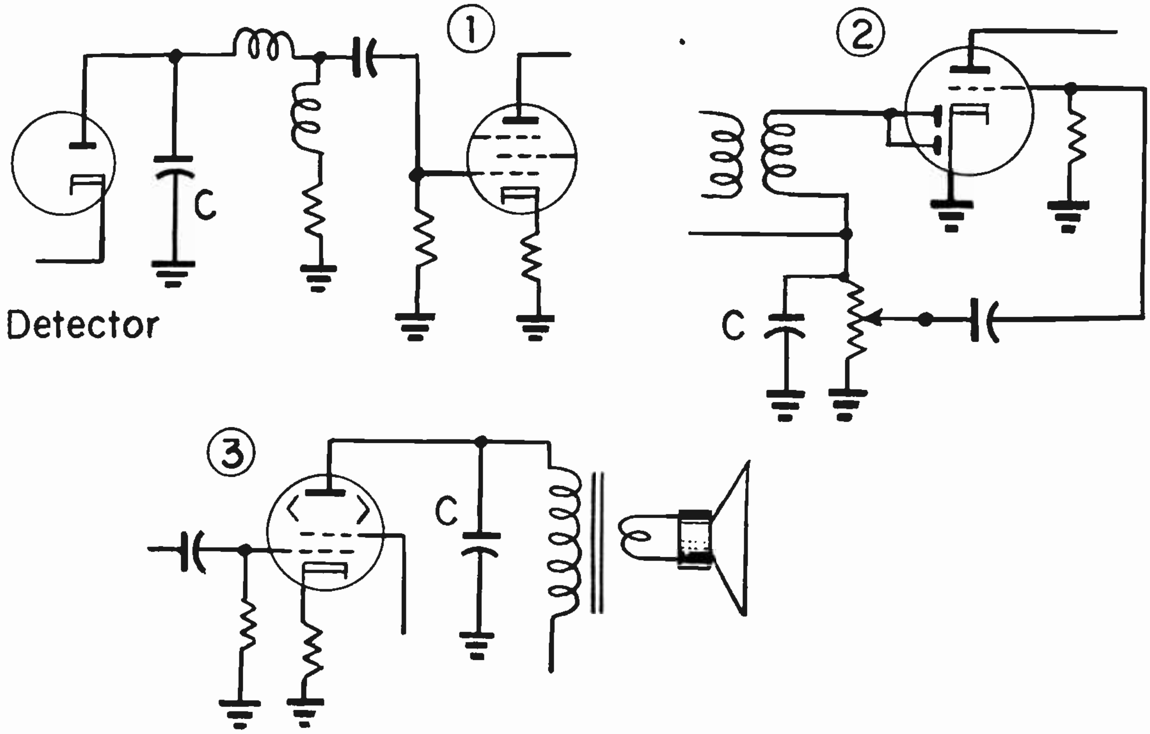

Fig. 6. Capacitors for bypassing and frequency correction.

A familiar example of removing unwanted high frequencies is illustrated at 1 of Fig. 6. The video detector receives intermediate frequencies. These frequencies appear at the detector output, along with demodulated video frequencies. The intermediate frequencies are prevented from reaching the grid of the video amplifier by bypassing them to ground through capacitor C. Capacitance of 5 or 10 mmf at C has reactance of only about 600 to 1,600 ohms at intermediate frequencies of 20 to 25 mc. But at medium video frequencies, which are not to be bypassed, the reactance is 8,000 to 16,000 ohms.

There is similar bypassing of intermediate frequencies at the output of a-m detectors, as in diagram 2. Bypass capacitor C usually is of about 250 mmf. This gives reactance of only about 1,400 ohms at the intermediate frequency of 455 kc, but reactance of more than 600K ohms at an audio frequency of 1,000 cycles.

In diagram 3 there is a capacitor, C, from the plate of the audio output tube to ground. The purpose of this capacitor is not to bypass high frequencies to ground, but to lower the effective impedance of the plate load at high frequencies. The plate load consists principally of inductive reactance in the speaker transformer. This reactance increases with frequency, and at the higher audio frequencies may so increase the plate load and consequent gain as to cause disagreeable emphasis of high-pitched notes. Reactance of capacitor C decreases as frequency goes up, and thus helps maintain a more nearly constant plate load and gain in the audio range.

PRINTED WIRING. Fig. 7 is a picture of two strips of phenolic insulation on each of which are four inductors. The inductors are flat spirals of thin copper, securely bonded to the insulation. These are examples of "printed wiring" as used for inductors in tuners, for inductors in high-frequency transformers or couplers, also for connections between circuit elements in many other electronic devices. Quite obviously, printed wiring does away with most of the problems of dressing and maintaining correct positions of ordinary conductors and small parts.

Although we speak of printed wiring, the method of forming conductors permanently fixed on sheets of insulation really is a variety of photoetching. The process commences with a sheet of insulation on whose

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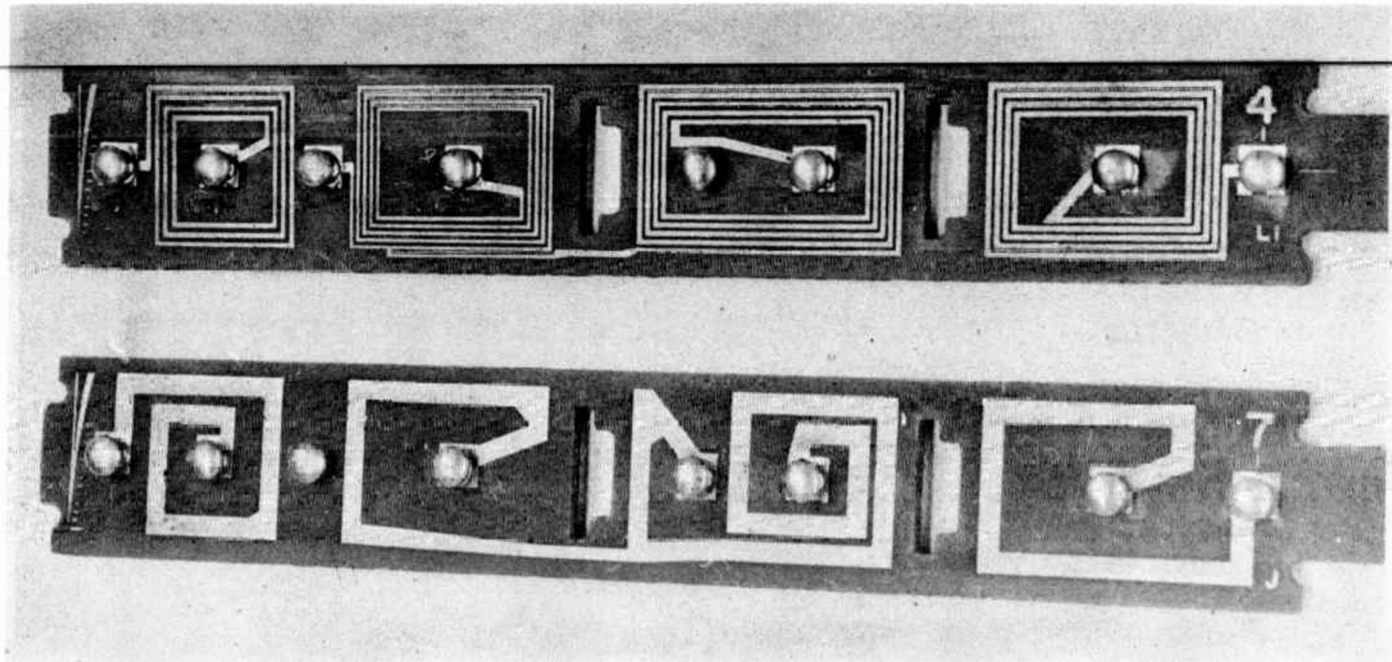

Fig. 7. Inductors on these channel strips from a television tuner are formed by so-called printed wiring.

entire surface is bonded a thin layer of copper. Over the copper is a coating of material having rather unusual properties. Any portions of this coating which later are exposed to light become semi-permanent after suitable chemical treatment, while parts not so exposed are removed from the copper by the same chemical treatment.

The design or layout of conductors to be formed in copper on the sheet of insulation has previously been photographed on film to form a negative. This negative, after development, is transparent along all the conductor lines, and opaque or dense black in all other areas.

The photographic negative is held in close contact with the coating on the copper while the combination is exposed to strong light. The light passes through transparent lines of the negative to enable the coating to become semi-permanent after chemical treatment. All portions of the coating protected from light by opaque parts of the negative are unaffected.

The entire plate, consisting of insulation, copper, and exposed coating, then is immersed in a chemical solution which removes the coating from all areas that have not been reached by light. That is, the coating is removed from all of the copper surface except the lines which are to form the desired conductors. Now only the circuit lines on the copper remain protected by the semi-permanent coating.

The next step is to immerse the plate in another solution which "etches" or eats away all of the copper not protected by the remaining coating, but which does not attack the semi-permanent coating. This leaves on the insulation only the lines of copper which are protected by the coating. These, of course, are the lines of the desired conductors or circuit, formed in copper securely bonded to the insulating support.

In Fig. 7 connections are made from the etched inductors to tubes and other circuit parts by means of metal studs which may be seen at the ends of the copper lines. When "printed wiring" is used for circuit connections in hearing aids and other small devices, the tubes, capacitors, and resistors may be mounted on the opposite side of the insulation, through which are suitable openings leading to the etched conductors.

Inductance and inductive reactance of printed "coils" may be adjusted in various ways. With one method a small piece of thin brass, copper, or bronze on the opposite side

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of the supporting insulation is moved by a screw with reference to the inductor. Moving the piece of metal to a position directly behind the coil provides minimum inductance, while moving it away from behind the coil increases the inductance. This is equivalent to moving a non-magnetic brass slug inside a coiled inductor.

With another method of adjustment a small, flat, non-magnetic plate is moved by a screw closer to or farther from the flat surface of the spiral-shaped inductor. Moving the adjuster plate closer to the inductor decreases effective inductance, moving the plate farther away increases effective inductance.

Where conductors must cross without electrical connection, one may be on the front of the insulating support at points where the other is on the back. In other cases the conductor on the supporting base is coated with insulating cement at the crossover. Then the other conductor is added by hand on top of the cement.

Capacitors may be formed by thin sheets of copper or silver on opposite sides of the supporting insulation, which acts as the dielectric. By using thin pieces of ceramic for the support it is possible in this manner to have capacitances up to 0.01 mf or more, occupying very small space.

Resistors may be formed on the insulating support by leaving gaps between ends of conductors, then applying in the gaps some kind of carbon or graphite composition furnishing resistance. The value of resistance is controlled by varying the width and thickness (cross section) and by using various lengths of resistance material in the gaps.

An entirely different style of "printed wiring" is employed in the units pictured by Fig. 8. What you see on the outside is merely a protective coating of phenolic composition, from which protrude tinned copper leads for external circuit connections. Inside the protective covering may be from one to four resistors. Interconnected with the resistors may be anywhere from one to five capacitors, forming complete electronic circuits or portions of circuits. Yet the largest of these units is only about 1-1/4 inches wide, 7/8 inch high, and 1/8 inch thick.

The internal capacitors are formed by depositing layers of silver on opposite surfaces of very thin ceramic material which acts as the dielectric. Capacitance values, controlled by using various areas of silver on material of suitable dielectric constant, range from 50 mmf or less up to 0.01 mf. Capacitance tolerances depend on the circuit and its requirements. In some units the tolerance is plus or minus 20 per cent, in others it is plus or minus 40 per cent, while

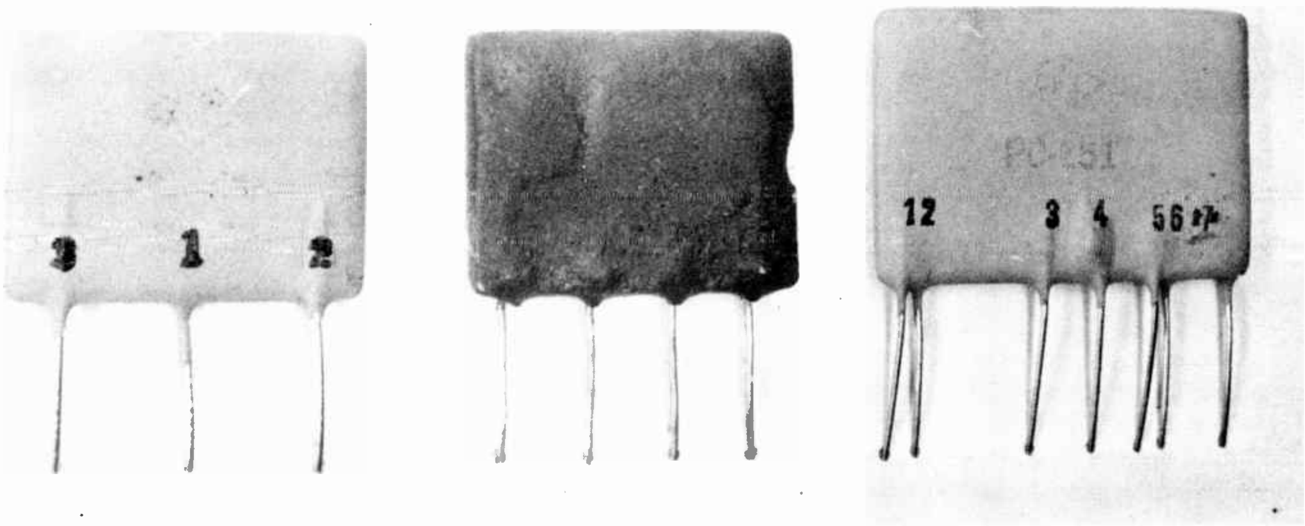

Fig. 8. In these units are electronic circuits consisting of resistors, capacitors, and conductors in various arrangements.

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in still other units the tolerance may be minus 20 and plus 50 per cent for capacitances of 1.000 mmf and less, or plus 80 per cent for larger capacitances.

Internal resistors consist of carbon or graphite or other suitable compositions deposited on parts of the ceramic not used as dielectric. These deposits consist of narrow strips joined between themselves and to metallic conductors as required for the circuit. Resistance values range from around 100 ohms to as much as 10 megohms. Resistance tolerances are plus or minus 20 per cent in almost all units. Resistor power ratings are from 1/10 to 1/5 watt.

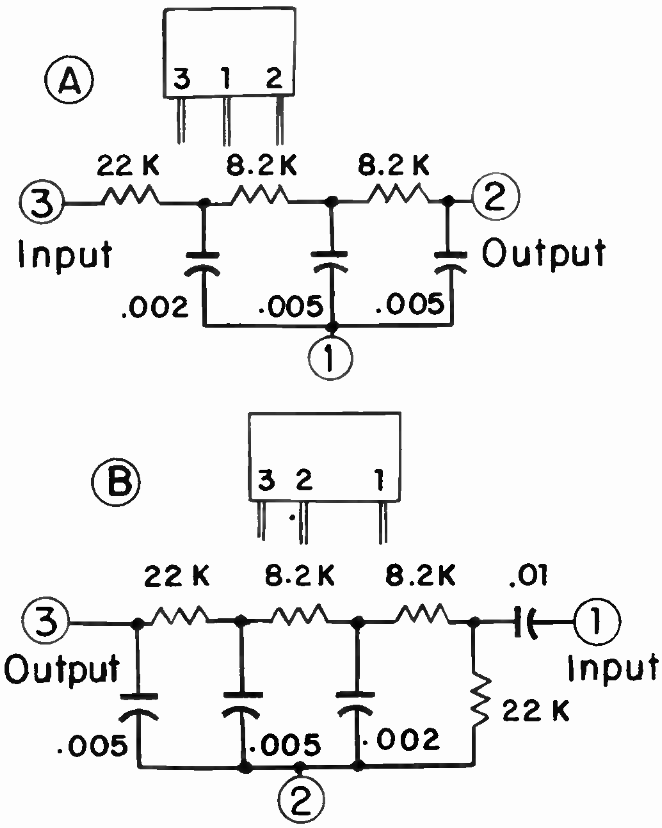

Fig. 9. Vertical integrating filters as contained in PC (printed circuit) units.

The printed circuit unit most widely used in television receivers is the vertical integrating filter. The style pictured at the left in Fig. 8 contains the circuit at A of Fig. 9. When checking this unit, measure total resistance between leads 2 and 3. Then tie leads 2 and 3 together while checking total capacitance between these leads and lead 1.

Another integrator circuit, shown at B of Fig. 9, contains an additional capacitor and a shunt resistor at the input end. This unit is checked for total resistance between leads 2 and 3, then for input capacitance between leads 1 and 2. If resistance checks OK between leads 2 and 3 you know that none of the three shunt capacitors are shorted.

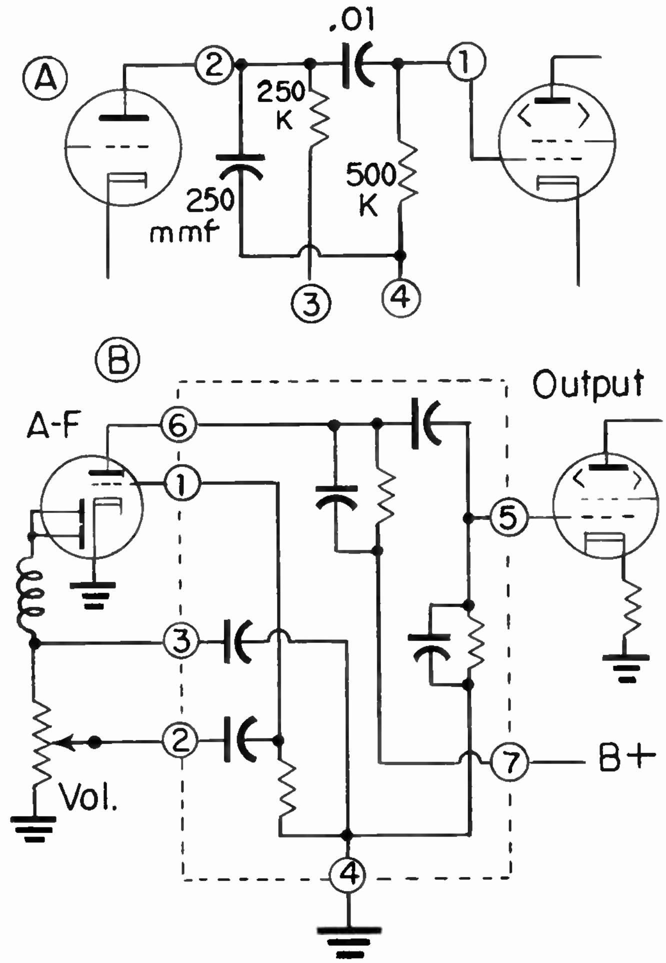

Fig. 10. Printed circuit couplers used between the plate of an a-f voltage amplifier and the grid of an audio output amplifier.

Other widely used printed circuits are those for coupling the plate of an a-f voltage amplifier to the grid of an audio output tube. Such a unit is illustrated at the center of Fig. 8. Its circuit connections are shown at A in Fig. 10. Tests would be made as follows. Measure the blocking capacitor between leads 1 and 2. Between leads 2 and 4 an ohmmeter should show infinite resistance or an open circuit if the 250 mmf capacitor or the .01 mf capacitor is not shorted. Measure the 500K resistor between leads 1 and 4. Measure the

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250K resistor between leads 2 and 3. Another audio coupler is pictured at the right in Fig. 8. Its connections are shown at B of Fig. 10.

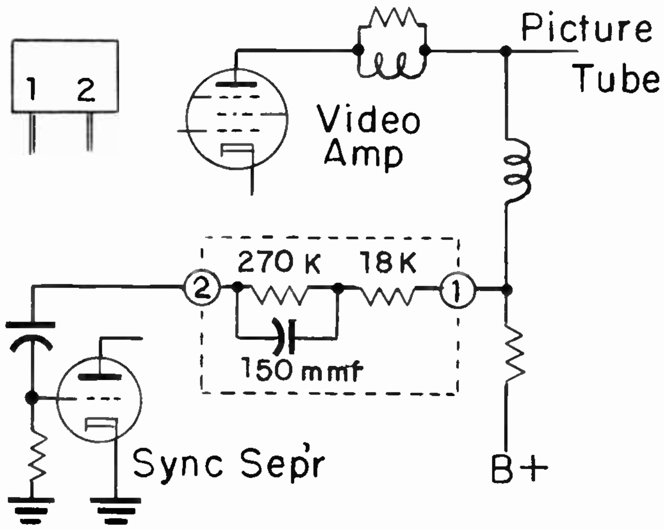

Fig. 11. A printed circuit unit between output of a video amplifier and input to a sync separator.

Printed circuit units are used for many filters and takeoffs. An example is shown by Fig. 11, where the unit is between the plate circuit of a video amplifier and the grid of a sync separator tube.

If one or more elements in a printed circuit become faulty it is desirable to replace the entire unit, since nothing can be done with individual resistors or capacitors. If a duplicate printed circuit is not available, the entire unit may be replaced with separate resistors and capacitors of equivalent values. Tolerances of replacement units should be no poorer, and resistor power ratings no less than mentioned earlier for the printed circuit units. Depending on internal connections and elements, it sometimes is possible to leave one of the leads disconnected and to replace the single element which thus is open circuited. The circuits illustrated are merely typical. Many others are available in standard units.

ELECTRON-RAY TUBES. An electron-ray tube is a kind of voltage indicator used in some radio sets, in many service testing instruments, and occasionally in television receivers. By means of a luminous pattern on a "target" which is visible through the glass envelope, the tube shows whether or not a connected circuit is adjusted for desired operating conditions. When used in radio receivers to indicate correct tuning, the electron-ray tube often is called a "magic eye".

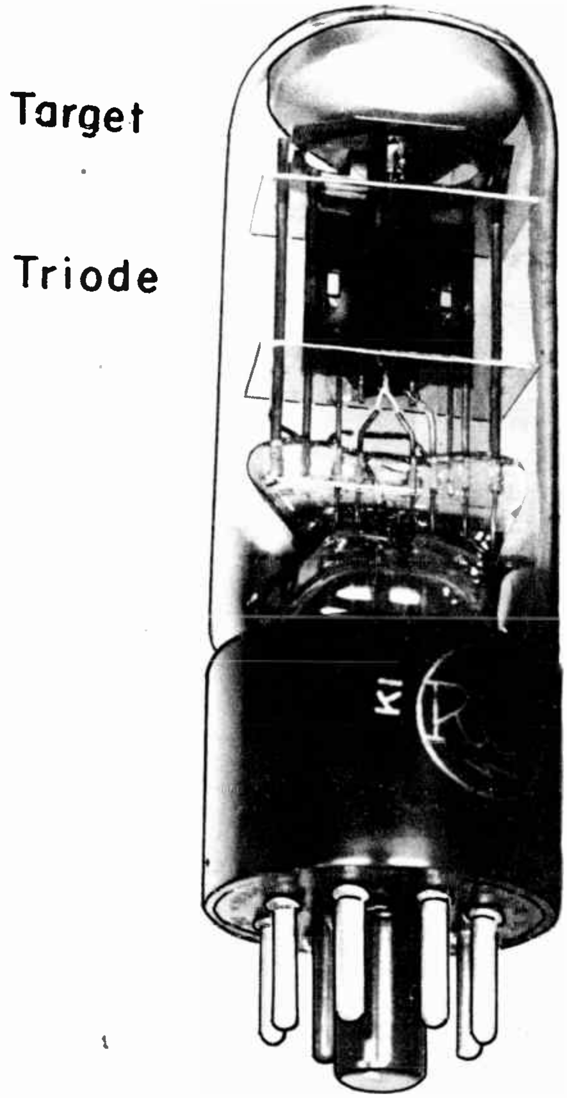

Fig. 12. An electron-ray tube, sometimes called a "magic eye".

One style of electron-ray tube is illustrated by Fig. 12. In the lower part of the envelope are the plate, grid, and cathode of a voltage amplifying triode. Up above the triode elements is a cup whose inner surface shows through the glass when you look toward this end of the tube. The inner surface of this cup, which is the target, is coated with fluorescent material quite like the phosphor for the screen of service oscilloscopes. A

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bright green glow appears on the target surface where it is struck by electrons.

deflector is attached to and is electrically part of the triode plate.

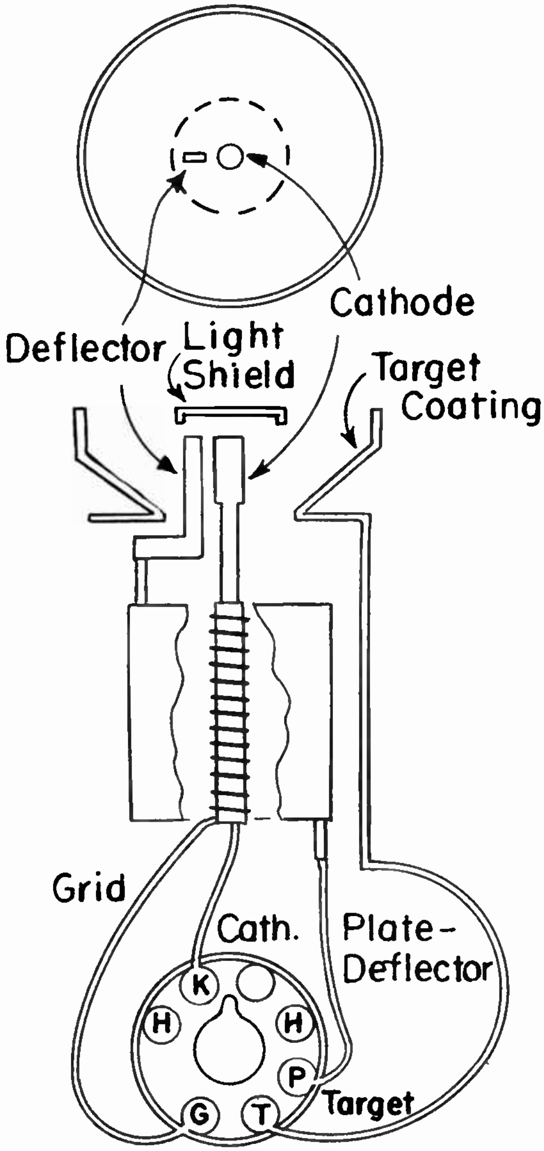

Fig. 13. How the principal parts are arranged within an electron-ray tube of the type containing an amplifier triode.

Some construction details are shown by Fig. 13. Electrons which strike the target come from an extension of the cathode, brought up into the center of the target cup. Electrons are attracted to the target because it is maintained at a potential of 100 to 250 volts positive with reference to the cathode. At one side of the cathode which is within the target is a thin, narrow strip of metal variously called the deflector, the deflecting electrode, or the ray-control electrode. This

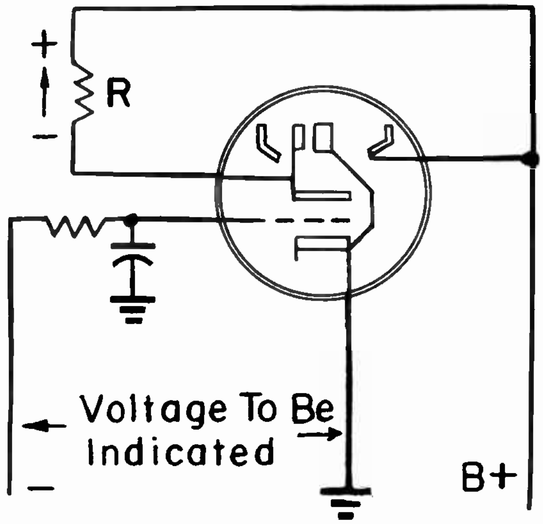

Fig. 14. Circuit connections for an electron-ray tube and its triode.

The electron-ray tube is connected to external circuits as in Fig. 14. The negative side of voltage which is to cause target indications is connected to the triode grid, and its positive side to the cathode. The triode plate and the deflector are connected to B+ and the target through resistance at R. The target is connected directly to B+.

Electron flow in the tube passes from cathode through the grid to the triode plate, then through resistor R. The plate end of R becomes negative with reference to its B+ end, which means that the connected triode plate and deflector are negative with reference to the target, although all these elements are positive with reference to the cathode.

The greater the plate current through resistor R, the greater is the voltage drop and the more negative will be the deflector with reference to the target at the other end of the resistor. Maximum plate current will flow when triode grid potential is zero with reference to the cathode. Therefore, with a zero grid, the deflector will be highly negative with reference to the target.

When the triode grid is made negative to the cathode, instead of zero, there is reduction of plate current, less voltage across resistor R, and the deflector becomes less

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negative with reference to the target. If the triode grid is made still more negative to the cathode, the deflector is made still less negative to the target.

Looking through the end of the glass envelope the target would appear as in Fig. 15. The light shield shown in Fig. 13 is not included in these diagrams. The only purpose of the shield is to hide the red glow of the hot cathode while looking at the green glow on the target.

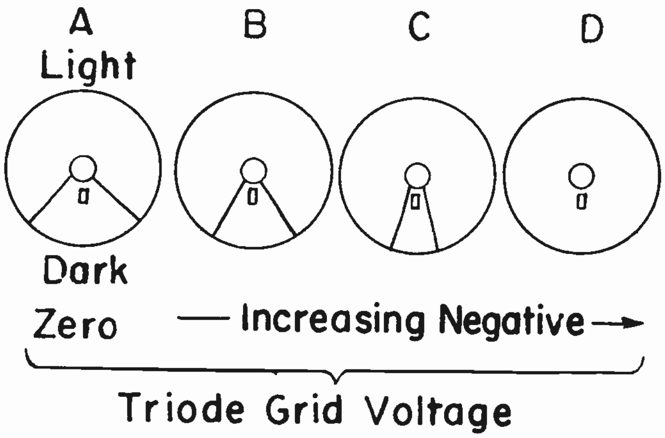

Fig. 15. How shadow angle varies on the target when there are changes cf triode grid voltage.

At A of Fig. 15 the triode grid is at zero potential to the cathode, and the deflector is at maximum negative potential to the target. The strong negative charge on the deflector, with reference to the target, repels electrons and prevents them from reaching the target on a pie-shaped sector which includes an angle of about 90 degrees. This sector remains dark. Because the target is positive with reference to the cathode, electrons flow to all the remaining target surface, and it glows brightly.

At B the triode grid has been made a few volts negative to the cathode. This makes the deflector less negative to the target, and the shadow angle becomes narrower, with more of the target lighted. At C the triode grid has been made somewhat more negative, and the shadow angle becomes still narrower. At D the grid has been made so highly negative, and the deflector so little negative to the target, as to shut off no electron flow to the target. The entire target area becomes uniformly lighted.

Width of shadow angle for any given negative grid voltage depends on the kind of electron-ray tube, on B+ voltage applied to the target, and on value of resistance and consequent voltage drop in resistor R.

In one kind of electron-ray tubes the triode section is of the sharp cutoff type. Approximate relations between shadow angles and grid voltages with a sharp-cutoff triode are shown by full-line curves in Fig. 16. Curve A shows performance with 125 volts on the target and resistance of one megohm between triode plate and target. Curve B shows the effect on shadow angle of increasing the target potential to 250 volts, the maximum permissible, with the same resistor between triode plate and target. The higher target voltage requires more negative grid voltage to produce any given shadow angle.

In another kind of electron-ray tube the triode is of the remote cutoff type. The broken-line curves of Fig. 16 show relations between shadow angles and negative grid voltages with a remote cutoff triode. Curve C illustrates performance with 100 volts on the target and resistance of a half-megohm between triode plate and target. With this low voltage on the target, the tube with remote cutoff triode behaves much like a tube with a sharp cutoff triode.

To make use of the remote cutoff characteristic in handling a much greater range of negative grid voltages it is necessary to use fairly high target voltages. Curve D of Fig. 16 shows performance of the remote cutoff tube with 250 volts on the target and resistance of one megohm between triode plate and target.

The maximum permissible target-to cathode potential difference for most electron-ray tubes is 250 volts. Target voltages of 180 to 220 volts give longer tube life and practically the same performance as maximum voltage. In some circuits there may be a cathode bias resistor on the electron-ray tube. Triode plate currents range from 1/10 to 1/4 ma in different tubes operated at B-supply voltages from 100 to 250. Target currents vary quite widely with individual tubes, ranging from somewhat less than one ma to four ma in most cases.

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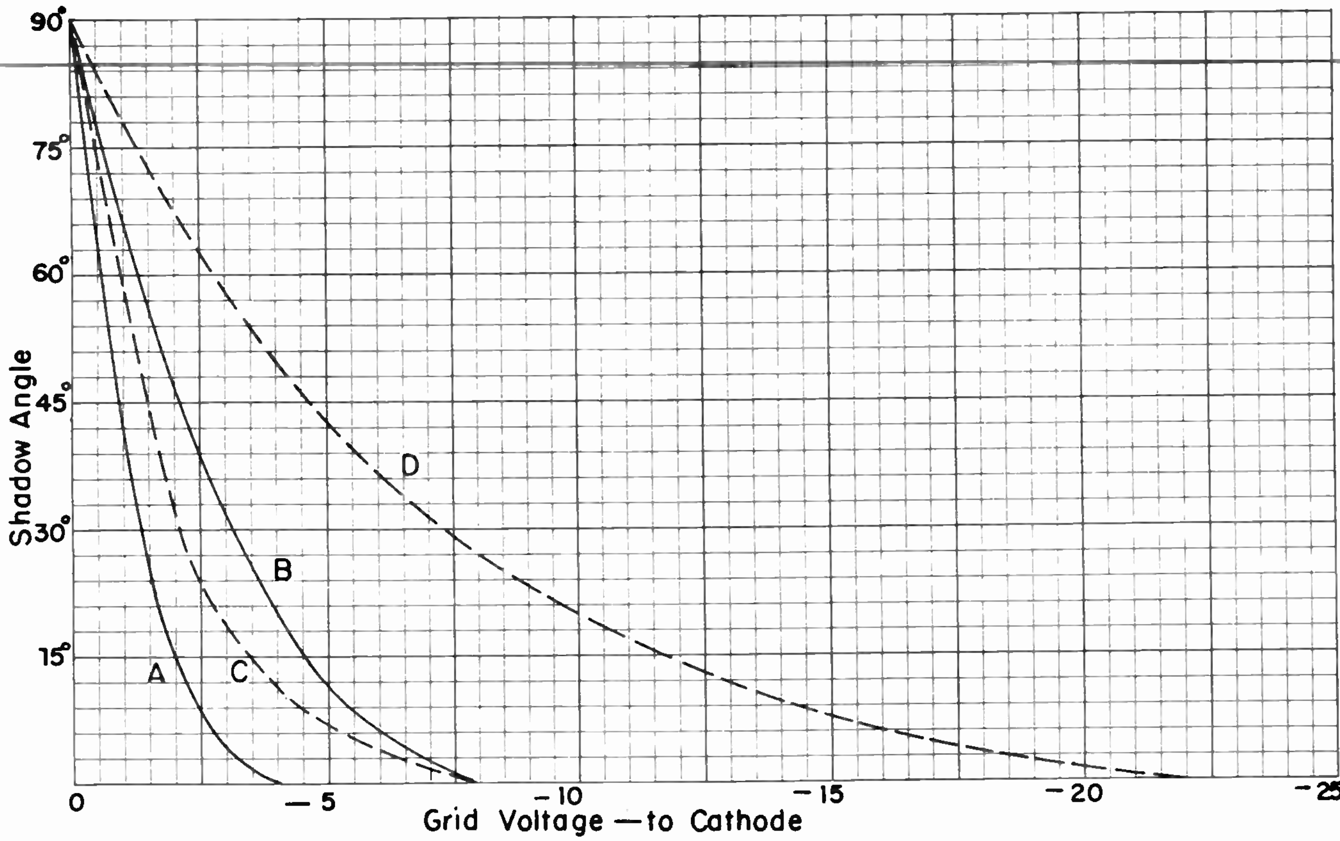

Fig. 16. Relations between shadow angles and grid voltages in electron-ray tubes having sharp-cutoff and remote-cutoff triode sections.

The resistor-capacitor decoupling filter in the grid lead of Fig. 14 prevents variations of indicated voltage from affecting the grid and causing fluttering of the target shadow. Values usually suitable for this filter are one megohm resistance and 0.1 mf capacitance.

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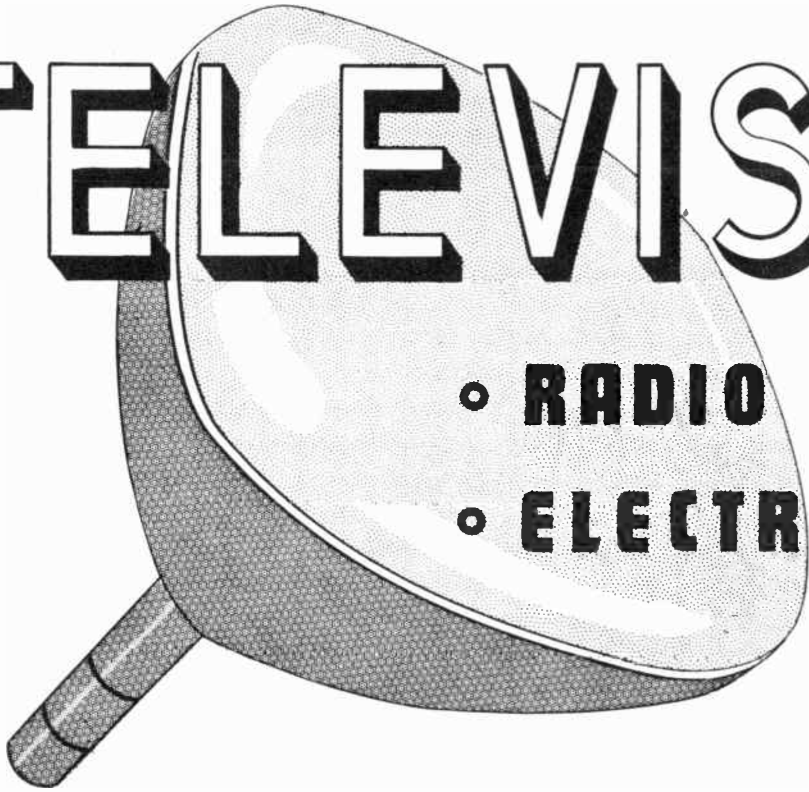
TELEVISION



• RADIO
• ELECTRONICS

LESSON 77 — NOISE IN TELEVISION PICTURES

Coyne School

practical home training

Chicago, Illinois

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Lesson 77

NOISE IN TELEVISION PICTURES

Fig. 1. This is a very "noisy" picture.

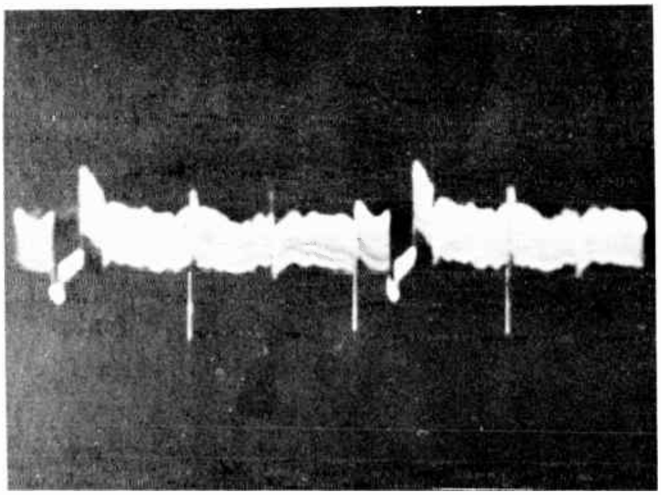

Fig. 2-A

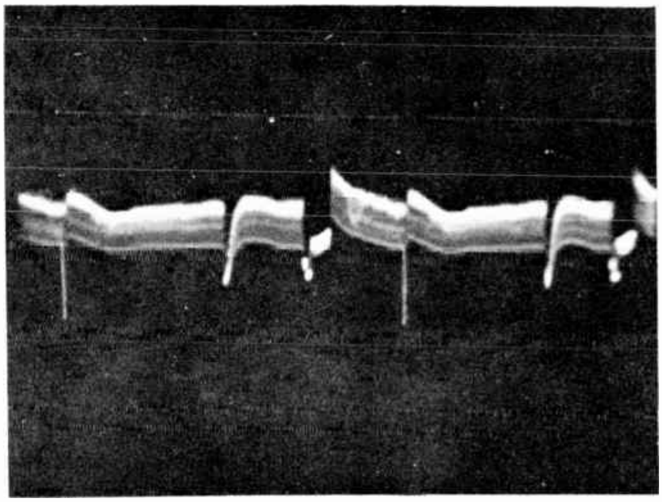

Fig. 2-B

Fig. 2. Noise pulses that drive the picture tube grid into the blacker than black level of signal voltage cause black streaks in pictures.

Fig. 1 is a photograph of a television picture strongly affected by noise. What we mean is this: Mixed with the picture signals are voltages which, were they in the circuits of a standard broadcast sound receiver, would cause noise from its speaker. The same voltages getting through the video section of a television receiver actually cause streaks, flashes, and flecks on pictures, but we refer to these effects as noise.

The dictionary says that noise is sound having no agreeable musical qualities, or that interferes with other sounds to which you wish to listen. What we call noise in television pictures results from voltages that cause only disagreeable streaking, flashing, or jumping of pictures. Noise voltages nearly always have the form of sharp pulses with sharp or ragged peaks. Fig. 2 shows how the oscilloscope sees noise pulses accompanying the video signal during two field periods.

When noise voltages drive the picture tube grid as negative, or more negative, than regular sync pulses there will be black streaks on the screen. This is because grid voltage is driven "blacker than black" at every noise pulse. You can see such noise voltages in Fig. 2. Resulting black streaks may appear, at any one instant, rather widely separated on the screen. The effect is shown by Fig. 3 where streaks have been drawn on a pattern photograph. There may be accompanying white streaks due to blocking of signals by negative charges remaining on capacitors after the cutoffs which cause the black streaks.

The great majority of noise voltages are caused by sparking, by arcing, or by very

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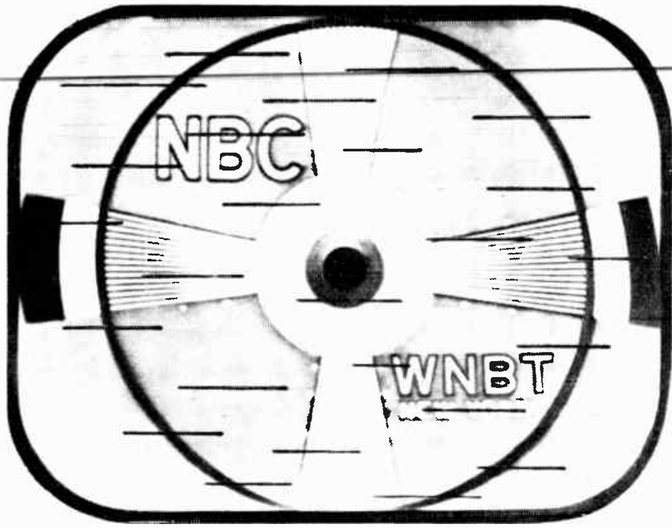

Fig. 3. At any one stant, noise streaks may appear widely separated.

sudden changes of current and voltage. Sparking may be so slight as to be invisible in ordinary light, or it may be in concealed places. The trouble may originate outside the receiver, or there may be faulty parts and connections within the receiver.

Sparking or sudden changes of current in any kind of electrical apparatus outside the receiver can cause radiation of electric or magnetic fields which may extend to considerable distances. These fields can induce noise voltages in a receiving antenna and its lead-in or transmission line. It is possible also for noise impulses to be carried by way of a-c power and lighting wires from a source to a receiver in the same building or on the same service line.

Noise consists of voltage that varies in amplitude. Such voltages cause trouble with television pictures and synchronization because picture and sync signals are in the form of amplitude modulation, and the circuits are responsive to variations of amplitude. Noise may ruin a picture yet have little effect on television sound, which is carried by frequency modulation and is little affected by variations of amplitude when sound amplifiers and detectors are working properly.

Frequencies of noise voltages extend all the way from a few cycles per second up into the television carrier bands. Noise may occur at any frequency, and over wide bands of frequency at the same time. Harmonics extend the range still further. Because of its wide frequency distribution, noise ordinarily affects reception on all channels to about the same degree. When received signals are weak, noise impulses may excite high-frequency tuned circuits into momentary oscillation at any channel frequency or any intermediate frequency.

TESTS FOR SOURCES OF NOISE. When looking for the source of severe noise, determine first whether the trouble is external or is within the receiver. Disconnect the antenna lead-in or transmission line from the tuner. Connect the two antenna terminals of the tuner together and to chassis ground. Set the channel selector where there is no local transmission. If noise effects disappear, noise voltage was entering through the antenna or the transmission line. Should noise effects persist, troublesome voltages originate in the receiver, come through the a-c power line, or possibly might be so strong as to be picked up by receiver wiring.

Power line noise usually may be detected if you have a good isolation transformer with grounded static shield, the kind used when servicing ac-dc sets having hot chasses. Operate the television receiver first from the isolation transformer, then directly on the building power line. Any additional noise evident with operation directly on the power line is line noise, which is reduced or eliminated by the isolation transformer. The set might be operated also with and without one of the power line filters mentioned in lessons dealing with decoupling.

How much noise originates in the receiver or comes through the power line, and how much comes through the antenna and transmission line may be determined as follows: Disconnect the transmission line as directed in the preceding paragraph, and set the channel selector where there is no local transmission. Turn the contrast control high, but keep brightness rather low. Noise normally produced by tubes and circuit resistance will show on the raster, about as in Fig. 4, provided there is not excessive noise entering through the a-c power line.

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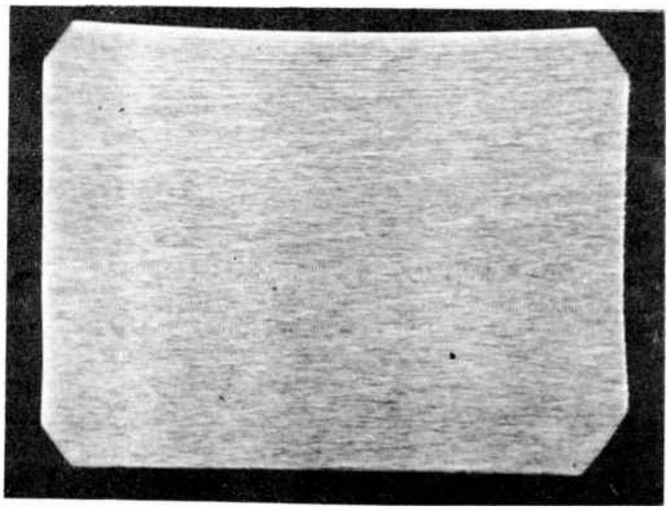

Fig. 4. Noise produced by tubes and resistances in the receiver will show on a raster, with no signal being received.

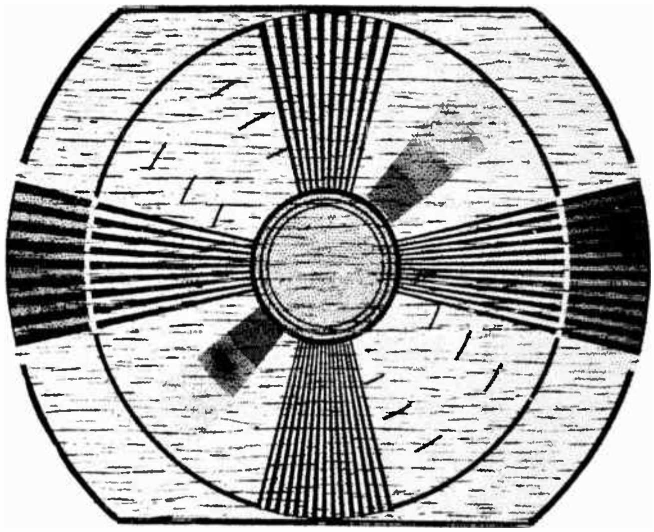

Fig. 5. Uniformly distributed black streaks usually result from steady sparking in electrical apparatus.

Reconnect the transmission line, tune in a station, and again turn the contrast control high, with brightness rather low. Noise effects in excess of those observed on the raster are due to noise from the antenna or transmission line. Noise due to pickup by the transmission line alone might be checked by disconnecting the antenna from this line, while leaving the line connected to the tuner.

EXTERNAL NOISE. Noise voltages may originate in certain household appliances containing motors or vibrators. Such noise sources include vacuum cleaners, food and drink mixers, sewing machines, and electric razors. Troublesome noise voltages seldom are caused by motors in fans, oil burners, modern refrigerators, air conditioners, dish washers, or hair dryers.

It is steady sparking at commutator and brushes of motors that causes trouble usually evident as small, overlapping, uniformly distributed streaks on pictures, much as shown by Fig. 5. Small motors of the universal type, for operation on either a-c or d-c power, have commutators and brushes. These are used in many household appliances. All d-c motors have commutators and brushes. Fortunately there are few d-c motors other than in apparatus such as farm and home lighting plants, and other engine driven devices. Street cars, also elevated and subway trains have d-c motors.

There are no brushes and no sparks in small shaded pole motors such as found in some hair dryers, electric clocks, and other appliances taking very little power when they start. Appliance motors which must start while loaded, as in refrigerators, stokers, and some air conditioners have no commutator or brushes when designed for a-c operation, but some of them have starting switches that spart only while the motor is getting under way from standstill. Other single-phase induction motors are of the capacitor start type, from which there is no sparking effect. Large motors operated from 220-volt and higher voltage power lines almost always are of the three-phase induction type in which there is no sparking at any time.

Sources of troublesome spark voltages found in offices, stores, and factories include such things as cash registers, electrically operated office machines elevators, and welding machines. Out of door sources of spark voltages include flashing signs, some neon signs, and some traffic signals. Any of the outdoor sources must be fairly close to the TV receiver to cause real trouble. Ignition sparks in automobiles, trucks, and busses affect pictures only when the TV antenna or transmission line are close to streets or highways carrying a great deal of such traffic. Flashes or streaks in pictures appear

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when electrical apparatus is switched on and off.

Severe noise effects often result from faults in building electric lighting systems. Look for loose lamp bulbs or bulbs with loose bases. There may be loose or dirty connections of wires in receptacles and outlets, or there may be defective wall switches or switches in lamp sockets or holders. With the television set operating, try turning lamp bulbs, moving them in their sockets if possible, turning switches on and off, and removing and replacing the plugs on power cords.

Modern fluorescent lamps of good quality give little or no noise trouble unless actually defective. If you suspect one of these lamps, turn it on and off while the receiver is in operation. Noise in pictures is most likely to result from a defective starter for a lamp causing trouble. The starter is a small cylinder, about 3/4-inch diameter and 1-1/4 inches long, that snaps into a bayonet socket in the lamp fixture. Try a new starter. They cost only a few cents at hardware and other stores.

Older fluorescent lamps may cause trouble. Trouble may come from new lamps having poor quality "auxiliaries", which are transformers and chokes. Such lamps may radiate noise fields to distances as great as 10 feet, or may pass noise voltages through the a-c power and light wiring to a television receiver.

REMEDIES FOR EXTERNAL NOISE. When you have determined that noise voltages are coming through the power line, examine the receiver wiring between its power cord connection and the primary of the power transformer or the power rectifier system of a transformerless receiver. If there is a low-pass filter consisting of series chokes or resistors and shunt capacitors to ground, examine the connections and terminals, measure the resistors, and check capacitors for opens or capacitances lower than rated values. Make repairs or replacements as needed. One example of a low-pass line filter is shown at A of Fig. 6.

If the receiver has no built-in line filter, or if you decide that the filter is ineffective, one may be installed between an a-c wall receptacle and the power cord plug, or better at the receiver end of the power cord. Line filters designed for television receivers may be had from supply houses. Even those cap-

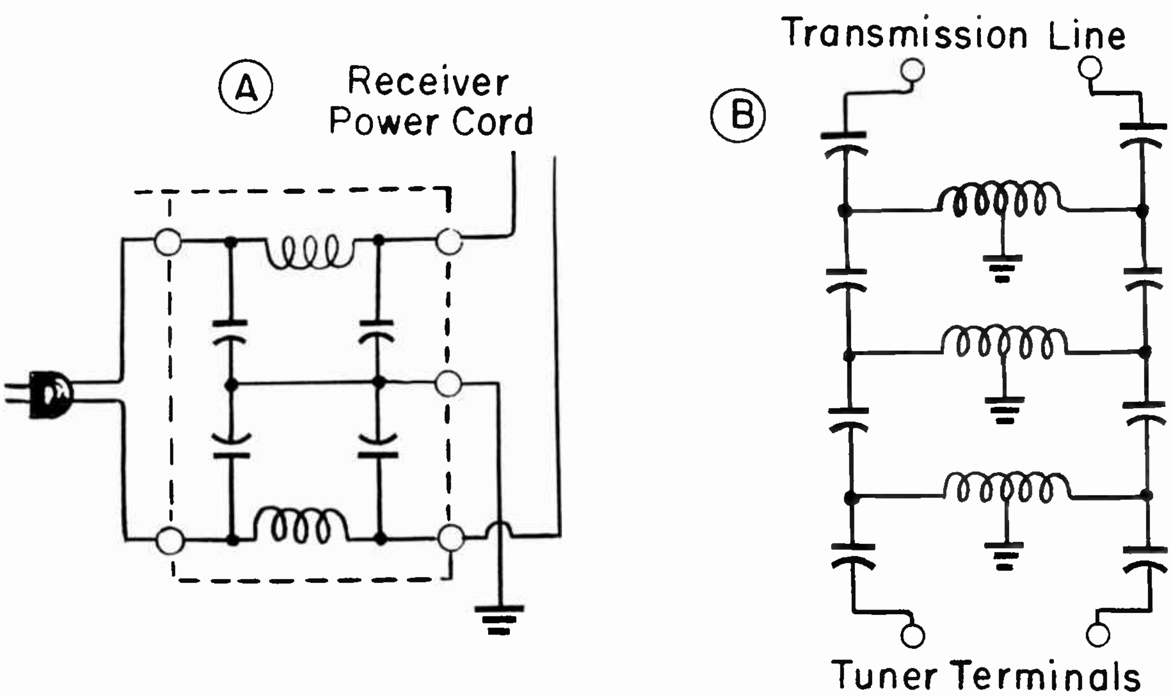

Fig. 6. Circuits in a low-pass power line filter (A) and in a high-pass antenna filter (B).

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able of greatly reducing heavy interference cost but a few dollars.

It is better, when possible, to install a line filter at the source of noise voltage. This is easily done when the source is an appliance or some motor-driven apparatus in the same building as the receiver. Turn off all suspected noise sources. Then, with the receiver in operation, turn on the sources one at a time until locating any offenders. Line filters for installation at sources are sold by television and radio supply houses in various types suitable for appliances or motors in all common power ranges.

When trouble from some small household appliance or other apparatus is not too severe it often may be eliminated by connecting a bypass capacitor between the two sides of the a-c line cord inside the housing of the troublesome device. Try a paper capacitor of 0.01 mf, rated for 200 d-c working volts when the a-c line voltage is 110-120. The capacitor pigtails will attach to the same terminals that carry the ends of the power cord.

If your tests indicate that noise voltage comes through the antenna or transmission line, the trouble may be reduced or eliminated by a high-pass filter installed at the tuner. A high-pass filter has capacitances in series with the line and r-f chokes shunted to ground. A television filter of this type passes freely all frequencies above about 40 mc, a range including all carriers, while greatly attenuating all lower frequencies where noise voltages are likely to be strong.

An example of a high-pass television noise filter is shown at B of Fig. 6. The four larger series capacitors are of 24 mmf and the smaller ones of 12 mmf. Total inductance of the center-tapped r-f chokes is 0.5 microhenry. Filters of this general types are stock items with supply houses. The units should be mounted as close as possible to the antenna terminals of the tuner, possibly on the chassis or in the cabinet.

RATIO OF SIGNAL TO NOISE. Whether pictures are seriously marred by noise depends on relative strengths of signal voltages and noise voltages at the grid-cathode circuit of the picture tube. If noise voltage is less than about one-tenth of picture signal voltage the noise won't be too objectionable to most viewers. But when noise gets up around one-sixth or more of picture signal voltage the result invariably is considered bad. It is the ratio of signal to noise that really counts.

Noise picked up by the antenna or transmission line enters the tuner along with desired signals. Both signal and noise will be amplified together, and equally throughout the receiver unless some receiver circuits are designed to reduce noise voltages.

If the receiver is fairly close to television transmitters, and if the antenna and transmission line are not too close to sources which radiate noise, there will be a satisfactory ratio of signal to noise in space around the antenna and line. If antenna and transmission line are of good quality or design and are properly installed the strong signals and relatively weak noise will reach the input of the tuner.

Where a receiver is far from transmitters, or where objects in between absorb or deflect a great deal of the transmitted power, signal strength at the receiving antenna will be weak. Then your problem is to pick up more signal, or less noise, or both. How this may be done is explained in detail by lessons on antennas and transmission lines, but some of the methods will be mentioned here.

It may be possible to rotate or "orient" an outdoor antenna to reduce noise more than signals, or to increase signal pickup without increasing noise proportionately. This is done by turning the antenna mast in its support. Such a change should be made while receiving the weakest channel or the one in which signals are accompanied by most noise, while observing the effect at the picture tube.

The antenna may be moved to a different position, where signal fields are stronger, noise fields weaker, or both. Elevating an antenna is almost certain to increase the signal, while reducing noise. A few more feet of antenna height often makes the dif-

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ference between satisfactory reception and pictures having little or no entertainment value. It is possible also to replace the original antenna with one of greater sensitivity, or with an antenna which is more directional. A directional antenna has strong pickup for signals coming from one general direction, and weak pickup for signals and noise coming from all other directions.

Where noise is picked up chiefly by the transmission line, the line may be rerouted through areas in which noise fields are not so strong. All transmission lines cause some loss or attenuation of signal strength. Signal strength may be increased by using a type of line having less loss than the original. In extreme cases of noise pickup by a transmission line the original may be replaced with a shielded line.

Should too much noise or too little signal enter the tuner, no amount of amplification in the receiver will help matters. That is, receiver sensitivity is of no avail when it strengthens signals and noise equally, without altering their ratio. In this connection do not confuse sensitivity, which means gain, with selectivity, which means frequency response.

Because noise ordinarily is at all frequencies its effects may be lessened by restricting the band of amplified frequencies, thus excluding noise at frequencies outside the narrowed band. Narrower frequency response means greater selectivity. A standard method for improving signal to noise ratio in weak signal areas is realignment of the i-f amplifier to narrow the response while increasing maximum gain. The response is not changed on the video intermediate frequency side of the curve, but is pulled in to exclude more of the low-frequency side. Picture definition will be poorer, but noise effects will be weaker.

Boosters or reamplifiers connected between transmission line and tuner often increase the ratio of signal to noise. Noise is reduced and signal strength increased if the booster narrows the frequency response while adding to total gain.

Tuned amplifier stages having high gain are more subject to noise trouble than those of lower gain, because high-gain resonant circuits are high-Q circuits, and a high-Q circuit exhibits the flywheel effect. Flywheel effect means a continuing back and forth swing of energy between capacitance and inductance of a resonant circuit. A noise impulse starts the swing, which continues after the impulse ceases, and thus makes the effect even more visible on the picture tube.

RECEIVER NOISE. We might classify sources of noise in three general groups. First are all the noises which originate outside the receiver, as already discussed. Second are noises generated within the receiver, even though everything is in perfect operating condition. Third are noises caused by defective parts and connections in the receiver. We shall now talk about noise generated in even the best of receivers, and later examine element and circuit defects which cause noise.

THERMAL NOISE. What is called thermal noise results from irregular movement of free electrons in all conductors. Whether or not there is current in a conductor, all its free electrons are continually moving about between atoms. Current means only that there is more movement in one direction than in other directions. But this greater total travel or average travel in one direction still is made up of countless electron jumps from one atom to another. These jumps cause small, irregular voltages in the conductor and between its ends. These are noise voltages.

This particular variety of noise voltage increases with rise of conductor temperature, because heat makes the electrons jump more energetically. Hence the effect is called thermal noise; thermal being a word for heat. Thermal noise increases also with conductor resistance; electrons must work harder to move in materials of high resistance.

When you tune between stations on a sound radio receiver equipped with ordinary types of automatic volume control, there is a decided hissing sound from the speaker. The hiss is amplified noise, chiefly thermal

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noise. Avc action increases the gain when there is no signal, and we hear the noise. Thermal noise exists at all frequencies, it cannot be tuned out.

Most thermal noise comes from resistors, because they have more resistance than other conductors of similar size, and usually run hotter than other conductors. It follows that thermal noise may be somewhat reduced by using resistors of greater wattage rating than required for actual power dissipation. Such resistors are larger and work at lower temperatures than resistors operated closer to their full ratings.

TUBE NOISE. Another kind of internal noise is produced by tubes, again as a result of electron motion. When electrons strike a screen or plate, the electrons give up their energy. This energy transfer is not at a rate absolutely uniform, because each separate electron delivers its load independently, and more of them may strike an element at one instant than at another. The very small variations of current due to this action cause noise voltages.

Tube noise is lessened by operation with plate currents considerably smaller than the tube is capable of handling in relation to its cathode emission and quantity of space charge. Tubes having high transconductance in comparison with plate current produce less noise than others. This means that voltage amplifier tubes tend to be less noisy than power amplifiers.

Triodes are inherently less noisy than pentodes, because in a triode there is no screen and no suppressor with which electrons may collide. The greater the number of elements between cathode and plate, the greater is the tendency for any tube to produce noise. In some recent types of television tuners the r-f amplifier stage contains a twin triode with its sections in series. The two triodes cause less noise than a pentode r-f amplifier.

We are talking here about noise produced by tubes in good condition. Defective tubes almost always are noisy. There will be much noise from a vacuum tube which has become gassy due to continued overheating of elements or other causes. The heavy ions produced by ionization of the gas collide with elements between cathode and plate. Heater-cathode leakage increases tube noise, because leakage current flows irregularly through cathode-heater insulation. If a pentode is used with incorrect plate and screen voltages, to allow secondary emission, there will be increased noise.

Fig. 7. The effect called snow results chiefly from thermal and tube noises, which become more apparent when received signals are weak.

SNOW IN PICTURES. Excessive thermal noise and tube noise cause pictures to appear as in Fig. 7. This is the effect called "snow" by technicians, who usually say it means a weak signal. Snow actually does mean a weak signal, it means that signal input to the tuner is so weak that the contrast or picture control must be turned very high to see any picture at all. Then the excessive gain strongly amplifies thermal and tube noises, as well as the weak signal. The ratio of signal to noise is much too small at the picture tube input, and we see the noise as snow.

HOW NOISE IS AMPLIFIED. Thermal noise and tube noise may be reduced by good design and correct operation, but they never can be wholly eliminated. These internally produced noise voltages combine with noise entering the tuner from antenna and transmission line, and noise entering by way of the a-c power line. As signals progress through the receiver, every stage and section

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adds its own thermal and tube noise, which then is amplified by all following stages. It is important to understand how noise is built up as it travels from stage to stage within the receiver, and the final effects at the picture tube of initial noise at the tuner and of noise added by all the following stages and sections.

To show what happens we shall assume that there is fairly good signal strength and not too much noise at the input to a tuner, but that noise is produced in the r-f amplifier stage of the tuner. This stage will amplify both the input signal and the input noise, and will add its own noise. Each following stage will amplify all noise coming to it, and will add more noise.

Growth of noise voltage in a receiver is illustrated by Fig. 8. We begin, at A, with only the noise coming from antenna and transmission line. At B noise is added in the r-f amplifier. Total noise is increased by amplifier gain, which brings us to C, the mixer input. At D the mixer stage adds its own noise. For simplicity, all noise added in receiver stages is assumed equal in strength to noise from the antenna, also to noise added in the r-f amplifier.

Next there is more gain in the mixer, and we come at E to the input for the first i-f amplifier stage. This amplifier adds noise at F. There is further gain in the first i-f amplifier and a proportionately higher noise level at G, the input to the second i-f amplifier. Once more there is added noise, at H.

We might continue similarly all the way to the final video amplifier, but at the right in Fig. 8 the fact of real importance has become plainly evident. Noise added in the second i-f amplifier is but a small fraction of the total. Amplified noise from the first

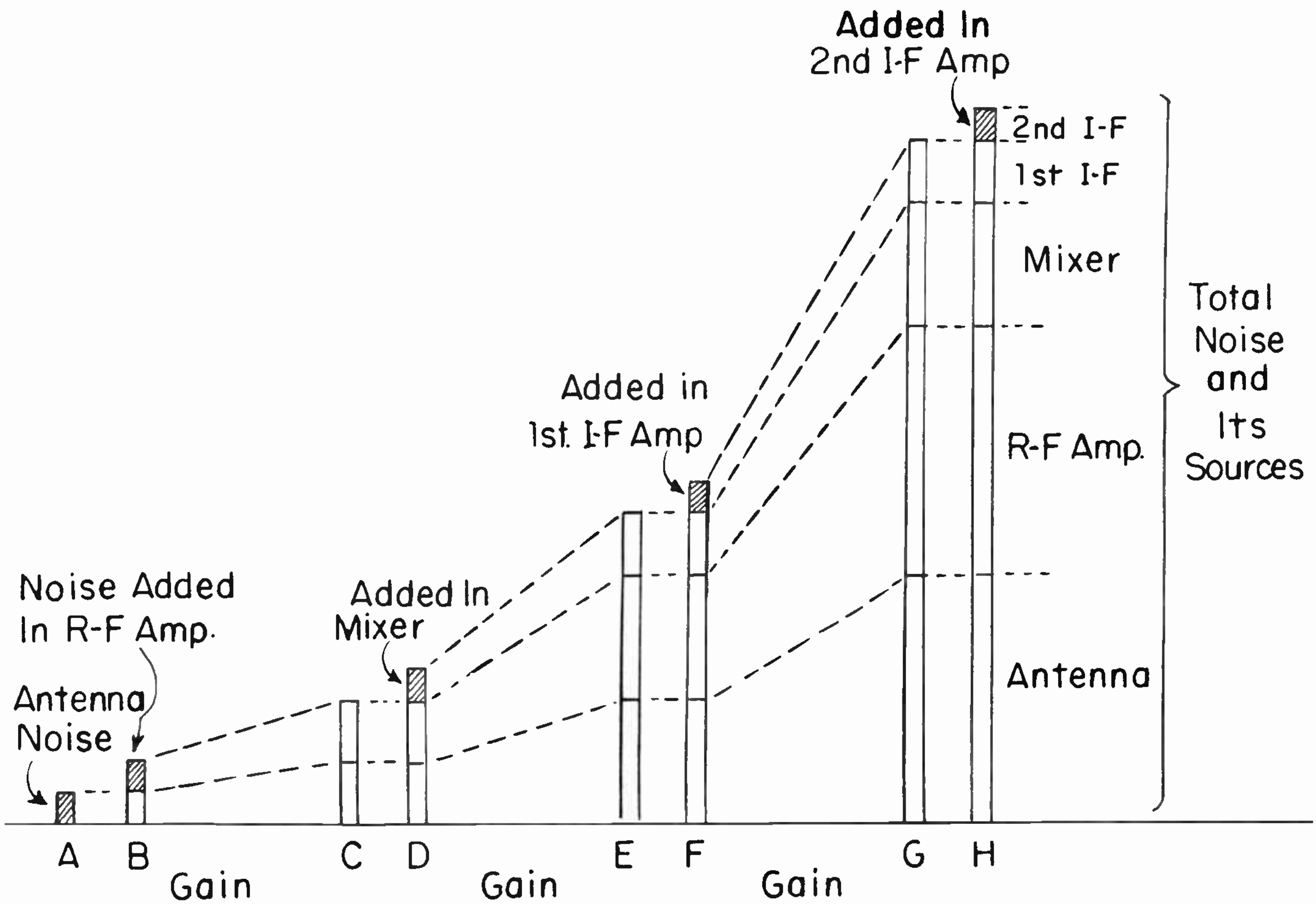

Fig. 8. Noise voltages originating at the antenna and r-f amplifier cause more trouble than noise added in following stages of a receiver.

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i-f amplifier isn't much greater. But amplified noise from the mixer is stronger than noise from two stages of i-f amplification. Amplified noise from r-f amplifier and antenna is far greater than all other noise combined.

From all this we learn that any really effective reduction of total noise must come from reduction of noise from the antenna and of noise from the r-f amplifier in the tuner. Noise introduced by any or all following stages is relatively unimportant by the time we arrive at the signal input to the picture tube.

NOISE DUE TO DEFECTIVE PARTS. It is fortunate that noise caused by defective parts and connections within the receiver may be eliminated by the competent technician. Otherwise these noises would be amplified just as are thermal and tube noises - and the earlier the stage containing the faulty circuit elements the worse would be the final result at the picture tube.

Among parts likely to cause noise when defective are contrast or picture controls, or there may be faulty action in brightness controls. Try operating these controls. If there is noise or a change in noise, look for wear and roughness of resistance elements over which sliders travel. If there are appearances of overheating, check associated circuits to locate the cause for overload or excessive current in the resistance element. Turns of wire sometimes loosen on wire-wound controls. The correction for any damaged control is a new unit.

Noise voltages are caused by various faults in selector switch contacts. If contacts have worked loose there is a possibility of tightening them by pressing or lightly tapping the rivets, but the looseness usually reoccurs after a short period of operation. Switch contacts may have been bent or twisted so that they make too little pressure on segments. Bent contacts often may be straightened by working very carefully. If contact surfaces or segments are scratches or worn into grooves, only replacement will make a satisfactory repair.

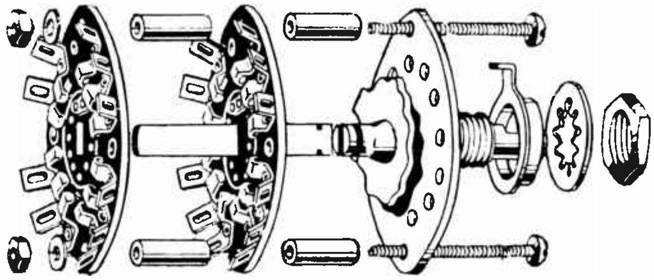

Fig. 9. Most rotary selector switches may be disassembled for small repairs or replacement of parts.

Most rotary switches may be disassembled to make contacts and segments more accessible for repair. Fig. 9 shows how one kind of switch comes apart. The sections are held on the mounting base by long screws and spacer tubes. When taking a switch apart, make a sketch showing relative positions of wafers, spacers, and all washers. Show also which sides of rotors are toward the front and which toward the back.

One of the more common causes for noise is dirt or slight coatings of oxide on contact surfaces of switches, including the rotary switches used for channel selection in many television tuners. Contacts are cleaned most easily and with least danger of damaging the surfaces by using liquids, of which carbon tetrachloride is best known. This and various other liquids for contact cleaning may be had from television and radio supply stores. Any of the liquids may be applied with a small, stiff brush to contacts which can be reached. Some cleaning liquids are under pressure in cans equipped with a thumb-operated valve. The valve opens a nozzle from which the liquid may be squirted onto contacts not readily accessible for brushing.

Use only enough of any liquid to cover the contact surfaces. Turn the switch back and forth through all its positions before the liquid dries, or while it is being applied. All the cleaning liquids dry rapidly. Some contain lubricants remain and allow switches to operate more freely after the cleaning. When used sparingly none of the contact cleaning liquids should have any tendency to cause short circuits nor to change electrical characteristics of circuits.

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Liquid contact cleaners are useful with many push-button operated switches, whose contacts often are quite inaccessible. In fact, these cleaners may be used with any style of switch having sliding contacts. When contact surfaces of resistance elements and sliders in control potentiometers are only dirty, not roughened or otherwise damaged, application of a liquid contact cleaner often will restore the control to usefulness.

Some of the most puzzling causes for noise are in defective connections of wires and leads to solder lugs and other kinds of terminal fastenings. Slight arcing or momentary high resistance occurs at such places. Make a check by using a non-metallic probe to lightly press or tap all suspected joints while the set is operating. Use needle-nose pliers or non-metallic tongs to move or lightly pull on wires or pigtails at terminal or lug connections. Be sure to check each separate conductor where two or more attach to the same solder lug or terminal. Any change of noise, or its disappearance, shows that you are moving a defective joint.

There may be rosin joints or cold solder joints. Try resoldering suspected joints with a hot iron while touching the joint with the end of a piece of rosin-core solder to provide flux. If wire ends or terminals appear corroded, scrape them clean, then resolder. Watch for wire strands which may make partial or momentary short circuits. Watch also for defective or missing insulation which may allow momentary shorts when the set vibrates or is jarred.

Corona discharge in the high-voltage supply for picture tubes will cause an effect similar to snow in pictures, while flashovers on high-voltage conductors will cause bright flashes, loss of sync, or may momentarily obliterate the picture.

When corona or arcing has existed in the past, a service man may have applied an excess of insulating cement. Some cements soften and flow when the receiver is warm, and get into terminals or cable connector contacts where they cause high resistance or intermittent opens. If a faulty connection seems to be coated with cement, scrape away the cement to allow closer examination. Cement may be softened or removed with cement solvents or thinners, or possibly with lacquer thinner obtainable from paint or hardware stores.

MICROPHONIC NOISE. A microphone changes vibrations of air or of solid objects into corresponding variations of current and voltage in an electric circuit containing the microphone. If a tube, capacitor, or other circuit element in a television or radio receiver can do the same thing it is said to be microphonic. A microphonic tube is one whose elements may vibrate because of improper internal supports. Vibration varies spacings between elements, varies internal capacitances and electron flows, and may thus cause plate currents and voltages to vary or alternate at the same rate as the vibration. These, of course, are noise voltages.

Parts other than tubes can produce microphonic noise voltages. For example, a capacitor or any other fairly large part containing metal might be supported so insecurely as to allow its vibration. Spacing between the metal-containing part and the chassis might vary during the vibration. This would change the capacitance to ground, and could introduce voltages at the vibration frequency.

A microphonic tube in a sound radio receiver causes the speaker to emit sound at the vibration frequency of the tube elements. The sound usually is a sort of ringing, or it may be a whistle or squeal which continues as long as the tube elements vibrate. A microphonic tube in a television set usually causes bright flashes on the picture tube screen, or may cause severe jumping and almost complete obliteration of pictures while microphonic vibration continues.

The tube most likely to give microphonic trouble in television receivers is the r-f oscillator in the tuner of sets having dual or split sound systems. Next in order of possible trouble are all voltage amplifier tubes, commencing with those nearest the tuner. Then come tubes in the sync section. Least likely to cause microphonic trouble are such heavy-duty tubes as audio amplifiers and sweep amplifiers.

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A tube whose elements lack proper support may commence its microphonic act when started into vibration by sound waves from a speaker mounted in the receiver cabinet, or when vibrated by any movement of the chassis. To determine which tube or tubes are microphonic, have the set in operation while tapping each suspected tube with a finger nail, with a pencil eraser, or with a small rod of wood or fibre over the end of which is a piece of rubber tubing.

Even though a tube is not actually microphonic, it may cause pictures to jump at the instant of each tap. Should symptoms continue for a period after each tap it is quite probable that the tube really is microphonic and should be replaced.

Test tubes for microphonic trouble only in the sockets where normally used. A tube may be microphonic in one position and not in another position, or there may be microphonic trouble with the chassis inside the cabinet, but not with it outside. Make final tests with any regular shield in place on the tube, with the chassis in its cabinet and the back fastened to the cabinet, and with sound volume turned fairly high.

Sources of microphonic trouble difficult to locate may be found with the oscilloscope. Connect the vertical input of the scope to the picture tube grid or cathode, whichever of these receives video signals. Adjust the scope for viewing a trace of either a vertical or horizontal period of video signal.

Now jar the chassis to observe the effect of microphonic action of the oscilloscope trace. Move the vertical input back to some point such as the output of the last video amplifier, then try to produce the microphonic effect. If the trouble has disappeared, the cause must lie between the present connection of the vertical input and the eariler connection to the picture tube.

Should microphonic trouble still show on the trace, move the vertical input of the scope further back, say to the video detector output, and try again. The same general procedure may be followed for stages in sync and sweep sections. When the trace remains stationary, the source of trouble is between the point at which the scope then is connected and the previous point at which trouble still showed on the trace. Following is a summary of causes and remedies for microphonic trouble.

1. Tube actually microphonic, elements not properly supported.

   Install a new tube.

   Substitute a tube of same type from another position, interchange the tubes.

   Try tilting the tube in its socket, to hold it more securely. This is only a temporary remedy.

2. Tube shield loose or vibrating.

   Tighten the shield on the tube and in the chassis clips, by lightly pressing or bending the shield metal.

   Solder the shield base to chassis metal.

   Fit the tube with a heavy shield made of lead. Sheet lead may be obtained from a plumber.

3. Socket does not hold tube securely.

   Examine the tube pins and socket openings to make sure they engage tightly. It may be necessary to install a new socket, possibly of better quality.

   For octal base tubes it is possible to install a cushion socket or floating socket. These are stock items with supply houses.

4. Sound waves of air within the cabinet.

   Excessive sound volume, reduce it.

   Deaden the inside of cabinet walls and top with thick felt or equivalent.

   The speaker may be too close to the affected tube; not much can be done other than fitting the tube with a heavy shield of lead.

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5. Loose fastenings.

Examine supports of the tuner. Look for loose screws or nuts. Check screws and lock washers of tuner adjusters. The tuner shaft or a fine tuning shaft may rest against sides of a chassis or cabinet opening.

6. Speaker vibrates mechanically or bodily.

Mount the speaker on rubber, or check condition of rubber mounts in use. See Fig. 10.

7. Chassis vibrates in cabinet.

Examine the condition of rubber cushion mounts which support the chassis.

Install rubber grommets or pieces of heavy rubber tubing between bottom of chassis and cabinet bottom. See Fig. 11.

8. Vibration of capacitors and other parts supported by pigtails.

Pigtails may be so long that supported parts are not held motionless. Shorten or tighten the connections, using additional spaghetti if leads are thus pulled closer to other conductors.

9. Filter chokes and speaker field coils.

If such parts are close to an affected tube the magnetic fields might be the cause of microphonic action, but this is unlikely because such fields have frequencies lower than probable rates of vibration in tube elements.

ANTI-VIBRATION MOUNTS. Fig. 10 shows some anti-vibration mountings or cushion mountings suitable for speakers, phonograph motors, small auxiliary chasses, and generally similar parts. The purpose of such mountings is to absorb vibration in themselves and prevent it from reaching the parts supported.

Every anti-vibration mounting must do two things. First, it must prevent all contacts other than through rubber between the part supported and whatever does the supporting. Second, the mounting must provide a support so secure that the receiver may be turned on its side or upside down without supported parts getting out of place. All rubber used in anti-vibration mounts should be live and springy. Rubber of kinds intended for insulation, even though called soft rubber, usually lacks the springiness necessary for absorbing vibration.

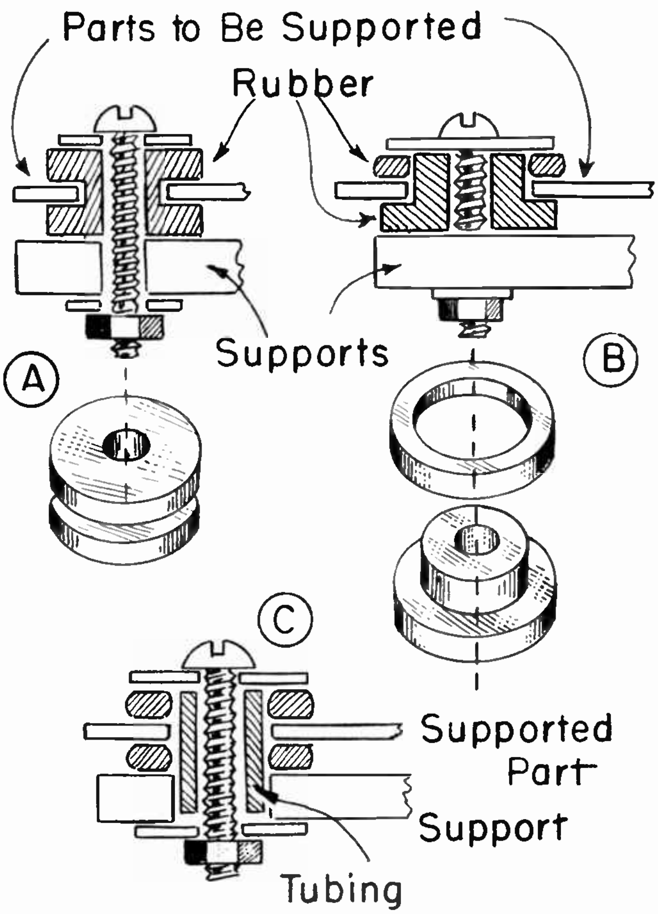

Fig. 10. Anti-vibration mountings for small parts such as speakers and phonograph motors.

In diagram A of Fig. 10 the rubber is of a form usually called a grommet. The attachment screw goes through a hole in the grommet. A groove around the outside of the grommet fits into a hole in the supported part. There is no direct contact between the support and the part supported, nor is the supported part in contact with the attachment screw.

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In diagram B the rubber parts consist of a ring or washer, and of a member usually called a chassis mount. Chassis mounts, rings, and grommets are available as stock items in many sizes.

Diagram C shows one expedient that might be used when no really suitable rubber parts are at hand. There are two rubber rings, which might be packing washers for joints in garden hose, or better be cut from a sheet of sponge rubber. The screw is kept from contact with the supported part by slipping a piece of rubber tubing over the screw. Rubber tubing can be had from drug stores and 10-cent stores.

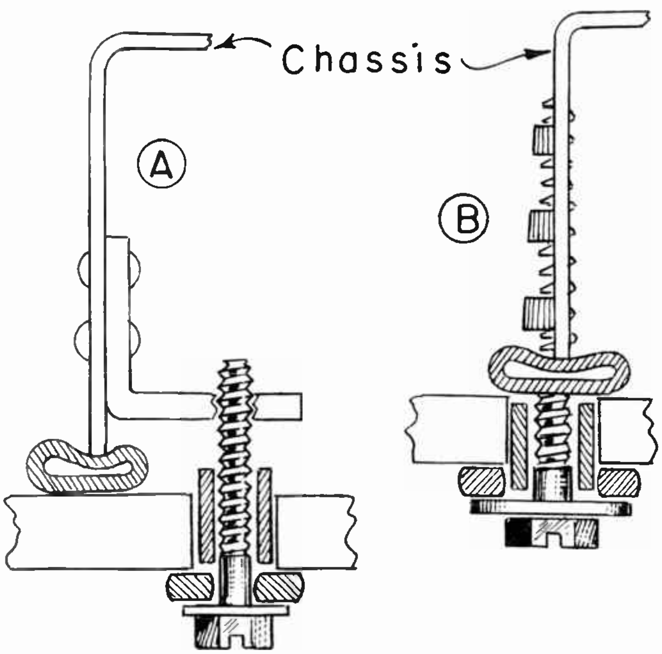

Fig. 11. Anti-vibration mountings for chasses.

Fig. 11 shows anti-vibration mountings for main chasses on bottoms or shelves of cabinets. At A the chassis has angle brackets into which thread the chassis mounting screws. The bottom edge of the chassis is kept off the cabinet by pieces of rubber tubing. Pieces of sponge rubber might be used here. The screw must pass directly into the angle bracket, for support, but the screw is kept from direct contact with the cabinet by a rubber washer and piece of tubing.

Diagram B shows an anti-vibration mounting for a main chassis held to its cabinet by long screws that thread themselves through loops punched from chassis metal. The bottom edge of the chassis rests on a piece of rubber tubing, which again might be replaced by a piece of sponge rubber. The screw is kept from direct contact with the cabinet by a rubber washer and piece of tubing. The rubber washers and tubing in both diagrams might be replaced to advantage by regular chassis mounts, such as used at B of Fig. 10.

NOISE, AGC, AND SYNC. As you know, negative grid voltage for automatic gain control in r-f and i-f amplifiers usually is obtained by rectification of sync pulses, by utilizing part of a detector output voltage, or by other methods which commonly are modifications of these two. When noise pulses pass through the same circuits as sync pulses, the effect of noise is to make agc voltage more negative. This lowers the amplification of r-f and i-f tubes, making it necessary to advance the contrast control if carrier signals are weak. Then noise appears stronger than ever, although pictures still are weak.

This action by which noise reduces picture strength while itself being emphasized is prevented to large extent by circuit designs explained in lessons on automatic gain control. Keyed agc systems protect automatic gain voltage from all noise pulses except those which happen to occur during the brief periods of sync pulses. Noise limiting and clipping prevent large changes of agc voltage due to noise. Delayed agc may help, provided it actually prevents reduction of gain while signals are weak.

When you have difficulty in locating the cause for noisy pictures, check the performance of an agc system. Try replacing the agc amplifier tube, if one is used. Measure agc tube voltages and measure changes of agc voltage while noise is apparent in pictures.

Strong noise pulses getting through to the sync section and sweep oscillators may cause temporary loss of horizontal synchronization, vertical synchronization, or both. The symptoms are diagonal bars or sidewise jumping when horizontal sync fails, or rolling of pictures up or down when vertical sync

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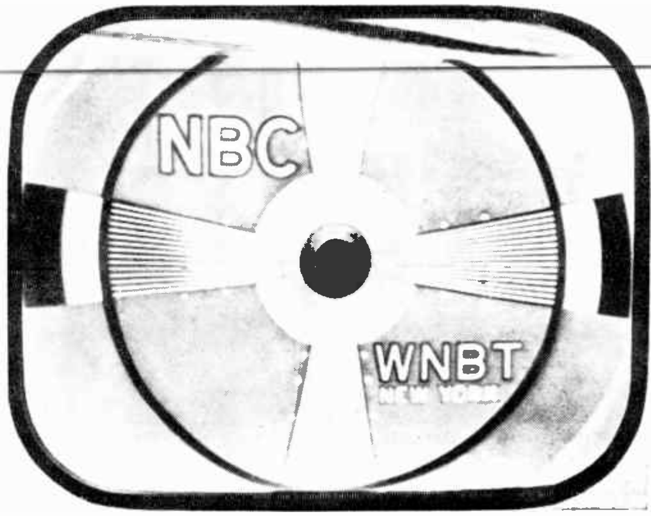

Fig. 12. Strong noise may so upset horizontal synchronization as to cause tearout.

is affected. Noise sometimes causes tearout, as shown at the top of the pattern in Fig. 12. There may be tearout also at the bottom of pictures.

In the lesson on "The Sync Section" are described many methods for using diodes, triodes, and pentodes for suppressing or cancelling noise pulses in sync circuits. All such tubes and circuits should be examined when noisy pictures are accompanied by loss of sync.

The principal reason for using automatic frequency control systems ahead of horizontal sweep oscillators is to maintain constant oscillator frequency in spite of noise pulses which may pass all the way through a sync section. Should the horizontal hold control seem unable to maintain steady pictures, while the control tube and its circuit voltages appear normal, make tests for excessive noise reaching the afc input.

About the only way to observe effects of noise voltages at sweep oscillators is with the oscilloscope. The vertical input of the scope may be connected to the plate or grid of a blocking oscillator, or to the plate or cathode of a multivibrator oscillator. If strong noise voltages are present it will be impossible to obtain clearly defined stationary waveforms. Traces will be fuzzy, jittery or covered with small pips and spikes which should not appear. Tests of this kind are not difficult, because at the elements of sweep oscillators there should appear fairly standard waveforms which are much the same in all receivers.

Automatic gain control and picture synchronization may be interfered with by noise originating either outside or inside the receiver. All the remedies previously outlined for preventing noise in pictures are equally good for keeping noise from agc systems, sync sections, and horizontal afc systems.

In this lesson we have dealt only with noise voltages. Noise voltages interfere with picture reproduction, consequently often are considered to be one variety of a large group of troubles classed as interference. However, we shall limit our own definition of interference to troublesome radio-frequency voltages occuring only in narrow bands, such as signals from unwanted television transmissions and from many other kinds of radio transmissions. Such r-f interference is considered after lessons on tuners and antennas, because these two determine how well a receiver installation will exclude r-f interference.

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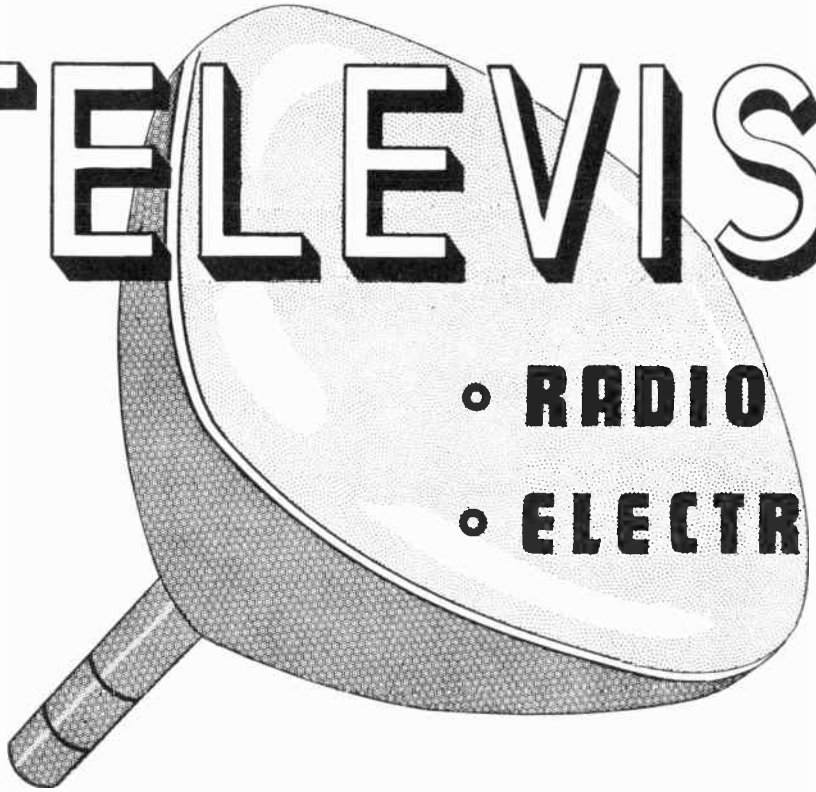

• RADIO

• ELECTRONICS

LESSON 78 — HUM AND SOUND IN PICTURES

Coyne School

practical home training

Chicago, Illinois

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Lesson 78

HUM AND SOUND IN PICTURES

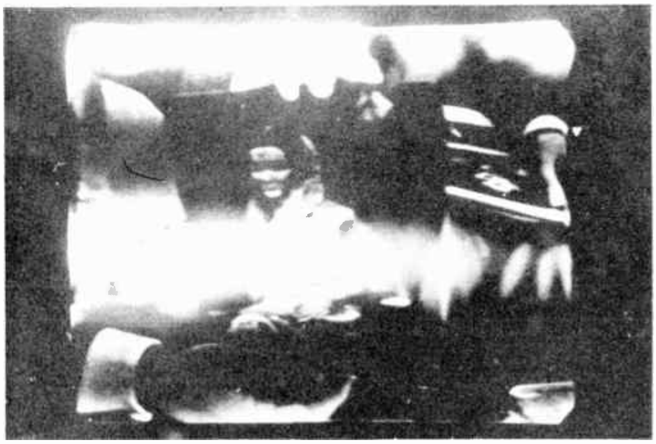

Fig. 1. Ripple voltage at 120 cycles may cause two dark and two bright horizontal bars on pictures.

Across the picture of Fig. 1 are two dark bars, with bright areas above and below each bar. This is what happens when a voltage at 120 cycles reaches the grid-cathode circuit of the picture tube. Were the same 120-cycle voltage to get into the audio amplifier and speaker of either a television or radio receiver it would cause audible hum. This is the reason why we speak of horizontal dark bars as being hum in the pictures.

Fig. 2 shows the reason why 120-cycle hum voltage causes two dark bars across pictures. The electron beam in the picture tube travels from top to bottom of the screen and completes one field in 1/60 second. During this 1/60 second of time the 120-cycle hum voltage completes two of its cycles, with two positive alternations and two negative alternations.

Each positive alternation makes the picture tube grid more positive, or actually less negative with reference to the cathode. This increases intensity of the electron beam and makes pictures brighter while the beam is traveling downward during the positive alternation. Each negative alternation of 120-cycle voltage has opposite effects, it makes the grid of the picture tube more than normally negative, decreases beam intensity, and makes pictures too dark while the beam is traveling downward during the negative alternation.

In Fig. 2 the 120-cycle hum voltage is shown as going through its zero just as the beam in the picture tube starts downward from the top of the screen, and as going through another zero just as the beam reaches the bottom of its travel. The result is two bright bars and two dark bars occupying equal vertical distances on the screen.

In Fig. 1 there is a bright area at the top of the picture, another one about half way down, and the beginning of a third bright area at the bottom of the picture. This indicates that the 120-cycle hum voltage was well into one of its positive alternations when the electron beam started downward. Then the troublesome voltage went through one complete negative alternation to cause a dark bar, through a complete positive alternation to cause a bright bar, another negative alternation for a dark bar, and was beginning still another positive alternation as the electron beam reached the bottom of the picture area.

Dark and bright bars may appear anywhere between top and bottom of the screen, depending on phase or time relations between hum voltage and vertical sync timing in the

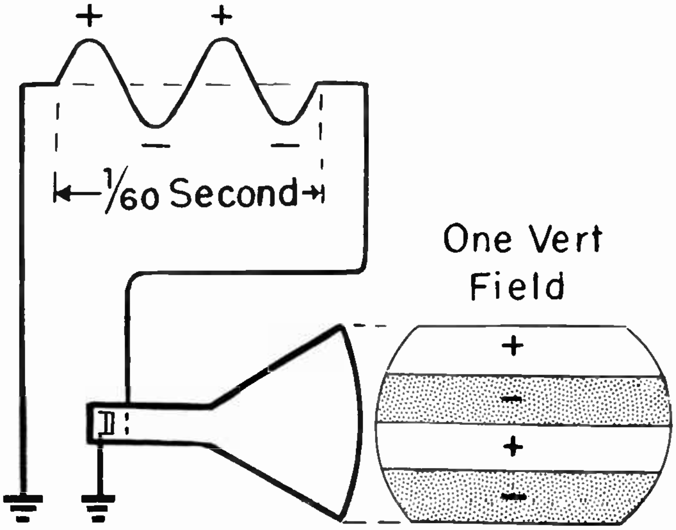

Fig. 2. How the 120-cycle voltage causes alternate dark and bright horizontal bars.

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receiver. Were frequency of hum voltage to be a little less than 120 cycles, all the dark and light bars would move continually downward on the picture tube screen. Were hum frequency a little more than 120 cycles, all the bars would move continually upward. Only when the interfering frequency is an exact multiple of vertical sync frequency, 60 cycles, will the bars stand still.

Whenever you can distinguish two complete dark bars or two complete bright bars, frequency of voltage causing the trouble is at or very close to 120 cycles per second. Ripple voltage from a d-c power supply having a full-wave rectifier and operating from a 60-cycle power line is 120 cycles in frequency. Consequently, two complete horizontal bars, either dark or bright, indicate that power supply ripple is getting to the grid-cathode circuit of the picture tube.

Supposing that in the grid-cathode circuit of the picture tube there is hum voltage at the power line frequency of 60 cycles. Such voltage might come from various places. For example, there might be heater-cathode leakage in some amplifier tube, allowing 60-cycle a-c voltage on the heater to get into the cathode, and thereby into signal circuits.

Fig. 3. A 60-cycle hum voltage causes one horizontal dark bar with brighter areas above and below, or might cause one complete bright bar between dark areas.

The result at the picture tube would be a single horizontal dark bar, as in Fig. 3. This dark bar is caused by the single negative alternation of 60-cycle hum voltage that occurs during each of the downward sweeps of the electron beam, which occur at a 60-cycle rate.

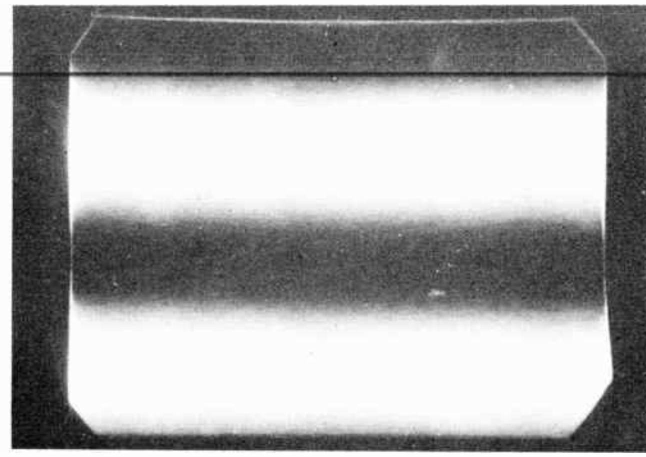

Fig. 4. Hum voltage effects show plainly on the raster.

You can see effects of 60-cycle and 120-cycle hum voltages even better on a raster than on pictures. If you believe that horizontal dark areas in pictures may be due to one of these hum frequencies, turn the channel selector to a position where there is no local transmission and advance the brightness control enough to illuminate the screen. A 120-cycle hum voltage will cause the effect shown by Fig. 4. A 60-cycle hum voltage would cause a single horizontal dark bar on the raster.

With only a raster there is no television signal to provide vertical sync pulses. Then vertical sweep will be synchronized by any hum frequency at or close to either 60 cycles or 120 cycles when this hum voltage can get into the sync circuit ahead of the vertical sweep oscillator. Then the hum bars will remain stationary on the screen of the picture tube.

Hum voltages whose effects are illustrated by Figs. 1, 3 and 4 are reaching the grid-cathode circuit of the picture tube, but are not reaching the sync and sweep circuits. When strong hum voltage reaches a sync or sweep circuit it makes pictures appear wavy all over, and especially so on the right-hand edge. Fig. 5 shows the effect of hum getting into the deflecting coils in the yoke on a picture tube. There are no dark horizontal bars, only waviness.

In many cases a hum voltage will reach the grid-cathode circuit of the picture tube, also the sync or sweep circuits. This hap-

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Fig. 5. Waviness results from hum voltage getting into sweep circuits.

pens when hum voltage gets into a video amplifier circuit ahead of the point at which sync signals are separated or taken from the video amplifier circuit to the sync section. The result is shown by Fig. 6. Dark horizontal bars are caused by hum voltage on the grid of the picture tube. Accompanying waviness, most noticeable on the right-hand edge of the picture, is due to hum voltage getting into the sync section and feeding through the sweep section.

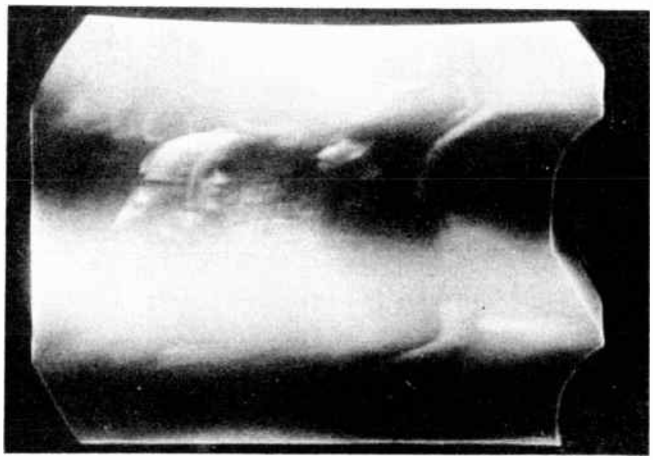

Fig. 6. Waviness accompanied by horizontal bars means that hum voltage is reaching the picture tube grid and also the sweep circuits.

<u>DETERMINING PROBABLE LOCATIONS OF HUM SOURCES</u>. A knowledge of television principles can save much time when tracing hum voltages. Here are some examples. If you see pictures like those of Figs. 1 and 3, with dark bars but no waviness, look first at the video amplifier, not in the sync and sweep sections. If you see something like Fig. 5, with waviness but no distinct horizontal bars, look first in the sync and sweep sections following the point where sync signals are taken from the video amplifier.

If, as in Fig. 6, there are horizontal bars plus waviness, look first at the video amplifier ahead of the sync takeoff point, because hum is affecting both the grid-cathode circuit of the picture tube and the sweep section of the receiver.

A general principle which helps locate the probable source of hum voltage is as follows: Voltages at frequencies so low as 60 and 120 cycles are not amplified by tubes in circuits tuned to carrier and intermediate frequencies, because such circuits cannot be resonant at hum frequencies. Therefore, don't commence looking for the source of hum in tuners or i-f amplifiers preceding the input to the video detector.

Only when you cannot quickly locate sources of hum voltage in a video amplifier, or in sync and sweep sections, is it time to check the i-f amplifier, and even as far back as the tuner. Although these high-frequency sections cannot directly amplify hum voltages, hum may so affect them as to change their gain at rates corresponding to hum frequencies. This might vary the strength of picture signals all the way through to the video detecotr, video amplifier, and picture tube. Hum effects in pictures would not be so severe as when hum originates in low-frequency circuits, but the effects would show.

Hum voltage in high-frequency amplifiers causes most trouble when it gets into grid circuits. Hum in screen circuits makes

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less trouble, but still enough to be plainly visible at the picture tube. Hum voltage in plate circuits of high-frequency amplifiers causes less trouble than hum voltage of equal strength in either the grid or screen circuits of the same amplifier.

The video amplifier is capable of strongly amplifying voltages at hum frequencies, because response of this amplifier goes down to 60 cycles or less. When looking for hum sources in a video amplifier, begin at the output of the video detector and work through to the grid-cathode circuit of the picture tube.

Circuits in the sync section are untuned. They are essentially resistance-coupled amplifier circuits, and as such respond strongly to hum frequencies. When looking for hum sources in a sync section begin at the point where sync signals are taken from the video amplifier and work all the way through to the inputs of sweep oscillators. Don't forget that d-c restorers are parts of sync sections in many sets.

Horizontal and vertical sweep oscillators, also horizontal afc systems, are strongly affected by hum voltages. There may be waviness in pictures, reduction of picture height and possibly of width, and generally erratic vertical sweep of the electron beam in the picture tube when sweep oscillator circuits carry hum voltages.

The greater the total amplification or gain following any source of hum voltage the worse will be the effect at the picture tube. For instance, should hum originate at a video detector the hum will be amplified by one or two video amplifiers, and will be strong at the picture tube. Hum voltage originating at a final video amplifier stage will not be further amplified, and ordinarily will cause less trouble at the picture tube.

Where hum voltage varies the gain of high-frequency amplifiers, the variations are magnified by all following amplifiers. Therefore, the greater the number of stages following the one first affected, the worse will be the final trouble at the picture tube. For this reason, hum getting into a first i-f amplifier causes more trouble than hum of equal strength getting into the second i-f amplifier. Also, hum commencing in a second i-f amplifier causes more trouble than the same hum commencing in a third i-f amplifier. But hum voltage getting into low-frequency amplifiers always is more troublesome than when it appears first in high-frequency amplifiers.

<u>HUM TESTS WITH VOLTMETERS.</u> Since hum voltages are alternating they may be measured with an a-c voltmeter, either a VTVM or a VOM with its function switch set for a-c volts. Many voltmeters, when set for a-c volts, indicate also any d-c voltage which may accompany alternating voltage in the measured circuit. To surely block d-c voltages, connect in series with the high-side lead of the meter a paper capacitor. Use the largest capacitance available, at least 0.25 mf, because you want least possible reactance at the low frequencies of hum voltages. The capacitor should be rated for at least 600 d-c working volts. Lower ratings would be enough for tests in some circuits, but you might unexpectedly run into high voltage when a receiver is in trouble.

A-c voltmeters are satisfactory for detecting ripple voltage on all B-plus lines. Commence measurements at points electrically near the output of the d-c power supply filter, where usually there will be at least a small ripple voltage. Additional filtering along lines to plates, screens, and grid returns, combined with filter action of decoupling capacitors and resistors, should bring ripple voltage too low for measurement at plate loads, screen connections, and grid returns.

There are difficulties when using any a-c voltmeter for measurement of hum voltage in signal-carrying circuits, because such a meter cannot distinguish between an alternating hum voltage and an alternating signal voltage. Therefore, when using an a-c voltmeter on signal-carrying circuits, first remove the signals by disconnecting the antenna lead from the tuner and connecting both antenna terminals of the tuner to chassis ground. As a further precaution, place the channel selector at a position where there is no local transmission.

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When making voltmeter tests in sweep circuits, at and beyond the outputs of sweep oscillators, there will be strong sweep voltages whether or not a signal enters the tuner. Sweep voltages will so affect voltmeter readings that added hum voltage would be difficult or impossible to detect, even were it present.

HUM TESTS WITH OSCILLOSCOPES. The presence of hum voltage in any circuit of a television receiver, also the hum frequency, are best determined with the oscilloscope. Before commencing such tests it is necessary to check pickup of the scope for stray 60-cycle magnetic fields in the room where you are working. In any building having a-c power and lighting lines there are rather strong 60-cycle magnetic fields. These fields cause 60-cycle traces on a sensitive oscilloscope when the vertical input prod is held almost anywhere in the room. These traces of stray fields may be confused with traces due to hum voltages.

It is essential to use a shielded vertical input cable. With this attended to, adjust the horizontal sweep of the scope for a trace showing one 60-cycle wave. A convenient way is to connect the oscilloscope ground lead to chassis ground on the receiver, and the vertical input to the ungrounded socket lug for the heater in any tube. Turn on the set and make the horizontal sweep adjustment.

Having adjusted the sweep rate, leave the oscilloscope ground connected to the receiver chassis, turn off the set, disconnect the vertical input lead and hold its prod near the receiver, but not touching it. Keep your fingers away from the metal tip of the prod. Advance the vertical gain of the scope while observing the height of the trace, which indicates stray field pickup.

Now touch the vertical input prod to chassis metal and to various points at which you may make hum tests. If there is no pickup of stray fields the trace will remain a straight horizontal line. Make mental note of any departures from a straight line with the prod in various places and with vertical gain at various settings. Any pickup shown on the trace should be allowed for when testing for hum after the set is turned on.

To proceed with tests for hum voltages, leave the oscilloscope adjusted to show one 60-cycle wave, leave the scope ground connected to chassis metal, and turn the channel selector where there is no local transmission, or disconnect the antenna lead from the tuner. Touch the prod of the vertical input cable to various places where hum voltage might be expected. Such places are listed and described later in this lesson. At each test point increase vertical gain of the scope until hum voltage appears on the trace, or fails to appear with maximum gain.

DETERMINING HUM FREQUENCY. Much time may be saved by determining early in the test procedure whether the trouble is caused by voltage at 60 cycles or at 120 cycles, because some faults can cause only 60-cycle hum, while others can cause only 120-cycle hum.

We have learned that one dark horizontal bar or one distinct wave along the right-hand edge of pictures means 60-cycle hum frequency, which is power line frequency. Two dark bars or two distinct waves on the right-hand edge mean 120-cycle hum voltage, which is ripple frequency from a full-wave rectifier operated on a 60-cycle a-c power source.

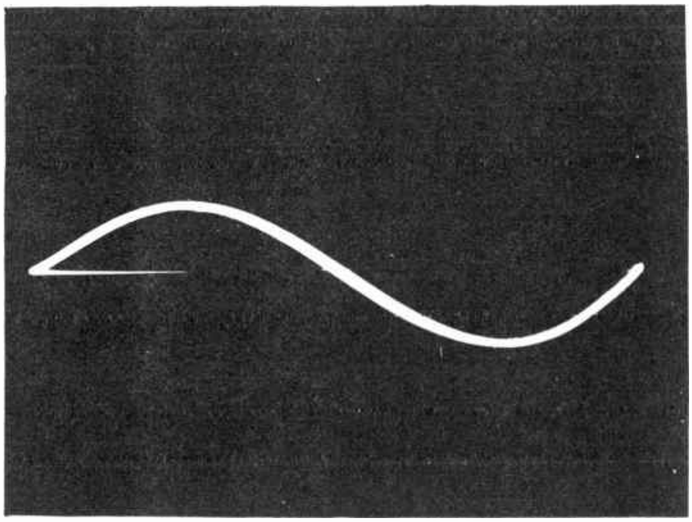

Fig. 7-A

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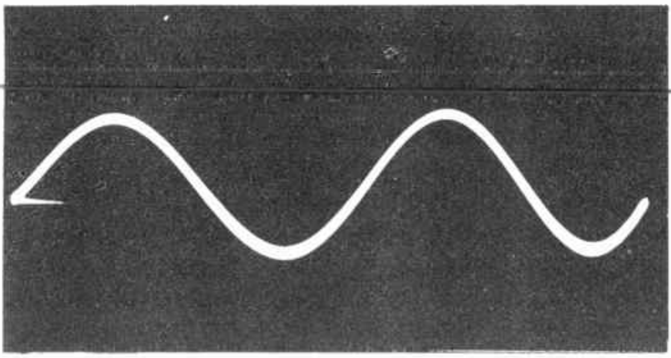

Fig. 7-B. With no other voltages present, hum voltages show on the oscilloscope as of approximately sine-wave form.

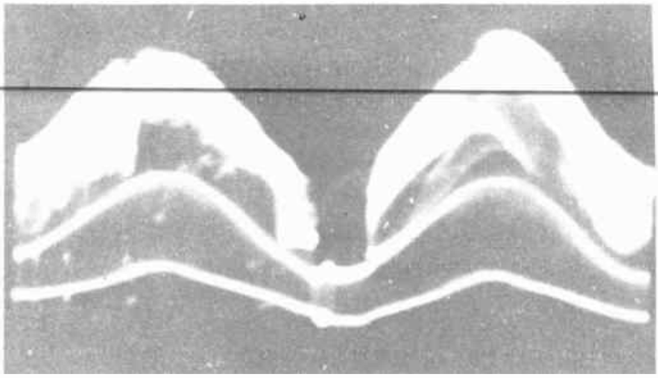

Fig. 8-B When signal voltage is present, it rides the hum voltage.

Should the oscilloscope trace during hum tests be a single wave, as at A of Fig. 7, there is 60-cycle hum voltage so long as the horizontal sweep of the scope is adjusted for 60 cycles. Two waves, as at B, indicate hum voltage at 120-cycle frequency. A 120-cycle trace of ripple voltage may not be of smooth sine-wave form, depending on how much filtering exists between the output of the power rectifier and the point of test.

While the oscilloscope horizontal sweep is adjusted for 60 cycles it is adjusted to the vertical field frequency, which is 60 cycles. If television signals are received during hum tests, and no hum voltage is affecting video circuits, you will see the signal waveform for one field, as at A of Fig. 8. Should 120-cycle hum voltage be present, the field signal will ride on the hum voltage as at B. Hum voltage at 60 cycles would put a single hump on the signal waveform, instead of the two humps formed by a 120-cycle hum voltage.

When you test in sync or sweep circuits while a television signal is received, the oscilloscope trace will show vertical sync pulses instead of a complete video signal, still assuming that the scope is adjusted for 60-cycle sweep. Hum voltage in the sync or sweep circuits then will cause the sync pulses to ride on a wavy trace, the waviness resulting from hum voltage.

If any steady high-frequency voltage, signal or otherwise, is present in a circuit being checked for hum, the high frequency will show up as in Fig. 9 when hum voltage is present and the scope is adjusted for 60-cycle horizontal sweep. At A the high-frequency voltage is riding a 60-cycle hum voltage, and at B is riding a 120-cycle hum. Were there no hum voltage, the high-frequency voltage by itself would appear as a luminous horizontal band with top and bottom edges straight. We looked at such traces when studying amplitude modulation.

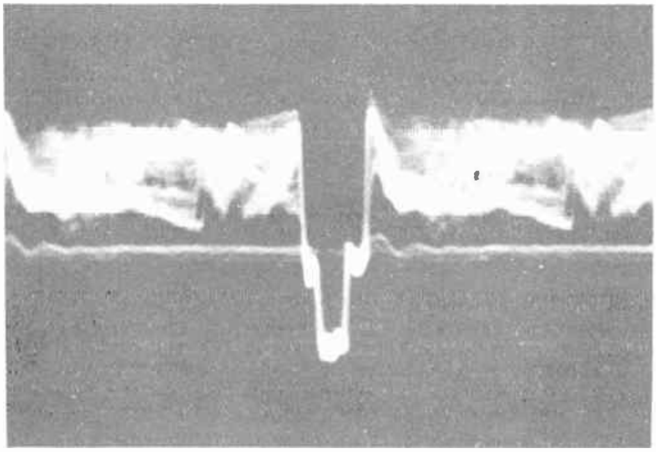

Fig. 8-A

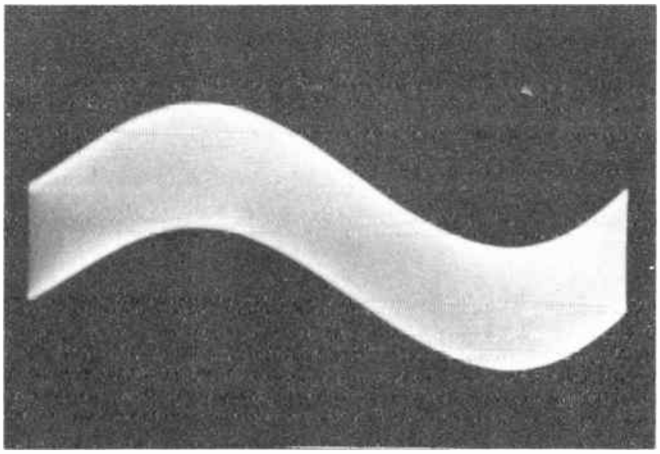

Fig. 9-A

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LESSON 78 — HUM AND SOUND IN PICTURES

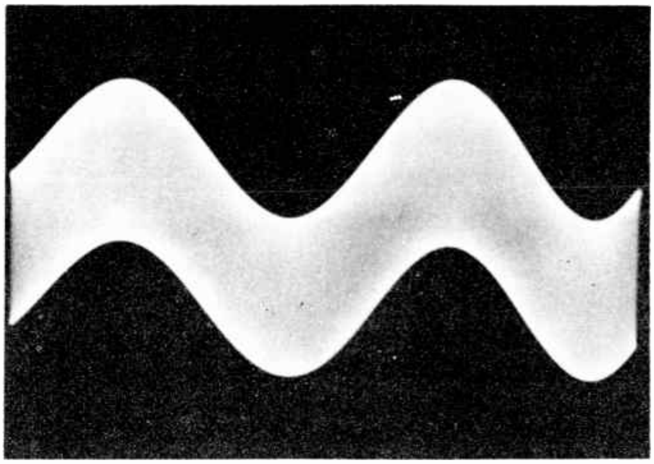

Fig. 9-B Steady high-frequency voltages will ride the hum voltages to cause broad bands.

The oscilloscope may pick up noise voltages instead of what we have defined as hum voltages. The difference between audible noise and audible hum is a matter of tone quality, not of pitch or frequency. Hum is soft and rather musical to the ear, because it originates from smoothly varying sine-wave voltages or from voltages which are approximately of sine-wave form.

Noise voltages are sharp and rasping when heard from a speaker, or they may cause hissing sounds. Oscilloscope traces of noise voltages have sharp peaks, or may be of irregular waveform, or may show a mixture of many random frequencies.

APPLYING HUM TESTS TO RECEIVER CIRCUITS. In following numbered paragraphs are listed the more probable causes for hum voltage. Unless you have good reason to suspect one certain part or circuit as causing hum, it usually is most economical of time to commence with tests most easily made on the receiver being handled, or with tests on parts most readily accessible. Then proceed to the more difficult measurements and checks.

When hum voltage has been identified as of only 120-cycle frequency make tests numbered 1 through 5. If hum voltage is of only 60-cycle frequency make tests numbered 6 through 8. If hum voltage has not been positively identified as of only 120-cycle or only 60-cycle frequency, but may be at either frequency, make tests numbered 9 through 13.

1. Ripple Voltage Excessive. Use an a-c voltmeter or the oscilloscope. Begin measurements at the output of the filter in the d-c power supply. Should ripple appear excessive here, make measurements at B-plus lines where they connect to dropping resistors and decoupling capacitors at a few tube circuits. If ripple is measurable at all of these latter points, proceed with following paragraphs 2 through 5.

2. Filter Capacitors Defective. Power supply filter capacitors may be so old as to have materially decreased their capacitance, and may be almost the equivalents of open circuits so far as filtering is concerned. Across each suspected capacitor connect temporarily a new electrolytic of equal or greater capacitance and equal or higher voltage rating. Should hum show a large decrease, or disappear, replace the original capacitor.

3. Filter Chokes Or Resistors Shorted. Ripple voltage should be decidedly less at the output than at the input of each of these filter elements. If there is no measurable difference, disconnect one terminal of the unit and use an ohmmeter to test resistance. The shorting might occur also in circuit connections to the unit that appears defective.

4. B-supply Connections Wrong. In an attempt to obtain more B-voltage on a particular circuit someone may have changed the connection of a B-plus line for amplifiers or other tubes to a point ahead of a filter choke or resistor, when the line connection should follow the choke or resistor. This reduces filtering for that line and for tubes connected to it. Check with a service diagram.

5. Power Transformer Shorted. If the power transformer seems to run excessively hot there may be shorted secondary turns. Then the secondary center tap no longer is at the electrical center of the winding, and rectified waves may be too far out of balance for smoothing by the filter. The only conclusive test is substitution of another power transformer.

6. Heater-cathode Leakage. The most reliable test is substitution of new tubes or tubes known to be good in all positions lead-

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ing to the point where hum voltage appears, and in all circuits which may be responsive to hum frequencies. Should a substitute tube reduce or prevent hum voltage, measure the a-c voltage on tube heaters. Excessive heater voltage and resulting excessive heater temperature can cause heater-cathode leakage or make it worse. Heater-cathode leakage cannot always be detected with an ohmmeter, because serious leakage may exist only while the tube is at normal operating temperature.

7. Power Supplies With Series Plate-cathodes. In receivers having d-c power supplies of the series plate-cathode type, hum may be due to electron emission from heaters to cathodes in tubes whose cathodes are highly positive to ground while their heaters are at practically ground potential. These cathodes are bypassed to ground through the same large capacitor or capacitors that prevent passage of signal voltages from the cathode circuits to plate circuits of other tubes. A faulty capacitor in one of these positions is almost certain to allow hum trouble.

8. Power Supplies With Intermediate Grounds. In receivers having d-c power supplies of the intermediate ground type the cathodes of some tubes are highly negative to ground. Heaters for these tubes may be fed from a separate insulated winding of the power transformer. If this winding and its heater lines are connected to the same B-minus potential as the cathodes there is not enough heater-cathode potential difference to cause trouble. Use an ohmmeter to make sure there actually is a connection from the heater wiring to B-minus.

With other intermediate ground systems the heaters of all tubes are fed from the same winding of the power transformer, and all are grounded on one side. Then there is large voltage between heaters and cathodes. The highly negative cathodes usually are bypassed to ground through capacitors having small reactance at the 60-cycle heater voltage. These capacitors should be checked, if used.

9. Wiring Connections Defective. Soldered joints or other terminal connections which are loose, dirty, or otherwise defective may introduce considerable resistance into two or more circuits connected to the joint. Then there is resistance coupling between the circuits, one of which may be carrying a hum voltage that passes into the other circuit or circuits. Check for such connections in the manner described for making noise tests, in another lesson.

10. Decoupling Faults. Lack of adequate decoupling capacitance or bypass capacitance often is the cause for troublesome hum voltage. Decoupling capacitors at plate loads, screen returns, and grid returns are, in effect, part of the d-c power supply filtering system. Check each one by temporarily paralleling it with a good capacitor of equal or greater capacitance and voltage rating. Should this reduce or prevent the hum, replace the original capacitor.

Where heater circuits are decoupled with capacitors to ground, and possibly with series r-f chokes, the primary purpose is to prevent passage of signals from one stage to others. However, shorted decoupling chokes and open or disconnected decoupling capacitors sometimes contribute to hum trouble.

The bypass capacitor for a cathode-bias resistor ordinarily need be only large enough to have capacitive reactance about 1/10 the resistance of the bias resistor. Where there is high resistance for biasing, bias voltage may be enough to put 60-cycle heater voltage hum into the cathode and connected circuits. Then bypass capacitance must be great enough to have low reactance at 60 cycles rather than at the signal frequency. As an example, bias resistance of 300 ohms would call for bypass reactance of no more than 30 ohms at 60 cycles, which would require no less than 89 mf of capacitance.

11. Dressing Faulty. Incorrect dressing of leads and parts is a common cause for troublesome hum voltages. When there is 120-cycle hum voltage, examine the positions of wires between the power transformer secondary and rectifier plates, and of wires between the rectifier cathode and filter capacitors, chokes, and resistors. Because high voltages in these wires are only partially filtered they cause oscilloscope hum

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traces which are peaked instead of having sine-wave form.

When there is 60-cycle hum voltage, check positions of heater wiring in relation to signal-carrying wiring and parts. Examine all wiring on the primary side of the power transformer. Don't forget that this primary wiring includes leads to the off-on switch on the front panel, and to any fuses or line-filter elements in primary circuits.

Wiring mentioned in the two preceding paragraphs may cause serious hum effects when close to conductors, capacitors, resistors, or inductors in plate and grid circuits or other signal-carrying circuits. Screen circuit wiring should be examined, because hum voltage in a screen circuit affects plate current almost as much as does grid voltage. In addition, examine all other high-impedance circuit wiring. A high-impedance circuit is one containing high resistance, large inductive or capacitive reactance, or any combination of these. One example is the vertical size control circuit leading to the sweep oscillator plate. The control is of high resistance. Receivers contain many other high-impedance circuits.

Magnetic fields at 60- or 120-cycle frequency from power transformers and filter chokes may put hum voltages into any other iron-core transformers which are too close. Even air-core transformers and couplers may pick up hum voltages from strong magnetic fields.

12. Power Transformer Loose. Should core iron in the power transformer vibrate, due to loose laminations, it may cause enough vibration of nearby tubes to make them act microphonic. Since vibration would be at 60 or 120 cycles, the result might be more in the nature of hum than noise. Try tightening screws that clamp the core iron, and those that hold the transformer to the chassis. Hum trouble sometimes stops when you tighten some screws more than others.

13. Shielding Faults. Probably the least likely cause for troublesome hum voltages is defective shielding, but in high-gain amplifiers this may be the real difficulty. Make sure that all shields are held securely on their supports and are in good contact with chassis metal. Make sure also that there are ground connections to socket lugs for internal tube shields and for shells of metal-envelope tubes.

SOUND BARS

While looking at horizontal bars caused by hum frequencies at the picture tube we learned that 60-cycle hum causes one dark bar and one bright bar, while 120-cycle hum causes two pairs of bars with each pair consisting of one dark bar and one bright bar. Should you see a still greater number of bars, as in Fig. 10, it should not be difficult to realize what is happening - the interfering frequency is higher than 120 cycles. Horizontal bars caused by frequencies higher than those classed as hum are called sound bars, because the sources are operating at sound frequencies or audio frequencies.

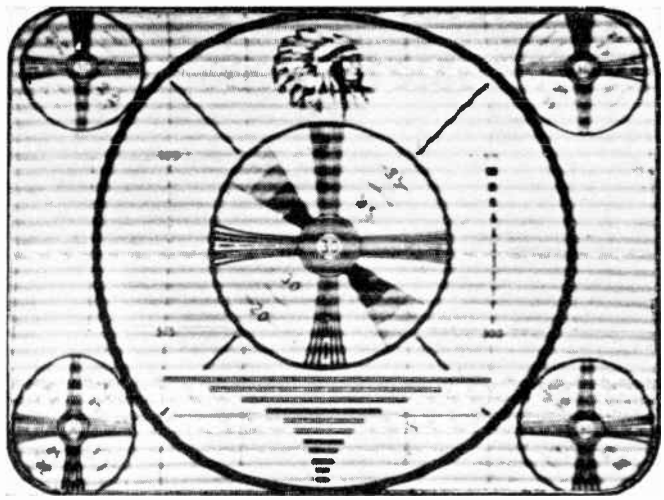

Fig. 10. Here we have an example of sound bars appearing on a pattern.

An easy way to learn some of the facts relating to sound bars is to feed variable audio frequencies into television receiver circuits. This may be done with an audio-frequency signal generator such as found in many service shops. When a hum frequency of 120 cycles is applied from the audio generator, the picture tube screen will show two pairs of horizontal bars.

When the audio frequency is increased gradually the bars move upward, faster and

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faster until they no longer can be seen. Then bars will reappear, this time moving downward, fast at first and then more and more slowly until they become stationary. Now there will be three pairs of bars. The frequency dial of the audio generator will read 180 cycles.

If audio frequency now is increased from 180 to 240 cycles the bars again move upward, then downward, and come to rest when there are four dark bars and four bright ones. The four pairs of bars appear on a raster as in Fig. 11. Any bars, sound or hum, show up on a raster even more clearly than on pictures. With continued increase of

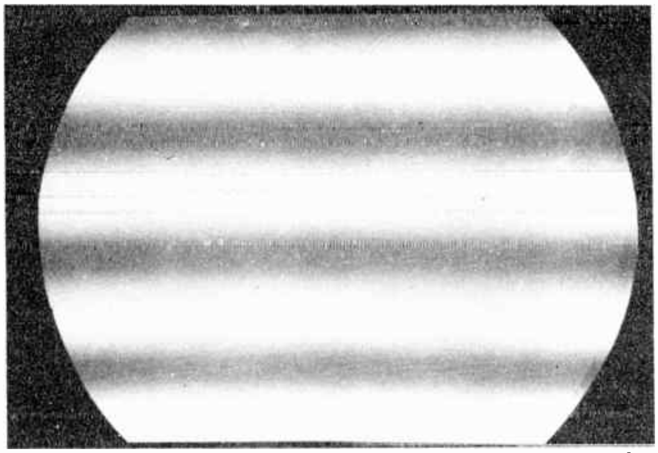

Fig. 11. Interfering voltage at 240-cycle frequency causes four pairs of sound bars.

audio frequency we observe the horizontal bars come to rest every time this frequency is an exact multiple of 60 cycles. These horizontal sound bars are formed in the same manner as hum bars.

The frequency which is causing sound bars may be determined quite closely by counting the number of either dark bars or bright bars, then multiplying this number by 60. Each dark bar or each bright bar formed during a downward sweep of the electron beam indicates 60 cycles of interfering voltage, just as each dark or bright hum bar indicates 60 cycles of hum voltage. As an example, when interfering frequency is 600 cycles there will be 10 bars of each kind, because 10 multiplied by 60 equals 600.

At 1,800 cycles there should be 30 pairs of bars, according to our rule, but you won't be able to count this many because some cycles of interfering voltage occur during vertical blanking periods. Each vertical blanking period takes up about 1/15 of a total field time, so 1/15 of the computed number of bars won't be visible. At 1,800 cycles two pairs or 1/15 of the total computed number of bars will disappear during vertical blanking, and only 28 pairs will remain.

Equal numbers of dark and light bars won't always be visible. Fig. 12 resulted from a 480-cycle interfering frequency, which should cause eight bars of each kind. Only seven dark bars show, the eighth being hidden by the picture tube mask.

Fig. 12. Some of the sound bars may be hidden by a mask, but would show when looking at the entire screen.

In spite of these small discrepencies you can come close to determining an interfering frequency, in cycles, by multiplying by 60 the greatest number of either dark or bright bars that can be counted. Identifying the frequency helps greatly in locating the probable source of trouble.

Upon further increase of frequency fed from the audio generator into receiver circuits, the number of horizontal bars will continue to increase, and individual bars will become narrower and narrower. At an audio frequency around 8,000 cycles there would be about 124 pairs of bars on the screen.

When audio frequency is raised to 15,750 cycles, which is the horizontal line frequency for television pictures, a major change occurs. On the screen will appear one dark vertical bar and one bright vertical bar, fill-

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ing the entire width of screen. Horizontal bars still are there, but with nearly 250 pairs of very narrow horizontal bars at 15,750 cycles of interfering frequency the bars become difficult to count. The screen will appear much as though the regular horizontal trace lines that form pictures were twice as thick as they should be.

From here on, every time the interfering frequency is increased by 15,750 cycles, one additional pair of vertical bars will appear on the screen. At 63,000 cycles there will be pairs of vertical bars, because 63,000 divided by 15,750 equals 4. A small portion of one bar will be invisible, as in **Fig.** 13, because it would be formed during horizontal blanking periods.

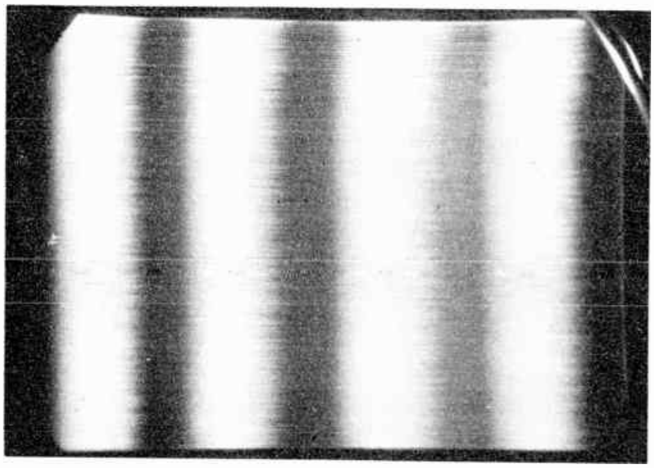

Fig. 13. This is the effect of interfering voltage at a frequency of 63,000 cycles.

The interfering frequency may be determined approximately by multiplying the number of dark vertical bars or the number of bright vertical bars by 15,750. For example, with 40 dark vertical bars or 40 bright vertical bars we multiply 40 by 15,750 to arrive at a frequency of 630,000 cycles or 630 kilocycles. Actually the interfering frequency would be a little higher, because some vertical bars would have been formed during horizontal blanking periods, but any frequency of this order should lead you to suspect that interference is from an r-f signal in the lower part of the standard radio broadcast band. This is getting us into methods of identifying radio-frequency interference such as dealt with in lessons on r-f interference.

Dark bars, bright bars, or both kinds, which are due to hum voltages and to higher-frequency audio voltages do not always show in the form of distinctly outlined areas. The bars may merge with large masses of dark or light tones in pictures, or bars due to weak interfering voltages may disappear in some areas of pictures. There is some possibility of confusing effects of other troubles with effects of hum and audio voltages until you have observed all kinds of faults in many receivers. Some examples follow.

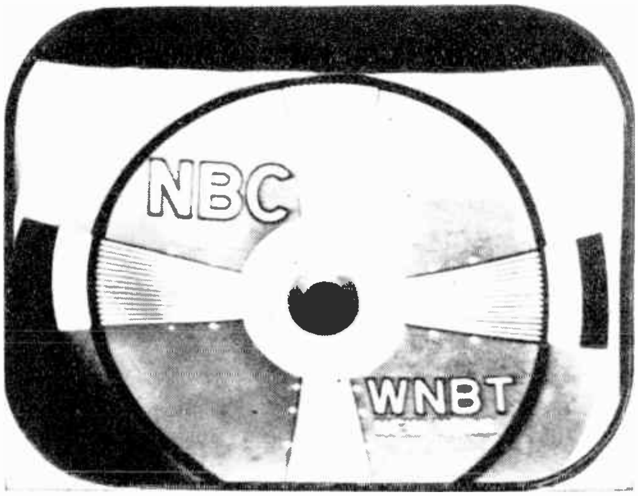

Fig. 14. Effects due to lack of centering or to misadjustment of an ion trap magnet should not be confused with hum bars.

The dark bar across the top of the screen in **Fig.** 14 is not a hum bar, it is due chiefly to insufficient picture height and partly due to incorrect centering. The dark shadow in the lower left-hand corner is due to wrong adjustment of an ion trap magnet.

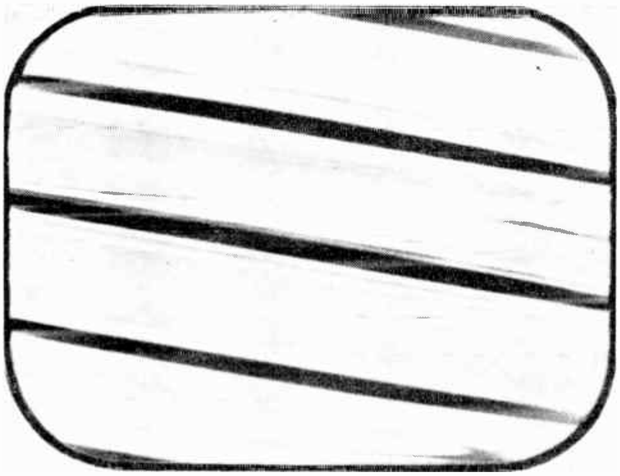

Fig. 15. These are not sound bars, they are due to lack of horizontal sync.

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Bright and dark bars in Fig. 15 should be easily recognized as due to lack of horizontal synchronization, not to interfering sound frequency. Sync bars tend to increase in number and become more nearly horizontal, or to decrease in number and become more nearly vertical just before the picture snaps into synchronization. Sync bars always disappear when you change from pictures to a raster, while sound bars often remain on the raster.

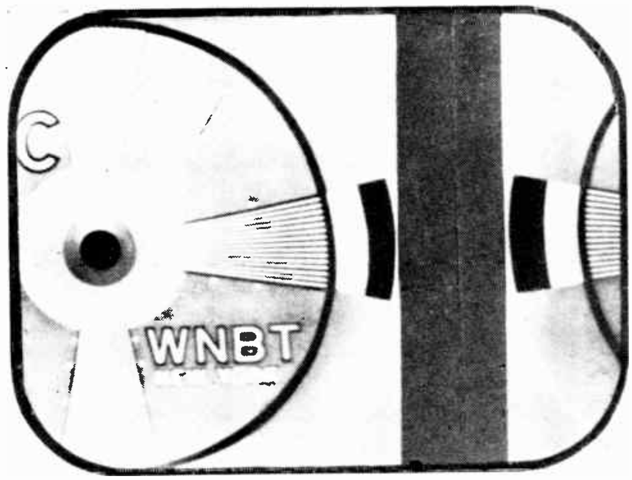

Fig. 16. A picture or pattern may be split by a vertical bar due to failure in the horizontal afc system.

A single dark vertical bar, as in Fig. 16, is not due to interfering voltage in the high audio-frequency range, but rather to faulty adjustment or to failure of parts in some types of horizontal afc systems. Pictures split at the bar, with the portion which should be at the right appearing to the left of the bar, while the portion which should be at the left appears on the right.

CAUSES FOR SOUND BARS. The behavior of sound bars often helps identify the cause for trouble. As an example, stationary bars, moving neither up nor down, mean that frequency of interfering voltage is remaining at some exact multiple of 60 cycles. Bars that move up or down on the screen mean that interfering frequency is not an exact multiple of 60 cycles. The slower the movement, the closer is the interfering frequency to an exact multiple of 60 cycles.

Should sound bars change continually in number and strength, while moving irregularly and occasionally disappearing, the interfering voltage probably results from speech or musical signals, both of which consist of many varying audio frequencies. These frequencies may originate in the audio system of the television set, or they may come from sound modulation on some broadcast a-m signal picked up by the television set, or they may be from modulated signals in some other television channel.

Following numbered paragraphs describe some common causes and suitable remedies for sound bars.

1. Volume Excessive, Microphonic Trouble. When sound bars appear while audio volume is high, and disappear with volume reduced, excessively strong sound waves in air within the cabinet may be forcing some tubes to act microphonic. If the receiver operates with dual or split sound, the tube most likely to cause microphonic trouble is the r-f oscillator of the tuner. Horizontal afc tubes in almost any receiver may cause sound bars when these tubes are vibrated. Try tapping suspected tubes, very gently, while the volume is only moderate. If sound bars then appear, the tube tapped actually may be microphonic.

2. Fine Tuning Misadjusted. When sound bars persist with low volume it is quite likely that sound intermediate frequency is too high on the frequency response curve of the i-f amplifier. First try readjusting the fine tuning control, if the receiver has such a control. When fine tuning is adjusted one direction the sound intermediate is brought higher on the frequency response, while the video intermediate is moved down. Then sound output from the i-f amplifier becomes too strong, while pictures and sync become too weak.

3. R-f Oscillator Misaligned. The r-f oscillator circuit in the tuner might be misaligned to bring the sound intermediate too high on the i-f response, with effects similar to those due to misadjustment of a fine tuning control. Misalignment of r-f oscillator circuits seldom causes sound bars on all channels, and usually causes strongest bars on only one channel.

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4. Slope Demodulator of Sound. If sound intermediate frequency is brought up onto a fairly steep slope of the i-f response curve, there actually may be demodulation of f-m sound signals. As these signals deviate to higher frequency they move higher on the slope and are subjected to more gain. When the f-m sound signals deviate to lower frequency they move down on the slope, and receive less gain. Such "slope demodulation" was the original method of recovering a-m audio signals from f-m intermediate signals.

A-m sound signals produced by slope demodulation can pass through the video detector and video amplifier to the picture tube in spite of i-f sound traps. These traps do not reject or bypass frequencies so low as in the audio range. This is true also of intercarrier beat traps, which are tuned to 4.5 mc. It is worth noting here that a 4.5-mc intercarrier sound signal reaching the picture tube does not cause horizontal sound bars even though it carries sound modulation. The result is very narrow vertical or sloping lines on the picture tube.

5. Traps Misaligned. In the i-f amplifier section or at the video detector of many receivers are traps for accompanying sound and for adjacent sound. Misalignment of these traps may allow sound signals to pass through the i-f amplifier to the video detector, where they cause voltage variations which are amplified in the video amplifier to cause sound bars at the picture tube.

6. Audio Amplifier Bypasses Faulty. Audio signal voltages may pass from the audio output amplifier into other circuits from which these voltages reach the video amplifier and picture tube. Examine bypass capacitors and capacitor connections for the plate load, screen, and cathode-bias resistor of the audio output amplifier tube.

7. Series Plate-cathode Power Supplies. In receivers employing series plate-cathode power supply systems, sound signals in cathode circuits of tubes in the sound section are bypassed to ground by a large capacitor. Sometimes a series resistor acts with this capacitor to form a low pass filter. Often there is more than one capacitor and more than one filter resistor. Check the condition of all such bypass capacitors, and examine connections to filter resistors where used.

8. Modulated R-f Interference. Sound-modulated r-f signals from various kinds of a-m radio transmitters may be picked up by the television antenna and passed through a tuner having too little rejection for such frequencies. Where the receiver is located close to a-m transmitters operating at radio frequencies in the television i-f range, the signals may be picked up on wiring of the i-f amplifier section. Trouble due to r-f signals from a-m transmitters is dealt with in lessons on r-f interference.

9. Sweep Oscillator Circuits. Audio voltages getting into the circuits of sweep oscillators usually cause appearance of bar effects quite different from those usually associated with hum and sound voltages. Fig. 17 resulted from a voltage at 720 cycles getting into the plate circuit of a vertical sweep oscillator of the blocking type, to cause very bright horizontal bars.

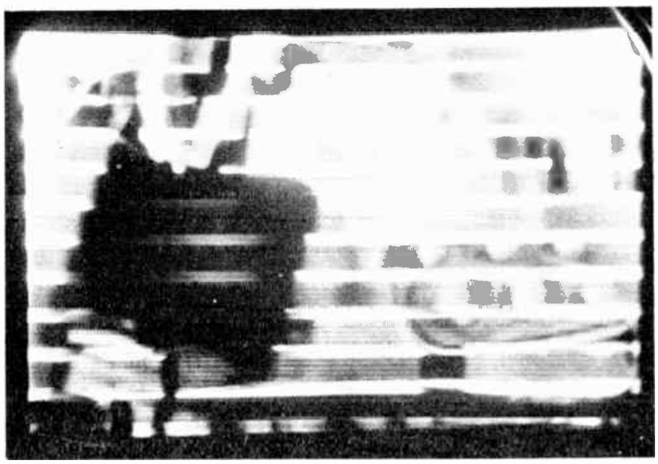

Fig. 17. Voltages at sound frequencies reaching a sweep oscillator may cause such effects as this.

The cause for the condition of Fig. 18 was strong ripple voltage, at 120 cycles, reaching the grid connections of a multivibrator oscillator. The picture is split along a dark horizontal bar, with the top of the picture below the bar and the bottom of the picture above the bar.

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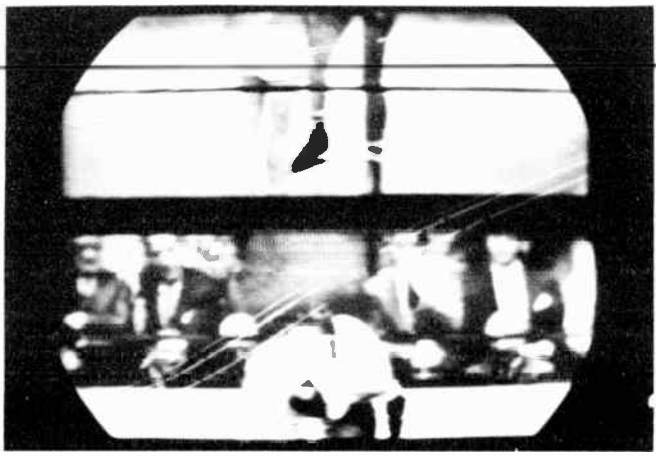

Fig. 18. Sound voltage at a sweep oscillator may split pictures along a dark horizontal bar.

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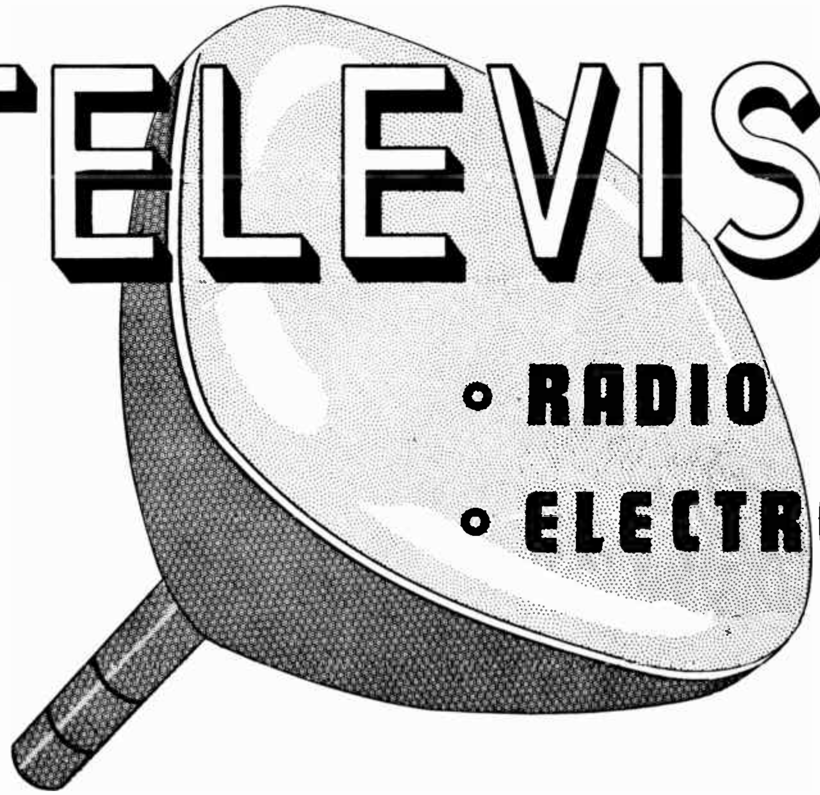
TELEVISION



- RADIO
- ELECTRONICS

LESSON 79 — TELEVISION TUNERS

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Lesson 79

TELEVISION TUNERS

Fig. 1. The top of a turret tuner. Screws which are near the tubes are alignment adjusters.

Every television tuner is a superheterodyne tuner, because all television receivers are of the superheterodyne type. The fact that a receiver is a superheterodyne type means simply that all carrier frequencies are changed to the same intermediate frequencies. Consequently, as shown by Fig. 2, we have for television the same sections and circuits as in many radio tuners for a-m and f-m sound broadcast reception.

In every television tuner at least one tube or one section of a tube acts as an r-f amplifier for carrier signals, and often there are two sections of a tube or two separate tubes working as r-f amplifiers.

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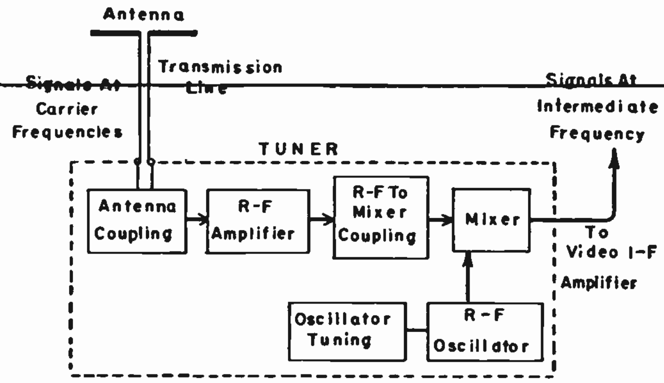

Fig. 2. Essential parts of a television tuner are the same as in all superheterodyne radio receivers.

Although it is customary in standard broadcast and f-m broadcast receivers to use a single converter tube as oscillator and mixer, television tuners have two separate tubes or else have a two-section tube for the two functions.

In many television tuners, but not all, there is a variably tuned coupling between antenna and r-f amplifier. In all television tuners there is a tuned coupling between r-f amplifier plate and mixer grid. This coupling may be of the transformer type, with tuning for both the r-f amplifier plate circuit and the mixer grid circuit, but sometimes is an impedance type having a single tuned circuit. The r-f oscillator circuit always is variably tuned.

Tuning for all couplings and for the oscillator circuit in any one tuner usually is either by variable inductances or else by variable capacitances. Variable inductances may be any of these types:

1. Separate coils or inductors for each channel.

2. Single continuous inductors tapped at values suitable for each channel.

3. Inductors whose values are varied by sliding contacts on the turns of coils.

4. Inductors having movable cores.

Methods of capacitance tuning include:

1. Continuously variable air-dielectric capacitors.

2. Separate adjustable mica dielectric capacitors for each circuit and channel, the adjustments being a service operation.

There are two principal methods of channel selection, as follows:

1. Step tuning. The selector dial has one definite position for each channel, with this position fixed by some kind of stop or detent mechanism on the tuner. Step tuning is employed when (a) the tuner has separate inductors for each channel, (b) has inductors tapped for each required channel value, or (c) has separate trimmer capacitors for each channel.

2. Continuous tuning. The selector dial may be moved continuously through positions for all channels in either band and through frequencies between channels. The dial may be adjusted for best reception of any channel. Either the low band or the high band of the vhf range is selected by a switch operated either by movement of the tuning dial or by a separate control. Continuous tuning is possible (a) with inductors having sliding contacts, (b) with inductors having movable cores, and (c) with air-dielectric capacitors. Any of these tuners may be fitted with a detent or channel stop device to make it act as a step tuner with fixed positions for each channel.

R-F AMPLIFIERS. Although most of the total gain in a television receiver occurs in the i-f amplifiers, it is desirable that the r-f amplifier have as much gain as possible while maintaining a high ratio of signal to noise at its output. Gain is almost directly proportional to transconductance of the amplifier tube or tubes, and is inversely proportional to total output capacitance. R-f amplifier tubes should have high transconductance and low input and output capacitances.

Until recently the typical r-f amplifier tube has been a miniature pentode of the sharp cutoff type, such as 6AG5, 6AK5, 6CB5, or 6CB6. The advent of cascode cir-

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cuits, described later in this lesson, brought different r-f amplifier tubes.

The use of tuned resonant circuits at both input and output of the r-f amplifier increases receiver selectivity and thus lessens interference from other television channels and other radio services. The tuned circuits and presence of an amplifier tube between antenna and r-f oscillator help prevent radiation of oscillator frequencies through the antenna to other nearby television receivers, in which severe interference may be caused. Reduction of oscillator radiation is one of the major problems in design of television receivers.

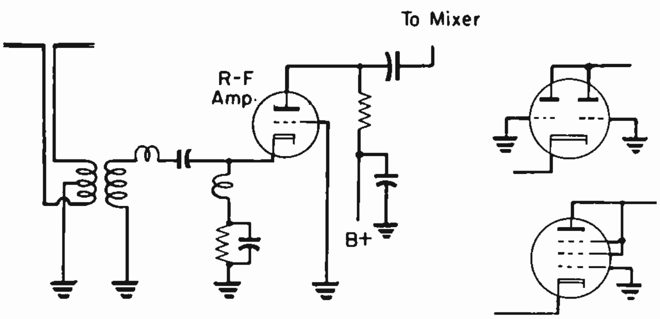

Fig. 3. Circuits for a grounded grid amplifier. Tubes sometimes are connected as at the right.

GROUNDED GRID R-F AMPLIFIERS. The desire for minimum tube noise and high gain at very-high and ultra-high frequencies has led to the use of some rather unusual circuits for r-f amplifiers. One such circuit is called a grounded grid amplifier, as illustrated in simple form by Fig. 3. A triode is used because it produces less noise than a pentode. But a triode of high transconductance has fairly large plate-to-grid capacitance, and when signal input is to the grid with output from the plate, feedback through this capacitance tends to cause oscillation at high frequencies. Such feedback may be neutralized or counteracted in ordinary amplifiers by an external feedback of opposite phase, but the grounded grid circuit employs other means.

With the grounded grid circuit of Fig. 3, signal input is to the cathode, signal output is from the plate, and the grid is grounded. The grounded grid acts as a shield between the signal input element (cathode) and the signal output element (plate) to reduce plate-cathode capacitance to a negligible value, usually less than 0.15 mmf. Feedback from output to input then is so small as to make oscillation highly improbable.

Where the grounded grid circuit is not used, and signals are applied to the amplifier grid, impedance of the input circuit is high, while the antenna and transmission line have low impedance, about 300 ohms. It is difficult to match these widely different impedances for satisfactory transfer of signal power from antenna to r-f amplifier. The cathode circuit of the grounded grid amplifier is inherently of low impedance, and can be made a good match for the low impedance antenna to allow relatively large power transfer.

Another advantage of the grounded grid amplifier is reduced radiation from the r-f oscillator. Energy from the oscillator would have to pass from plate to cathode in the r-f amplifier to reach the antenna, but on its way encounters the grounded grid acting as an effective shield.

Grounded grid amplifier circuits may employ a single triode or a twin triode with all elements connected in parallel. Grid bias is provided by voltage drop in the cathode circuit, as with any cathode bias system.

There is no signal inversion between cathode input and plate output of the grounded grid amplifier. When signal voltage makes the cathode more positive we have the equivalent of a more negative grid, as is true in all cathode-biased amplifiers. The result is less plate current in the plate load, less voltage drop in that load, and a more positive voltage remaining at the plate. Thus we see that a more positive cathode makes a more positive plate, and, of course, a more negative cathode would make a more negative plate. This means that there is no inversion of signal polarities between input and output of the grounded grid amplifier.

CASCODE R-F AMPLIFIERS. The cascode r-f amplifier, widely used in television tuners, makes use of two triodes in series, as shown in simplified form by Fig. 4. Signals from the antenna are applied in the

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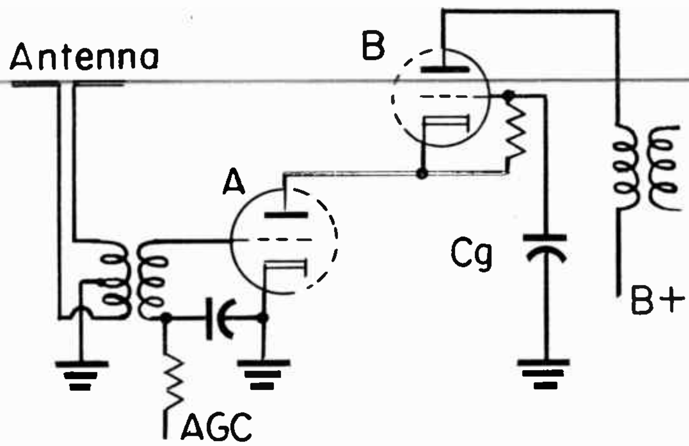

Fig. 4. The elementary principle of the cascode r-f amplifier.

usual manner between grid and cathode of triode A, and are amplified. Triode A forms the cathode-to-ground circuit for triode B, which is connected as a grounded grid amplifier. Amplifier signal voltage in triode A thus exists in the cathode circuit of triode B, being equivalent to signals put into the cathode circuit of any other grounded grid amplifier.

Advantages usually claimed for the cascode amplifier are as follows:

Tube noise is low because of using triodes.

It is possible to design the circuit for high gain at high frequencies without danger of feedback oscillation. Oscillation is prevented by the grounded grid of the second section, also by the fact that plate load for the first section is the low impedance between cathode and grounded grid of the second section.

There may be more nearly equal gain for all channels in both the vhf bands than in most other r-f amplifiers.

Radiation from the r-f oscillator is reduced by the grounded grid of the second section.

Because cathode-plate current paths in the two triodes are in series, total voltage from the B-supply divides between them, usually with approximately half the total used in each section. Since triode B as a whole operates at more positive B-voltages than triode A, the grid of triode B must be maintained at a positive potential to ground and cannot be conductively connected to ground. The grid is, however, grounded for r-f voltages and currents through very small reactance of capacitor Cg, which usually is of capacitance in the neighborhood of 1,000 mmf. In Fig. 3 a d-c grid return for triode B is provided by a resistor between its grid and cathode.

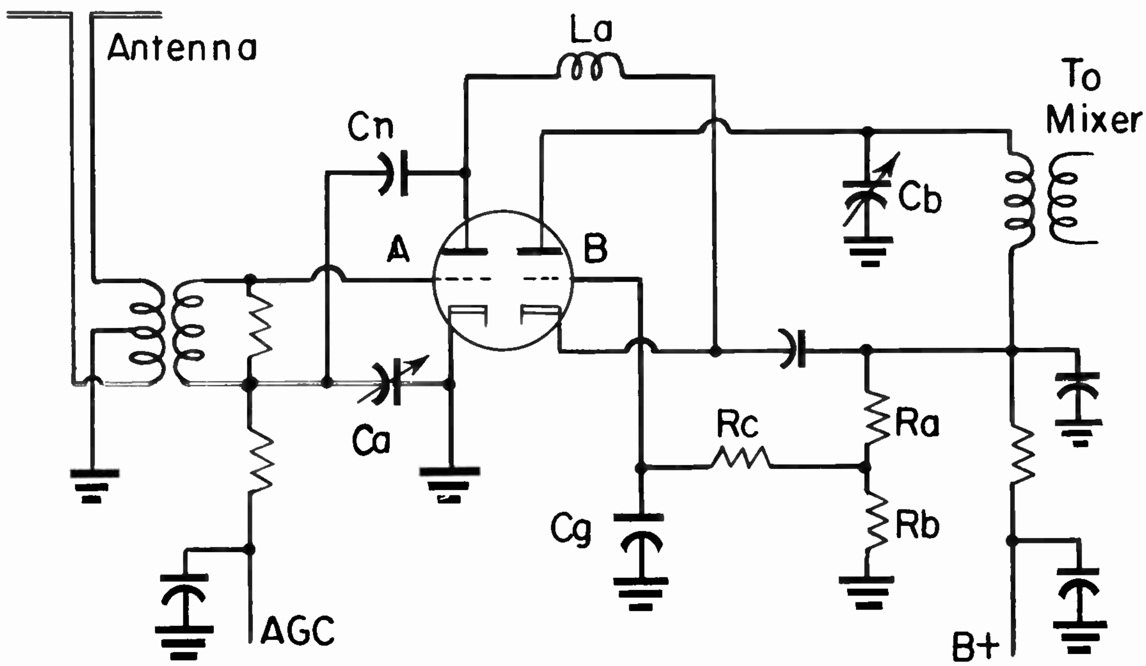

Fig. 5. A practical circuit for a cascode r-f amplifier

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Fig. 5 shows a practical circuit for a cascode r-f amplifier. The tube is a twin triode designed especially for this circuit. Inductor La, in series with the signal transfer path from first plate to second cathode, counteracts the normal tendency for gain of an r-f amplifier to decrease at higher received frequencies.

The series inductor La, in combination with tube capacitances and stray circuit capacitances, forms a series resonant circuit which would become resonant and of minimum impedance at a frequency somewhat higher than carrier frequencies of channel 13. Accordingly, the impedance decreases as the receiver is tuned from lowest to highest channel frequencies, signal transfer increases, and gain is more uniform on all channels.

Capacitor Cn, between the plate and the low side of the grid circuit on triode A, neutralizes feedback that occurs through grid-plate capacitance within this triode section. Because reactance and impedance in the plate circuit decrease with rise of frequency, as in a capacitor, the plate circuit acts as though it were a capacitor. When a plate load is thus capacitive, internal feedback opposes signal voltage applied to the grid. That is, the internal feedback is degenerative. Capacitor Cn is connected in such a way that plate signal voltages passing through it will assist signal voltages coming to the grid - it provides a regenerative feedback. Adjustable capacitors Ca and Cb are used during alignment.

Grid potential on triode B of Fig. 5 is maintained in correct relation to cathode potential of this section in the following manner. Assume, as an example, a d-c potential of 250 volts to ground at the plate of B, and a drop of 125 volts between plate and cathode in this section. Cathode potential then is 125 d-c volts to ground. Now we must make the grid somewhat less positive to ground in order that the grid may be negative with reference to the cathode.

The grid is maintained positive to ground, and negative to its cathode, by taking positive grid potential from a voltage divider consisting of resistors Ra and Rb connected between a B-plus line and ground. Potential at the junction between these divider resistors is taken through resistor Rc to the grid of triode B. Resistances at Ra and Rb are proportioned to furnish at the grid whatever positive d-c potential is required for correct biasing in relation to the cathode of triode B. Resistances at Ra and Rb sometimes are equal, or Rb may be of greater resistance than Ra. Values commonly range from 100K to 2 megohms for the two divider resistors. Resistor Rc carries no current, since the grid is negative to its cathode, and has no voltage drop. Resistance at Rc usually is in the same general range as that of the divider resistors.

Agc voltage is applied only to the grid of the first triode of the cascode amplifier, but voltage at the grid of the second triode is varied in the same polarity and at the same time. This is because plate resistance of the first triode acts as cathode resistance for the second triode, and furnishes cathode-bias for the second triode.

Agc action is explained as follows: Assume that a change of agc voltage makes the first grid more negative. This increases plate resistance in the first section, and more of the total B-supply voltage appears as drop in this section. More drop means that the first plate and the conductively connected second cathode become more positive to ground. Making the second cathode more positive is equivalent to making the second grid more negative, as with any cathode-bias system. Thus the grid of triode B automatically becomes effectively more negative when the grid of triode A is made more negative. Of course, making the grid of A less negative results in an effectively less negative bias on the grid of triode B.

TUBES FOR CASCODE R-F AMPLIFIERS. All tubes designed especially for use in cascode amplifiers are miniature twin triodes having base pin connections shown by Fig. 6. Note that an internal shield, connected to base pin 9, is between the sections. This pin must be connected to chassis ground to reduce capacitance between the sections. All the tubes are designed for peak potential differences of 200 volts between cathodes and heaters. This is necessary because the cath-

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ode of the grounded grid section usually is 125 to 150 volts positive to ground, while one side of the heater circuit ordinarily is grounded.

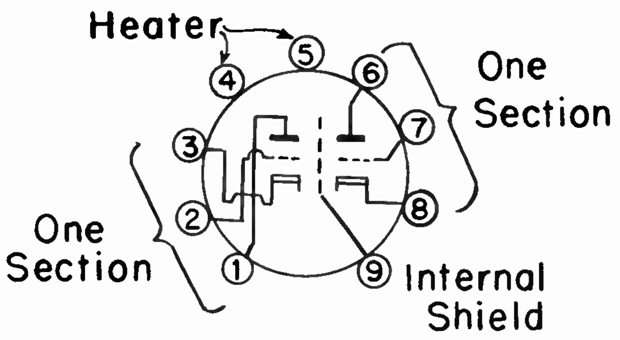

Fig. 6. Base pin connections for twin triodes used in cascode r-f amplifiers.

Operating characteristics of types 6BQ7, 6BQ7-A, and 6BZ7 are nearly enough alike that these three are directly interchangeable. The 6BQ7 has somewhat less transconductance than either of the others when operated with the same plate voltage and current. The older type 6BK7 has different internal capacitances and takes about twice as much plate current as the other types, therefore is not directly interchangeable with the others unless the circuit is altered.

TWO-STAGE R-F AMPLIFIERS. Circuit connections for a two-stage cascode type of r-f amplifier with variable capacitance tuning are shown by Fig. 7. Inductances and capacitances in all tuned circuits are altered for response in either the low band or the high band channels of the vhf television range. Band switching is accomplished by double-throw switches numbered 1 to 7 on the diagram. In their full-line positions the switches are set for high-band reception, channels 7 to 13, and in brokenline positions for low band reception, channels 2 to 6. All the switches are operated together by one of two concentric control knobs. The other knob operates variable air-dielectric capacitors Ca and Cc for selecting a desired channel in either band. The r-f oscillator circuit, not shown here, is similarly switched and tuned.

Separate antenna coupling circuits for each band are connected to the antenna line by switches 1 and 2, and to the grid of the

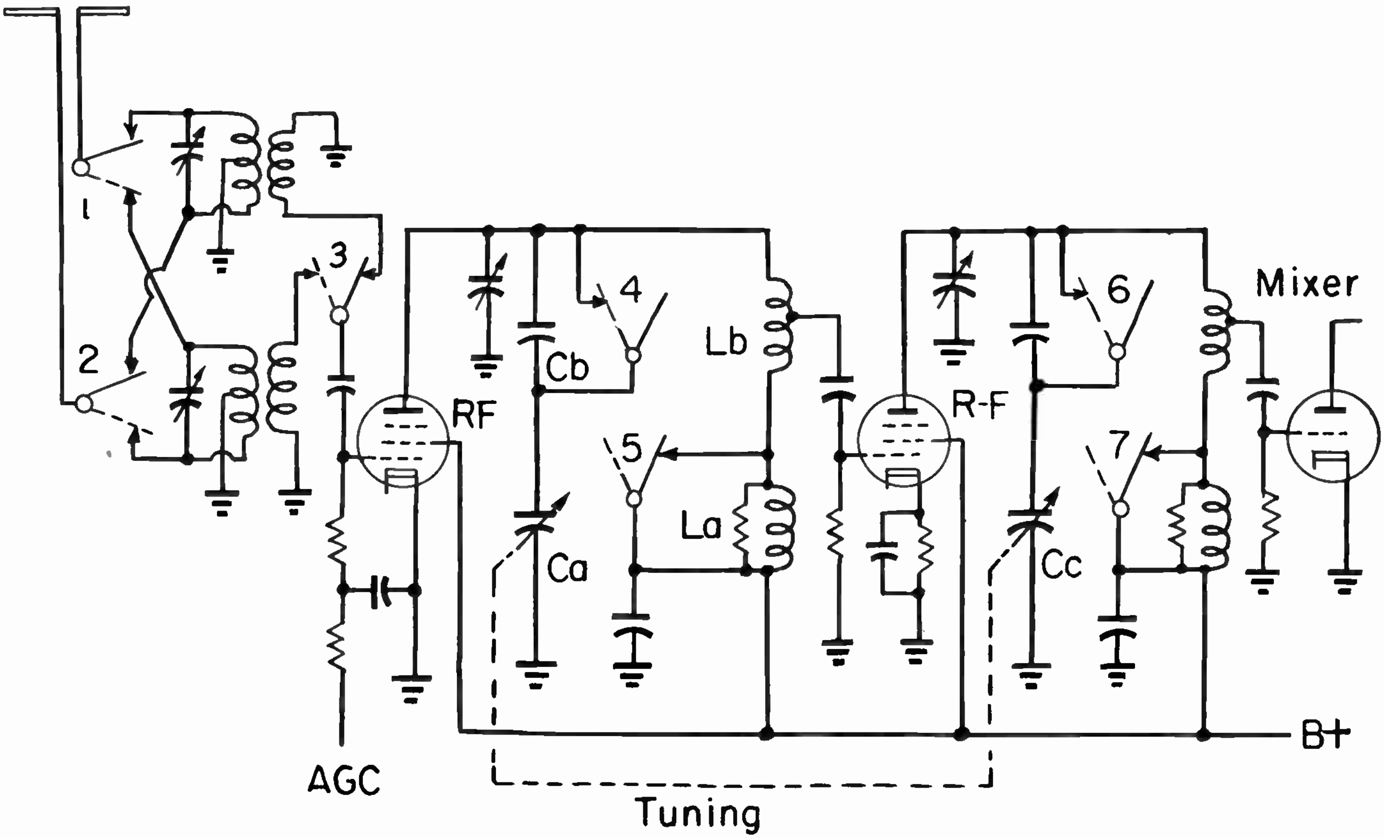

Fig. 7. A two-stage r-f amplifier used in some television receivers.

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first r-f amplifier by switch 3. The plate circuit of the first r-f amplifier is tuned by a parallel resonant circuit that includes capacitors Ca and Cb, and inductors La and Lb. For high-band reception these two capacitors are in series, thus reducing their effective capacitance for high-frequency response. Inductor La is shorted by switch 5, thus leaving only the inductance at Lb, which is sufficient for high-band tuning.

For low-band tuning capacitor Cb is shorted by switch 4. Removing this capacitor from in series with capacitor Ca increases the effective capacitance in the tuned circuit. Switch 5 opens to remove the short from inductor La, thus leaving inductors La and Lb in series for increased inductance required for low-frequency tuning. Inductors and capacitors in the plate circuit of the second r-f amplifier are switched similarly to those in the first plate circuit.

The two cascaded r-f amplifiers are stagger tuned. The first stage peaks at approximately the video carrier frequency of a channel, while the second stage peaks at approximately the sound carrier frequency of the same channel. The pass band of the two stages together is wide enough for all frequencies in any one channel. Adjustable trimmer capacitors used during alignment are across the high- and low-band antenna coils of Fig. 7, also between plates and ground on each of the r-f amplifiers.

It should be mentioned that stagger tuning is common in all two-stage cascade r-f amplifiers, being employed also in tuners whose inductances rather than capacitances are varied for channel selection.

R-F OSCILLATORS. Practically all r-f oscillators or local oscillators in television tuners employ some modified form of the basic Colpitts circuit, the principles of which are explained in the lesson on "The Superheterodyne". Channel tuning is accomplished either by varying the inductance of the oscillator circuit or else by changing the capacitance.

In all modern television receivers the r-f oscillator is tuned to a frequency higher than that of the received carrier. The difference or beat frequency becomes the intermediate frequency used in the receiver.

Oscillator circuits are designed to produce a single sharply defined frequency which beats with the video carrier to form the video intermediate, and with the sound carrier for the sound intermediate frequency. The oscillator frequency beats also with all carrier frequencies between and on either side of the video and sound carriers to form corresponding intermediate frequencies.

Whereas the r-f oscillator has a sharp frequency response, the r-f amplifier and mixer circuits must have responses wide enough to provide approximately equal gains for the entire carrier and intermediate frequency ranges of any one channel being received.

If a tuner has three tubes, as with the example of Fig. 8, one tube may be the r-f amplifier, another the r-f oscillator, and the third a mixer. Otherwise, two of these tubes may be r-f amplifiers, and the third a dual type serving both oscillator and mixer functions. If the tuner has only two tubes, one is an r-f amplifier and the other is a dual tube used as oscillator and mixer. The r-f amplifier tube may be a pentode, or a twin triode used as a cascode amplifier, and in a few tuners is a single triode.

Many combined oscillator-mixer tubes are the 6J6 7-pin miniature twin triode, whose base pin connections are shown at A of Fig. 9. A single cathode serves both sections. The 12AT7 9-pin miniature twin triode is a fairly common oscillator-mixer tube. Its base pin connections are shown at B. This tube has a center-tapped heater whose sections are connected in parallel for 6.3-volt operation or in series for 12.6 volts. The 12AT7 is designed primarily for grounded grid circuits, but is in general use for grid-input circuits.

Other dual tubes have a triode section for use as an r-f oscillator and a pentode section for mixer. Base pin connections for the miniature 6X8 triode-pentode are shown at C of Fig. 9. This tube has a single cathode serving both sections. Another triode pentode, the 6U8, has base pin connections as at

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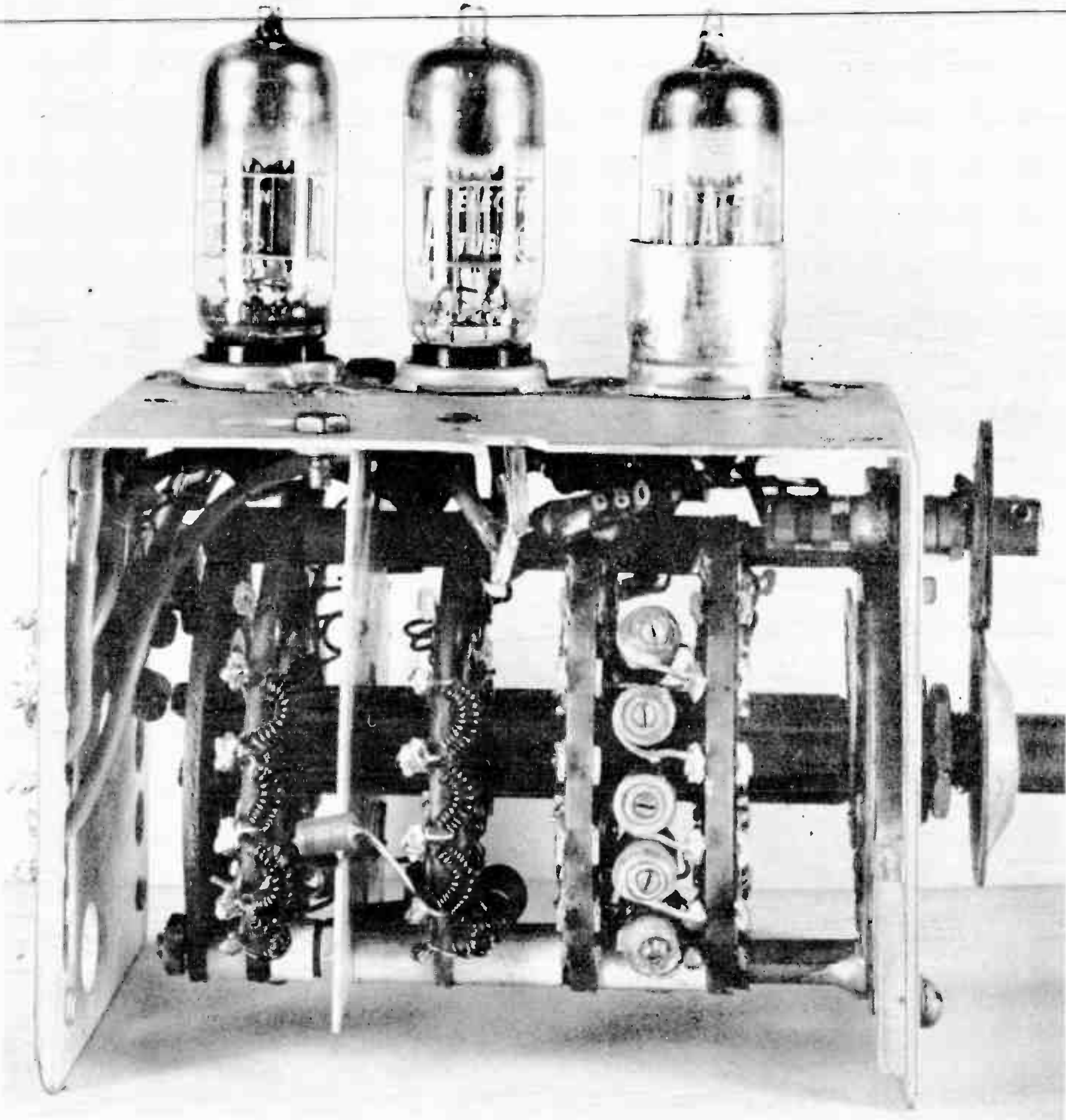

Fig. 8. A tuner with separate tubes, left to right, for r-f amplifier, mixer, and r-f oscillator. Note the oscillator alignment adjustments underneath the oscillator tube.

D. There are separate cathodes for the two sections. The pentode suppressor element is internally connected to the pentode cathode.

OSCILLATOR-MIXER COUPLINGS. Voltage at the oscillator frequency must be coupled into or "injected" into the grid-cathode circuit of the mixer, where oscillator frequency beats with carrier frequencies coming to the mixer grid from the r-f amplifier.

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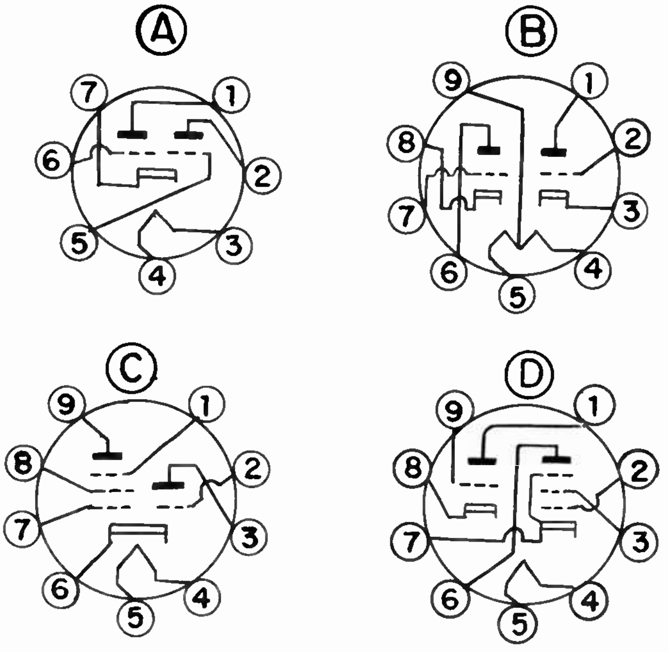

Fig. 9. Base pin connections of dual tubes used as oscillators and mixers in tuners.

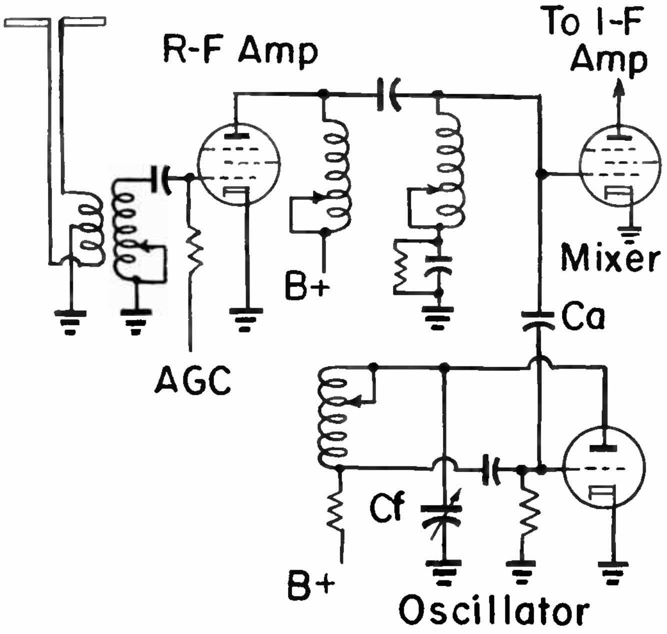

Fig. 10. Oscillator voltage is applied to the mixer grid through a capacitor.

In Fig. 10 voltage from the oscillator circuit is injected into the grid of the mixer through capacitor Ca, which here is connected between the grid of the oscillator and the grid of the mixer. This capacitor sometimes is between the mixer grid and the plate side of the oscillator circuit. The same oscillatory voltage exists throughout the entire resonant grid-plate circuit of the oscillator. Capacitor Ca usually is of some value between 1 mmf and 3 mmf, although sometimes it is of slightly more or less capacitance.

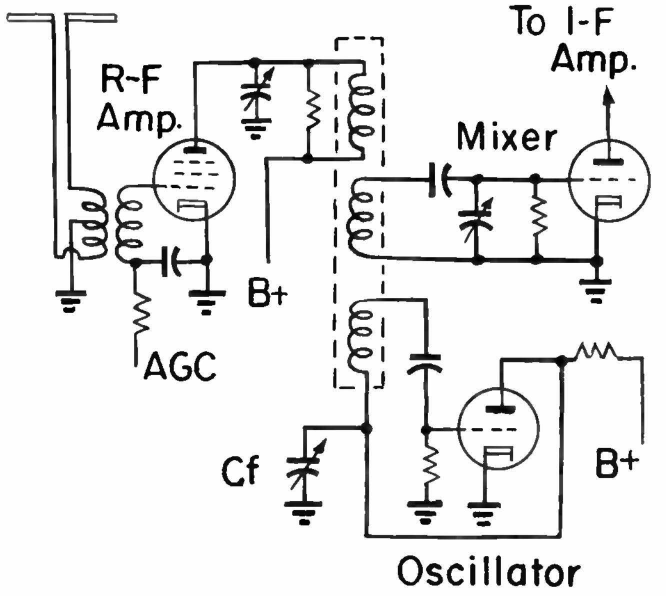

Fig. 11. Oscillator voltage is inductively coupled into the mixer circuit.

In Fig. 11 there is inductive coupling between oscillator and mixer circuits. The oscillator inductor is mounted fairly close to the inductor of the mixer grid circuit. On the same support is also the inductor in the plate circuit of the r-f amplifier, from which amplified carrier signal voltages are inductively coupled into the mixer grid circuit.

Various other methods are used for transferring oscillator voltage to the mixer. There may be one or more link couplings between inductors in the two circuits. In some tuners the tuning inductors for oscillator and mixer are connected through a small capacitor such as used between r-f amplifier and mixer circuits in Fig. 10.

FINE TUNING. It is necessary that oscillator frequency remain very nearly constant in order to keep video and sound intermediates where they belong on the frequency response of the i-f amplifier. Should oscillator frequency become too high, both intermediates shift to higher frequencies on the i-f response. Then sound signal output from the i-f amplifier may become too strong (sound bars appear) while video output be-

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comes so weak as to allow sync trouble and lack of strong details in pictures. Should oscillator frequency drop too low, the intermediates shift to lower frequencies on the i-f response. Then sound may almost disappear, while pictures become excessively bright.

Oscillator frequencies for each channel will be exactly right immediately after alignment by a competent technician. But normal aging of tubes and other circuit components eventually changes the oscillator frequencies. If the tuner is a type designed for continuous tuning, the operator naturally compensates for slight changes of oscillator frequency by adjustment of the selector dial, just as the dial of a radio set is tuned for best sound.

If the tuner is designed for step tuning, which means a fixed position of the selector for each channel, it is usual practice to provide a fine tuning control which allows compensation for changes in the oscillator circuit. Fine tuning is accomplished by a small variable capacitor, or capacitors, on the oscillator circuit. Examples are shown at Cf of Figs. 10 and 11. Fine tuning capacitors most often are operated by a knob concentric with the channel selector knob or pointer.

In a few tuners the fine tuning capacitors are small air-dielectric types with two or three plates, quite similar to radio tuning capacitors except for size. The majority of fine tuning capacitors are, however, made with some solid dielectric utilized in a great variety of mechanical constructions.

Fig. 12 illustrates one style of fine tuning control. The capacitor consists of a cylinder of dielectric material around the outside of which is a metal band acting as the outer plate of the capacitor. The inner plate is a cylindrical brass slug moved lengthwise by a rod passing through and fastened into a springy lever which is supported at its lower end on the tuner frame. The position of the slug in the stationary dielectric cylinder may be adjusted during service by loosening and moving the two nuts that hold the threaded slug stem in the upper end of the lever.

The lever and attached capacitor slug are moved for fine tuning by the end of the

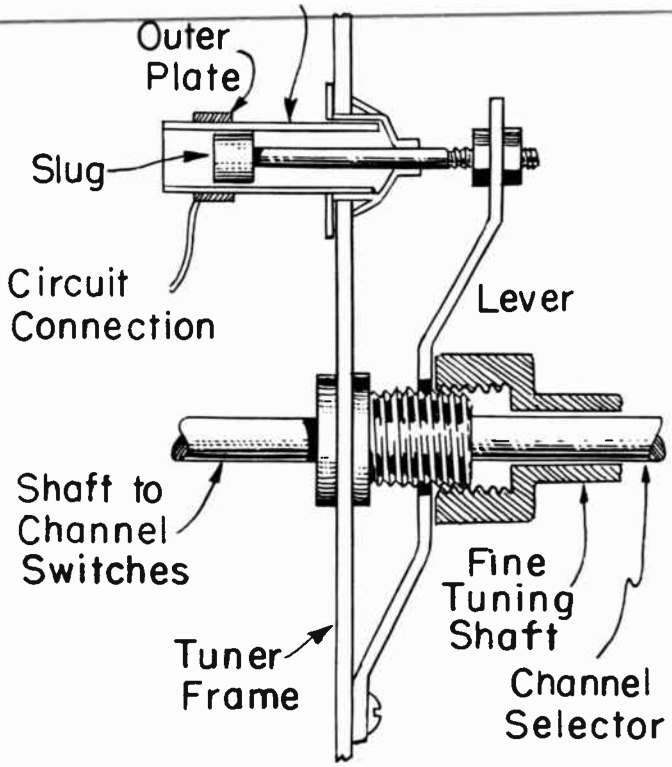

Fig. 12. One style of fine tuning capacitor having cylindrical dielectric.

fine tuning control shaft, which threads onto a bushing fastened to the tuner frame. When the operator rotates the control shaft it moves on its threads toward or away from the frame, thus moving the capacitor slug as may be required for tuning.

Fig. 13 shows construction and operation of a fine tuning capacitor used with many tuners of the turret style, in which separate inductors for the various channels are carried by a rotating drum. A cam-shaped wafer of phenolic composition having high dielectric constant is rotated by the fine tuning shaft to bring more or less of the dielectric into the space between two stationary capacitor plates, thus altering the capacitance.

The inner capacitor plate, which is connected to the plate-grid circuit of the r-f oscillator, is a small metallic disc carried in a ring of insulation which is mounted in an opening of the tuner frame. The outer capacitor plate is a piece of flat steel fastened to the tuner frame, and thereby connected to chassis ground.

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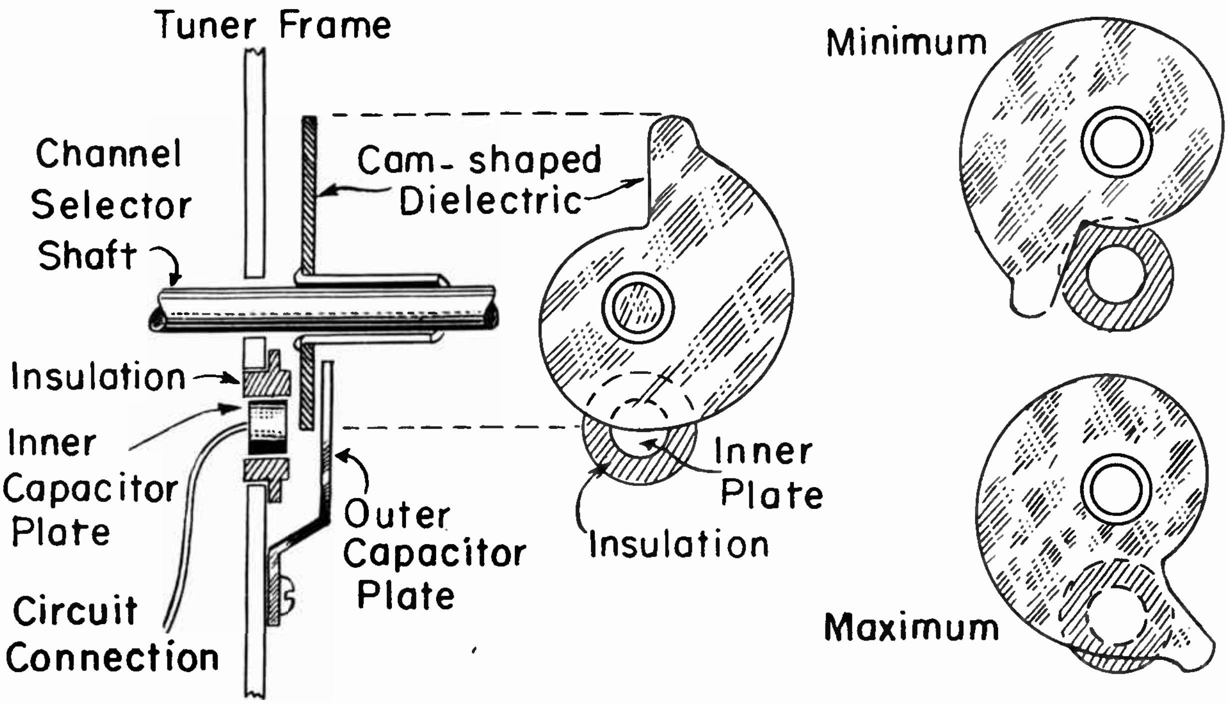

Fig. 13. Construction and action of a fine tuning capacitor used on many turret tuners.

With the dielectric wafer turned to its mid-position, as shown by the larger diagram, there is solid dielectric material between about half the exposed surface area of the inner plate and metal of the outer plate. Effective capacitance then is about half of maximum. When the dielectric wafer is rotated all the way counter-clockwise, as at the upper right, none of the solid dielectric is between the capacitor plates, and capacitance is minimum. When the wafer is rotated fully clockwise, as at the lower right, there is solid dielectric between the entire surface of the inner plate and the outer plate. This provides maximum capacitance. The projection on the wafer comes against stops on the outer plate to prevent rotation beyond the positions illustrated for minimum and maximum capacitances.

Fine tuning controls sometimes make use of dual capacitors, of which two examples are illustrated by Fig. 14. The high sides of a dual capacitor may be connected to the grid side and to the plate side of a Colpitts oscillator circuit, with the low sides to ground. Probably you recall that the original or elementary Colpitts circuit includes grid and plate capacitors to ground. Dual capacitors are used also in tuners that are switched between low and high bands of the vhf channels, with one capacitor for each band.

At A in Fig. 14 the inner capacitor plates, which are movable and grounded, consist of two small brass cylinders on a shaft that threads through a metal bushing in the tuner frame. The outer plates, which remain stationary, are two metal rings carried in an insulating tube which fits around the inner plates and mounts on the frame bushing, although shown separately in the illustration. The shaft carrying the inner plates is rotated by a friction drive mechanism that turns the threaded shaft in the bushing threads, thus moving these plates farther into or out of the stationary outer plates. This movement varies the capacitances.

At B in Fig. 14 the capacitor rotor is a half-cylinder carried on the inner end of the fine tuning shaft, which is concentric with the shaft for channel selection. One stator plate for the low band and another for the high band extend around part of the rotor and are separated from the rotor by dielectric tubing not shown in the drawing.

A rotor generally similar to that of Fig. 14 at B may be used with only a single stator

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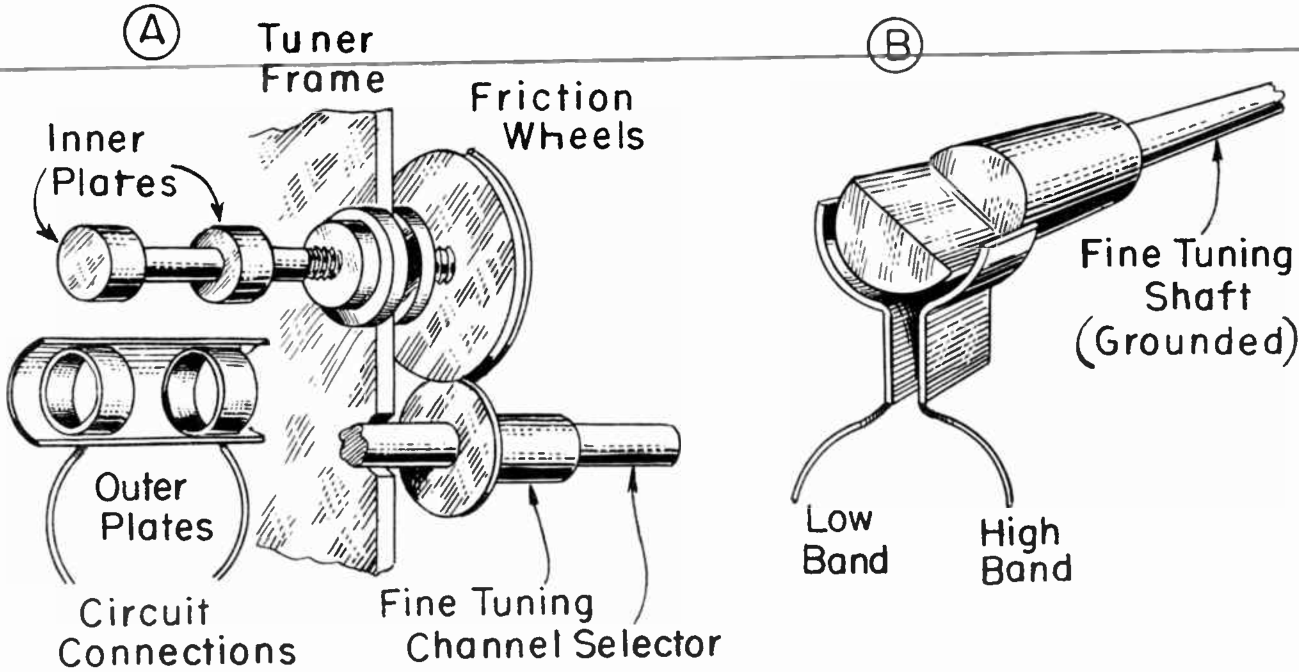

Fig. 14. Dual capacitors for fine tuning.

plate when only one fine tuning capacitor is required for the oscillator circuit. Still other fine tuning capacitors consist of two small circular metal plates, one stationary and the other on a threaded shaft which is turned in a threaded bushing to move the plates closer together or farther apart for varying capacitance.

Fine tuning capacitors commonly have values from less than 2 mmf to as much as 5 mmf as maximums, with minimums of half or less than half the maximums. Any given change of fine tuning capacitance causes greater change of oscillator frequency in the high channels than in the low ones. This is because less tuning capacitance or inductance is needed for high-frequency tuning, and the fine tuning capacitance becomes a greater percentage of the total. Total variation of oscillator frequency by fine tuning usually is on the order of two to three mc, or slightly more.

With receivers having intercarrier sound systems, fine tuning is adjusted primarily for best pictures. Unless the r-f oscillator is aligned far from its correct frequency, to unduly weaken or strengthen sound signals, the 4.5-mc intercarrier beat signal with its sound modulation remains unaffected. This 4.5-mc signal going to the sound section always remains the difference between video and sound intermediates, and this difference cannot be changed.

With receivers having dual or split sound systems, fine tuning is adjusted primarily for best or loudest sound. This is necessary because the sound intermediate frequency must be almost exactly right in order that the sound signal at this frequency may fall within the pass band of the sound i-f amplifier sections.

FREQUENCY DRIFT. Resonant frequency of a tuned circuit might be exactly correct shortly after a receiver is turned on. But with continuous operation, temperatures of all parts become higher. Tube elements and supports will expand, and possibly shift their positions enough to slightly increase internal capacitances. Windings and supports of inductors will expand or may warp a little bit with heating, and the altered dimensions change inductances and distributed capacitances to some extent. Will resonant frequencies remain unchanged? Of course not. There will be drift, usually to lower frequencies.

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Frequency drift due to temperature rise may be lessened by constructions which keep temperatures fairly low. For example, tubes may be operated with small plate currents and voltages, for reduced power dissipation. Resistors may be large enough to dissipate their powers at low temperatures. High-Q construction, with small energy losses, will help. Insulation may be of ceramic materials which expand relatively little with heating. The chassis may be well ventilated, while tubes, resistors, and other hot components are mounted high, where their heat will not be carried upward into other parts by air currents. All these are matters of original design, and not too much can be done about them after a receiver is built.

It is possible in original design, also during service replacements when you are expert enough, to compensate for downward frequency drift by installing capacitors having negative temperature coefficients. These are described in the lesson on "Fixed Capacitors and How They Act".

We find more temperature compensating capacitors in tuners than in other sections of receivers, but they often are used in other high-frequency circuits. Frequency drift in r-f oscillators is most troublesome, but may cause trouble also in r-f amplifier and mixer circuits. A few of the more common uses for temperature compensating capacitors are shown at points numbered on the diagram of Fig. 15. Circuits of this diagram are completed only to an extent illustrating relations of TC (temperature compensating) capacitors to various inductors. Explanations follow.

1. So far as r-f voltages and currents are concerned this capacitor is in parallel with the inductor in the plate circuit of the r-f amplifier.

2. This capacitor is in series with the inductor in the mixer grid circuit

3. Parallels the coupling inductor between mixer plate and first i-f amplifier.

4. In series with the oscillator grid-plate inductor.

5. This TC unit, in conjunction with an ordinary capacitor from oscillator plate to ground, is effectively in parallel with the oscillator grid-plate inductor.

6. Carries 4.5-mc sound signals from the video detector to the tuned coupler on the grid of the 4.5-mc sound amplifier.

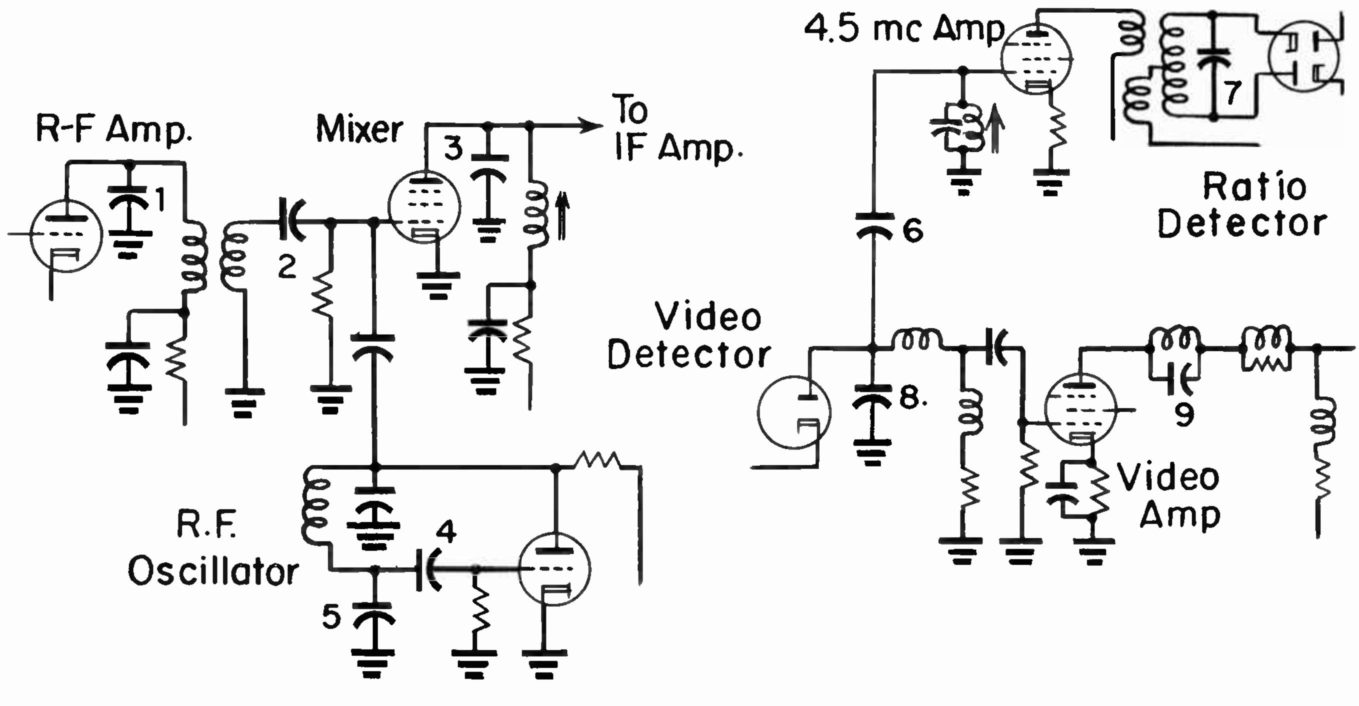

Fig. 15. Capacitors identified by numbers on the diagram are temperature compensating types.

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7. In parallel with the secondary winding of the ratio detector transformer.

8. From video detector plate to ground.

9. Across the inductor of the 4.5-mc intercarrier beat trap.

Some receivers might have all the temperature compensating capacitors of Fig. 15, or might have more. Other receivers might have only a few of these TC units, and some of the few might be at points not shown on the diagram. In general, temperature compensating capacitors are directly or effectively in parallel with inductors in tuned circuits whose frequency is to be stabilized, or may be in series with inductors or with other capacitors which affect resonance. Service diagrams do not always indicate where capacitors are of the temperature compensating type, nor do all service parts lists show which capacitors are of this kind.

You must watch for temperature compensating capacitors during service work, and make sure that replacement units are of the same ratings. In Fig. 16 you can see two TC capacitors mounted on the oscillator socket in the tube shelf of a television tuner. These particular capacitors show clearly because they are white.

Temperature compensating capacitors should warm up at the same rate as circuit elements whose inductances or capacitances may change when heated. It is common practice to mount TC capacitors on tube socket lugs when circuit connections permit, or close to sockets otherwise. Sockets heat at about the same rate as the tubes. TC capacitors are supported by their own pigtails, not in clips or other kinds of heat-conducting mounts.

If any number of TC capacitors have the same coefficient they may be paralleled for

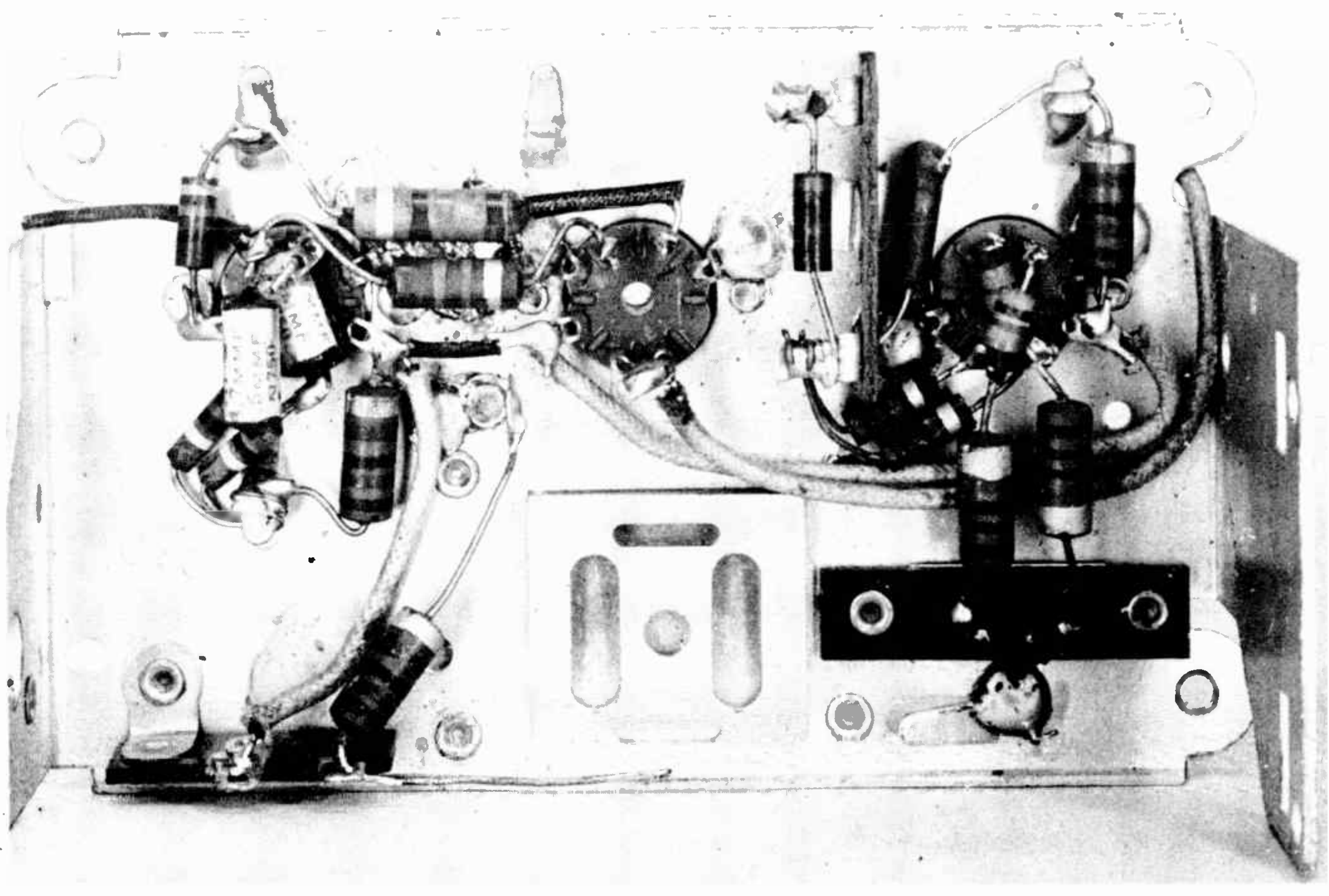

Fig. 16. Temperature compensating capacitors are on the oscillator socket at the upper left.

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increased capacitance, and the group will have the same coefficient as one. For instance, two or more NTC -750 capacitors in parallel still have NTC (negative temperature coefficient) of -750.

Frequency drift may result from causes other than temperature change. For example, variations of d-c voltages on plate, screen or grid of a tube will change the plate resistance. This will alter the tube transconductance and also the resonant frequency of a connected circuit. This is one reason for filtering out ripple voltage to the greatest practicable extent, and it is a reason for using voltage regulators when power line voltage is likely to fluctuate to any great extent.

It is especially important to reduce frequency drift in r-f oscillators of sets employing dual sound systems. In the sound i-f amplifier of such systems the pass band usually is about 300 kc or 0.3 mc. Should r-f oscillator frequency drift by half of this, or 0.15 mc, it would throw i-f sound signals far to one side on the pass band. On channel 13, with oscillator frequency of 237 mc as an example, this would be a drift of only about 0.06 per cent, or only one part in 1,600.

With intercarrier sound, oscillator drift of any probable extent has little effect on sound response, because the modulated intercarrier beat remains at 4.5 mc regardless of r-f oscillator frequency.

A fine tuning control might be used by the operator to compensate for oscillator frequency drift in receivers having dual sound systems. The difficulty is that fine tuning then requires adjustment during or after the warmup period. Then, the next time the set is turned on cold, the former fine tuning adjustment for hot conditions will be incorrect, and another adjustment will be needed. Temperature compensation is more satisfactory.

PUSH-PULL RESONANT CIRCUITS. A number of tuners have employed what are called push-pull circuits for plates or grids of r-f amplifiers, mixers, and r-f oscillators. Connections for an r-f amplifier with a push-pull plate circuit are shown by

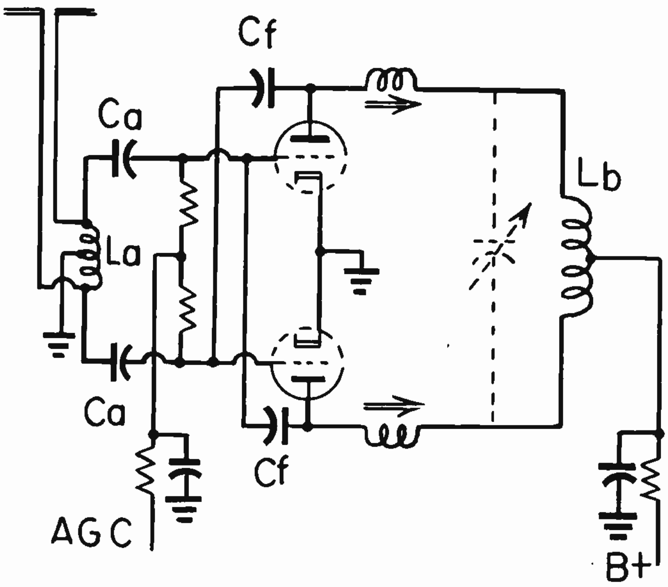

Fig. 17. An r-f amplifier using a twin triode with a push-pull plate circuit.

Fig. 17. The tube, as in all push-pull tuner circuits, is a twin triode, often a type 6J6. The two grids are connected through coupling and blocking capacitors Ca-Ca to a center-tapped inductor La whose outer ends go to the antenna transmission line. At any one instant, signal voltage from the antenna is of opposite polarity at opposite ends of inductor La, and at the two grids of the amplifier tube.

Since grid voltages vary in opposite polarities at the same time, plate currents and voltages in the two sections of the tube must vary oppositely. Because inductor Lb is connected between the two plates, one end of this inductor is made positive while the other end is made negative. In effect, these opposite potentials "push" signal current into one end of the plate inductor while they "pull" signal current out of the other end. D-c plate voltage is applied equally to the two sections of the twin triode from the center tap of the plate inductor.

Each amplifier plate is connected to the grid of the opposite section through small capacitors Cf-Cf. Feedback of plate circuit signal energy through these capacitors is of such polarity, or in such phase relation to grid signal voltages, as to reinforce the signals. Grid returns are through resistors to the agc bus.

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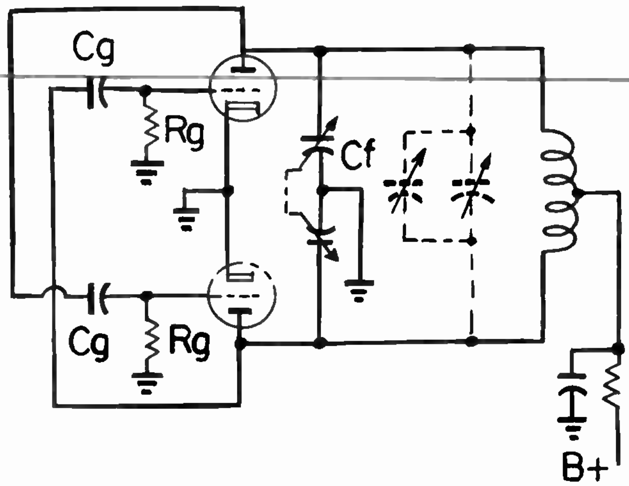

Fig. 18. Push-pull plate circuit as used for an r-f oscillator.

Fig. 18 shows connections for a push-pull oscillator. Again the tube is a twin triode. As is true of nearly all r-f oscillators, there is grid-leak biasing by means of capacitors Cg and resistors Rg. Oscillating voltages which reach the grids through capacitors Cg are fed back from the plate circuits, with each plate circuit feeding to the grid of the opposite triode section. Strength of oscillations depends on feedback energy, which depends in turn on reactances of the grid capacitors, and on the amount of grid bias as determined by relations between capacitances at Cg and resistances at Rg.

The push-pull oscillator plate circuit is essentially the same as the push-pull amplifier plate circuit of Fig. 17. In tuners having the oscillator plate circuit tuned by altering its inductance, there usually will be a dual fine tuning capacitor at Cf. Where channel tuning is by means of a variable capacitor across the plate inductor, as in broken lines, fine tuning may be handled by a single small adjustable capacitor paralleling the tuning capacitor.

Tuning inductance in any push-pull circuit may be altered for channel selection in various ways. Many step tuners have a single inductor tapped at intervals, or have a number of inductors in series, with taps between them, and with connections to taps through a rotary selector switch. Other step tuners have a single inductor for all channels in one band, tuned by means of a paralleled variable capacitor. Still another method utilizes separate inductors for each channel, with any one inductor switched into the active circuit as required.

RESONANT LINES IN TUNERS. Circuits of Figs. 17 and 18 are constructed with lumped inductances and capacitances, meaning with compact coils for inductance and with compact capacitors for capacitance. These lumped elements may be replaced by what is called a quarter-wave shorted resonant line.

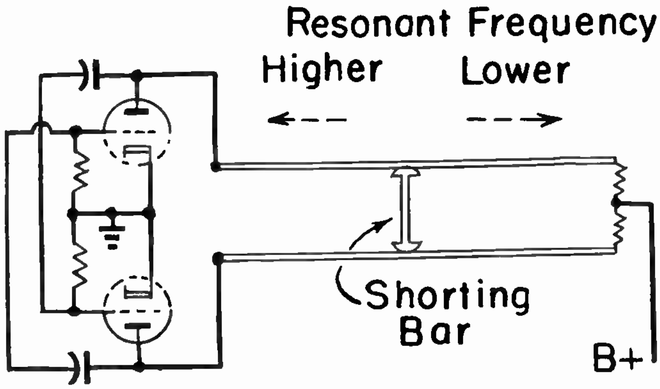

Fig. 19. Quarter-wave shorted resonant line in the plate circuit of a push-pull oscillator.

Fig. 19 illustrates the principle of a resonant line as used in the plate circuit of a push-pull oscillator. The line consists of two paralleled conductors, with between them a movable conductive bar providing a short circuit between the sides of the line. The two conductors possess inductance proportional to their electrical lengths as measured from the tube sections to the shorting bar. Between the sides of the line is capacitance, also proportional to their electrical lengths.

Moving the shorting bar along the resonant line varies inductance and capacitance together. At any position of the shorting bar, effective inductance and capacitance are resonant for some frequency. They act just like a parallel resonant circuit constructed with a coil and capacitor. As the shorting bar is moved closer to the tube plates, effective inductance and capacitance decrease together, and resonant frequency increases. Moving the bar farther from the tube plates, to increase the non-shorted length of line, increases both inductance and capacitance to cause decrease of resonant frequency.

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We speak of this arrangement as being a quarter-wave line for the following reason. At any frequency of resonance, the electrical length of each side of the line is equal to one-quarter the length of an electromagnetic wave at the same frequency. For instance, at the center frequency of channel 10 (195 mc) one wavelength is about 5 feet and 3/8 inch. A quarter-wavelength would be about 15-1/8 inches.

The electrical equivalent of a quarter-wavelength in resonant lines of a tuner is much shorter, in inches, than the theoretical length. This is because, in addition to inductance and capacitance of the line conductors, there is much inductance and capacitance in the tube sections and in associated wiring and circuit parts. Also, electrical length may be increased within limited space by adding some coiled series inductors and some small capacitors between the sides of the line.

Practical applications of tuned quarter-wave resonant lines are shown in lessons dealing with details of tuner construction, also in lessons on ultra-high frequency reception.

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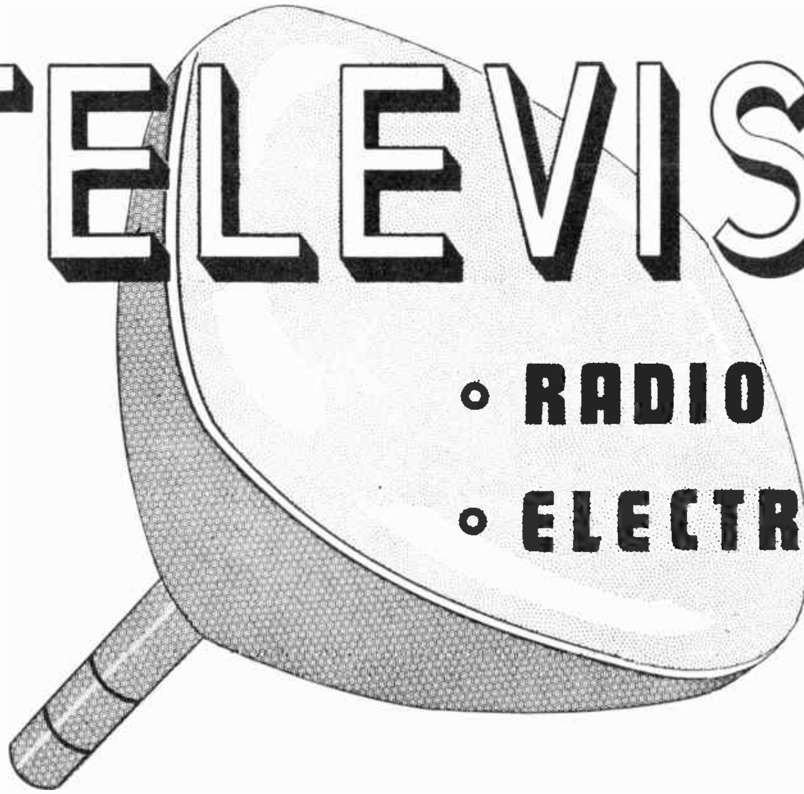

• RADIO

• ELECTRONICS

LESSON 80 — TUNER CONSTRUCTION AND REPAIRS

Coyne School

practical home training

Chicago, Illinois

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Lesson 80

TUNER CONSTRUCTION AND REPAIRS

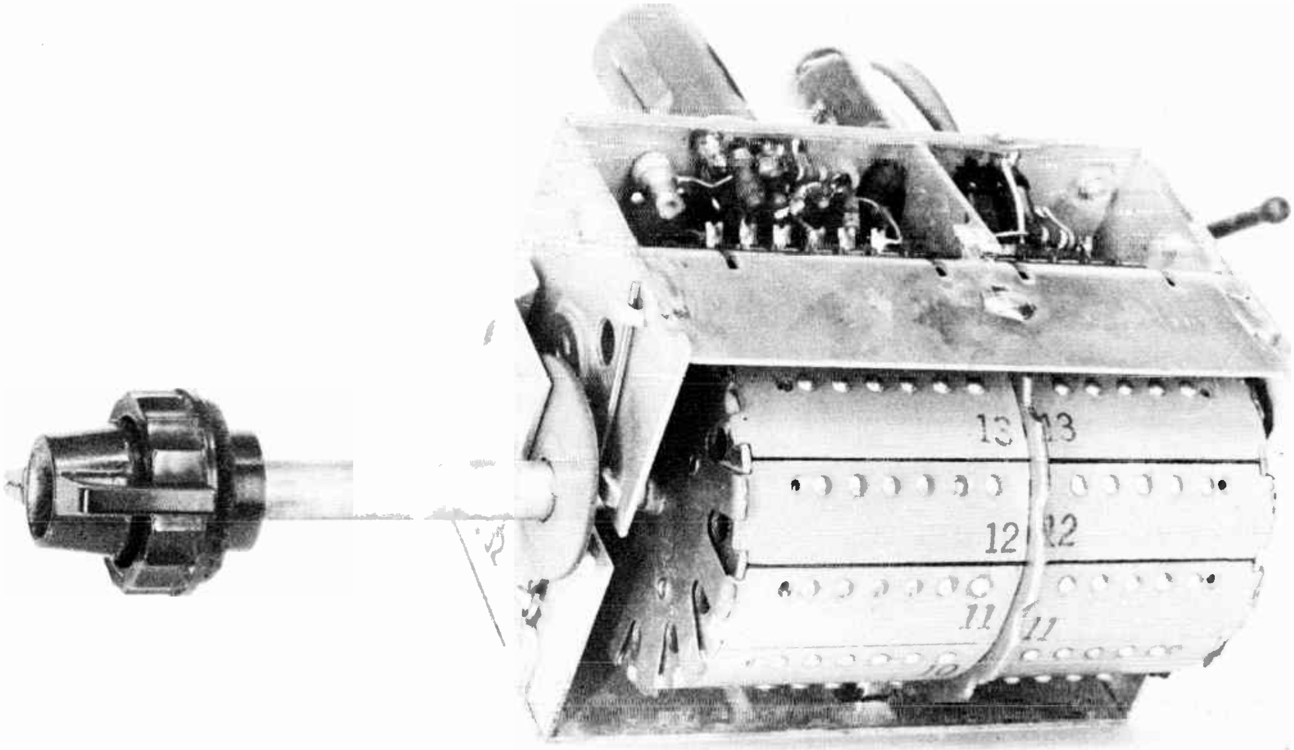

Fig. 1. A turret tuner.

Tuners are constructed with any of a wide variety of circuits for amplifier, mixer, and oscillator tubes. There may be the familiar grid-input circuits generally similar to inputs for video, sound, and sync amplifiers. Instead there may be grounded grid circuits, cascode circuits, push-pull circuits, or resonant line circuits. More than one of these basic circuits may be used in the one tuner.

Sometimes we find step tuning, while again there will be continuous tuning with band switching. Tuning inductance may be varied by using separate inductors for each channel, or with series tapped inductors, or with movable cores for inductors. Variable capacitance tuning may be by means of air-dielectric capacitors or with solid- dielectric types.

Methods of channel selection account for many of the differences between tuners. To mention only a few of these methods:

Inductors for each channel may be mounted on a rotating cylinder or drum to make what is called a turret tuner.

Individual channel inductors may mount on a flat plate which slides to required positions.

Stationary inductors may be selected, or their taps connected to tube circuits, by a rotary switch.

Either inductors or capacitors may be selected by a push-button mechanism.

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Inductors whose turns form a spiral may be tuned by sliding contacts rotated around turns of the spiral.

Movable cores may be raised or lowered by cams or by some arrangement of levers.

The many electrical and mechanical designs have been put together in almost every possible combination of form tuners of various makes and types. To attempt examination of each and every one of these combinations would take many, many lessons, and would not be worth the effort. Instead we shall get acquainted with common principles and with constructions which have been used and now are used in greatest number.

TURRET TUNERS. The underside of one style of turret tuner, with shields removed, appears as in Fig. 1. Here we see the cylindrical drum that is rotated by the channel selector shaft and knob. Attached to the drum are strips of insulation. On each strip or each pair of strips in line lengthwise are inductors which tune the antenna, r-f amplifier, mixer, and r-f oscillator circuits for one channel. The drum is rotated to bring the strip or strips for a desired channel into the position where contact buttons engage stationary springs mounted on insulation attached to the tuner frame. Leads extend from the springs to tube socket lugs and various circuit elements carried by the tuner frame.

After a turret tuner of the general style pictured by Fig. 1 is removed from the main chassis of the receiver, the tuner drum may be taken from its frame as follows:

1. Remove from the tuner frame the fine tuning outer capacitor plate, which is held by one or more screws. Fig. 2 shows this plate and other parts at the selector shaft end of a tuner.

2. The fine tuning shaft with its attached cam-shaped dielectric wafer now will slide off the concentric shaft that rotates the drum.

3. Remove the curved tension spring and then the fibre spacing washer from the channel selector shaft or drum shaft.

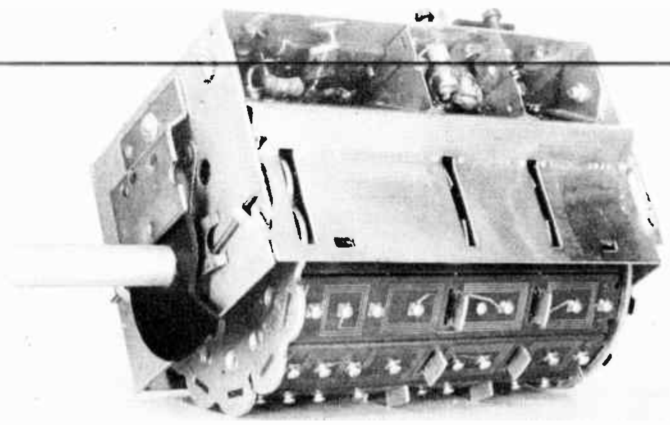

Fig. 2. For taking the turret drum from this tuner the first step is removal of the fine tuning shaft and dielectric wafer.

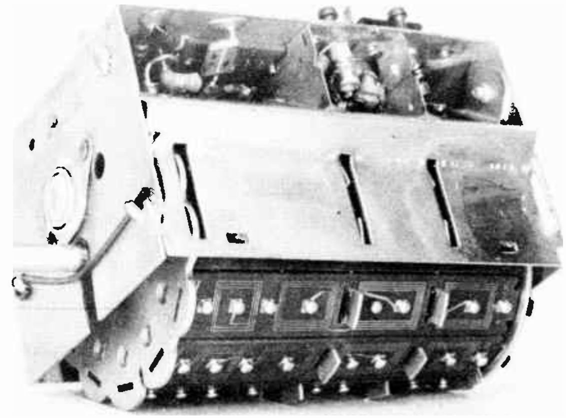

Fig. 3. The drum shaft fits into slots of the tuner frame, where it is held by spring wires.

4. Now, as shown by Fig. 3, you will see that the selector shaft and drum are held in U-shaped slots of the frame by spring wires at front and back of the tuner. One or both ends of these two wires snap onto hooked projections on the tuner frame. Lift either ends of both wires out of the projections.

5. Hold the tuner so that the turret drum won't drop onto anything which might damage it. With a thin-bladed screw driver lift the detent spring, on one side of the frame, to allow the selector shaft and drum to slide freely out of the U-shaped slots. A turret drum thus removed from its frame is pictured by Fig. 4.

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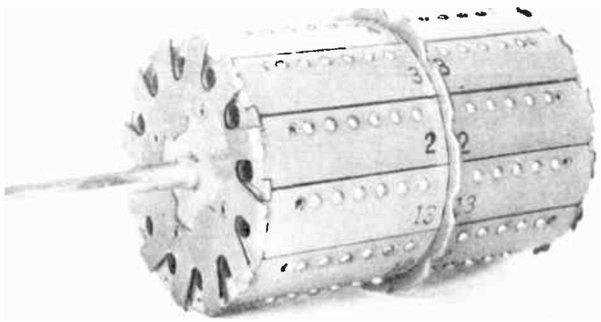

Fig. 4. A turret drum removed from a tuner.

These instructions apply in a general way to removal of drums from several makes of turret tuners. Replacement is made by reversing the steps. The fine tuning wafer shown in the photographs must clear the inner circular plate of the fine tuning capacitor, but this wafer is intended to rub against a small projection on the outer plate to prevent vibration and microphonic effects. The tension spring should hold the fine tuning wafer against this small projection.

In most turret tuners the channel strips are held on the drum by some form of spring clip which presses projections of the strips firmly into suitable slots or openings on the drum structure. On a few tuners the channel strips are held in place by screws.

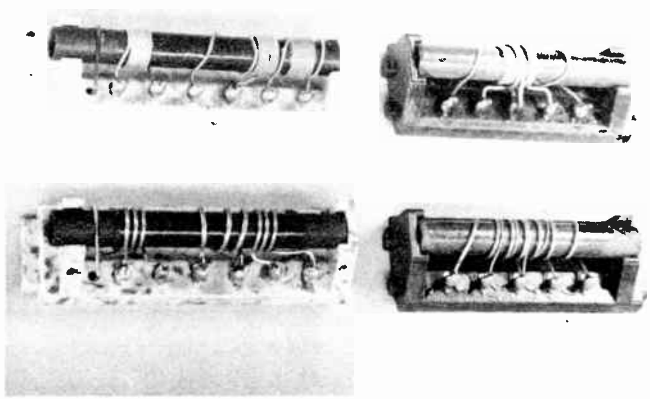

Fig. 5. Inductor strips after removal from one style of turret tuner.

Fig. 5 shows pairs of strips for two channels as they appear when removed from a drum. The coils and supporting forms seen here are toward the inside of the drum when in operating positions. Strips of the upper pair are for a low-band channel, those at the bottom for a high-band channel. Windings on the strips for either channel, in order from left to right, are for the r-f oscillator, mixer grid circuit, and r-f amplifier plate circuit. Then, on the second strip of either pair we have the coupling transformer between antenna and r-f amplifier grid.

In the lesson on "Dressing of Leads and Parts" we looked at a picture of two channel strips on which inductors are formed by printed wiring.

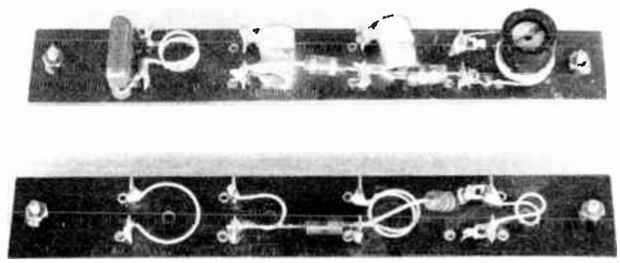

Fig. 6. On these turret drum strips are capacitors as well as inductors.

Fig. 6 is a picture of the inward-facing sides of two channel strips on which are not only inductors but also coupling and blocking capacitors. From left to right along either strip the inductors are for antenna tuning, for r-f amplifier plate, for mixer grid, and for oscillator. The tuner strip at the top of the picture is for a low-band channel, the bottom one for a high-band channel.

Nearly all turret tuners provide for service alignment of oscillator frequency on each channel, even where antenna and mixer circuits are non-adjustable. Inside the oscillator inductors of Fig. 5 are threaded brass slugs whose screw driver slots are accessible through a hole in the front of the tuner frame. On printed wiring strips there are

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screw adjustments for metal plates located behind each oscillator inductor, with screw slots accessible through a hole in the front of the tuner frame. As the drum is rotated for tuning, the oscillator adjustment screw for the selected channel comes into position behind the hole in the frame.

If there is a suitable opening in the front of the cabinet, the oscillator alignment screws of these turret tuners may be reached after taking off the channel selector and fine tuning knobs. The chassis need not be removed from its cabinet. Many other types of tuners are designed to allow oscillator alignment in similar manner.

Other tuners are of such construction that the chassis must be taken out of its cabinet for all tuner alignment, including oscillator adjustments. With the design of Fig. 6 some strips must be taken off the tuner, after removal from the cabinet, to allow reaching adjustments for other strips while in positions where they connect to tube circuits. Oscillator alignment for the upper strip is by means of a threaded brass slug inside the inductor at the right. On the lower strip this adjustment is made by spreading or squeezing turns of the oscillator coil.

After any shields which enclose the drum are removed, it is possible to remove the channel strips from many turret tuners without taking the tuner off the main chassis. Although the tuner of Fig. 7 is out of its chassis, this picture shows several channel strips removed. Inductors on remaining strips may be seen inside the drum. Visible at the bottom of this picture are stationary

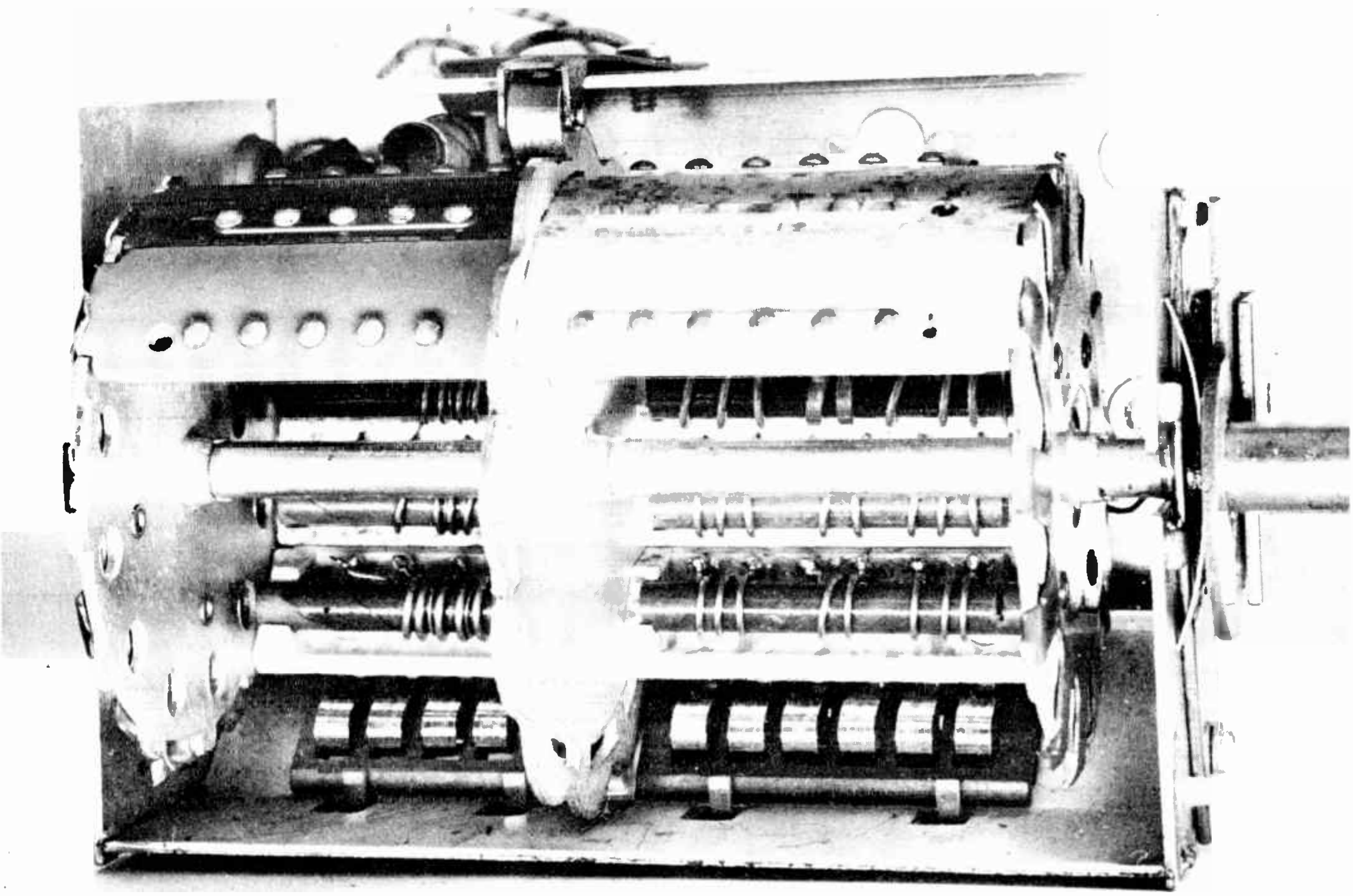

Fig. 7. Some strips have been removed to show the inside of this turret drum, with other strips remaining in place.

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spring contacts which are engaged by button contacts on the outside of channel strips as the drum is rotated.

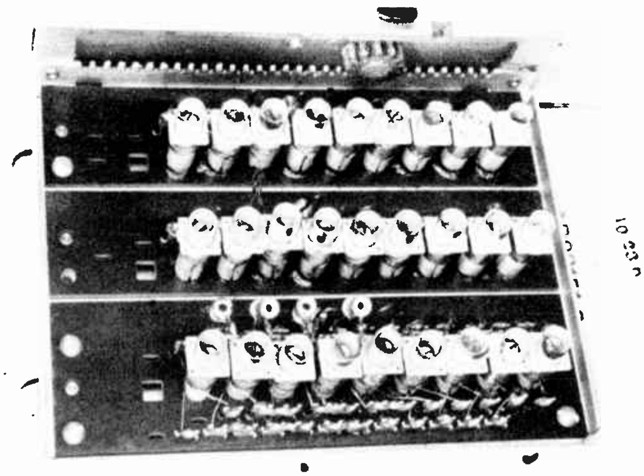

Fig. 8. The underside of the sliding inductor plate of a tuner.

SLIDING PLATE TUNERS. Fig. 8 is a picture of the underside of a tuner similar to the turret type in that inductors are moved for channel selection while everything else remains stationary, but otherwise quite different. Inductance units are in three rows. Units in the row at the bottom, which would be toward the rear of the receiver chassis, are two-winding transformers for coupling the antenna to the grid of the r-f amplifier. Those in the center row tune the mixer grid circuit. Inductors in the row at the top, which would be toward the front of the chassis, tune the r-f oscillator.

The inductor units are mounted on three strips of insulation attached to a metal carriage that is moved to the right or left for channel selection. This movement is by means of a toothed rack along the front edge of the carriage, into which meshes a pinion or small gear turned by the channel selector knob.

Windings of the inductor units are connected to contact points which extend through the supporting insulation. As the carriage is moved, these inductor contacts for three units that tune any one channel engage stationary contacts from which leads go to tubes, capacitors, and resistors in the portion of the tuner above the chassis.

Inside each coil form is an adjustable brass slug for alignment. These adjusters are made accessible with the chassis removed from its cabinet, or may be reached through the bottom of the cabinet with the chassis still in place. Single inductor units tune pairs of high-band channels 7 or 8, 9 or 10, and 11 or 12. When the tuner carriage is moved to receive the higher channel of any pair, part of the total inductance is cut out by means of a tap connection on the winding.

STATIONARY CHANNEL INDUCTORS WITH SWITCH. There have been quite a few tuners in which inductors for each channel or for pairs of channels remain stationary while being connected to tube circuits by a rotary selector switch. Such a unit is pictured by Fig. 9. Inductance units are supported around a central rotary switch operated by the channel selector knob or dial.

The long tubular coil forms visible in the photograph are for low-band channels. On each form, from left to right in the picture and from front to back in the receiver, are windings for the r-f oscillator, the mixer grid circuit, and r-f amplifier plate circuit. Alignment adjustments for these low-band inductors are made by spreading or squeezing turns at the ends of the coil forms.

On the opposite side of the tuner switch, not visible in the photograph, are small wire-wound inductors for the high-band channels. Inside each of the inductors for r-f amplifier plate and for mixer grid circuits are small brass screws for alignment adjustments. High-band oscillator coils are aligned by spreading or squeezing the coil turns.

Another tuner with stationary inductors and rotary selector switch is pictured in the lesson on "Dressing of Leads and Parts". From the front end or shaft end of that unit, and in order toward the rear, are inductors for r-f oscillator, for mixer grid, for r-f amplifier plate, and for antenna coupling on the low-band channels. Individual antenna coupling inductors are not used for high-band channels. Adjustable cores for r-f oscillator alignment are accessible through holes in the front of the receiver chassis. Adjustable cores for alignment of all other inductors

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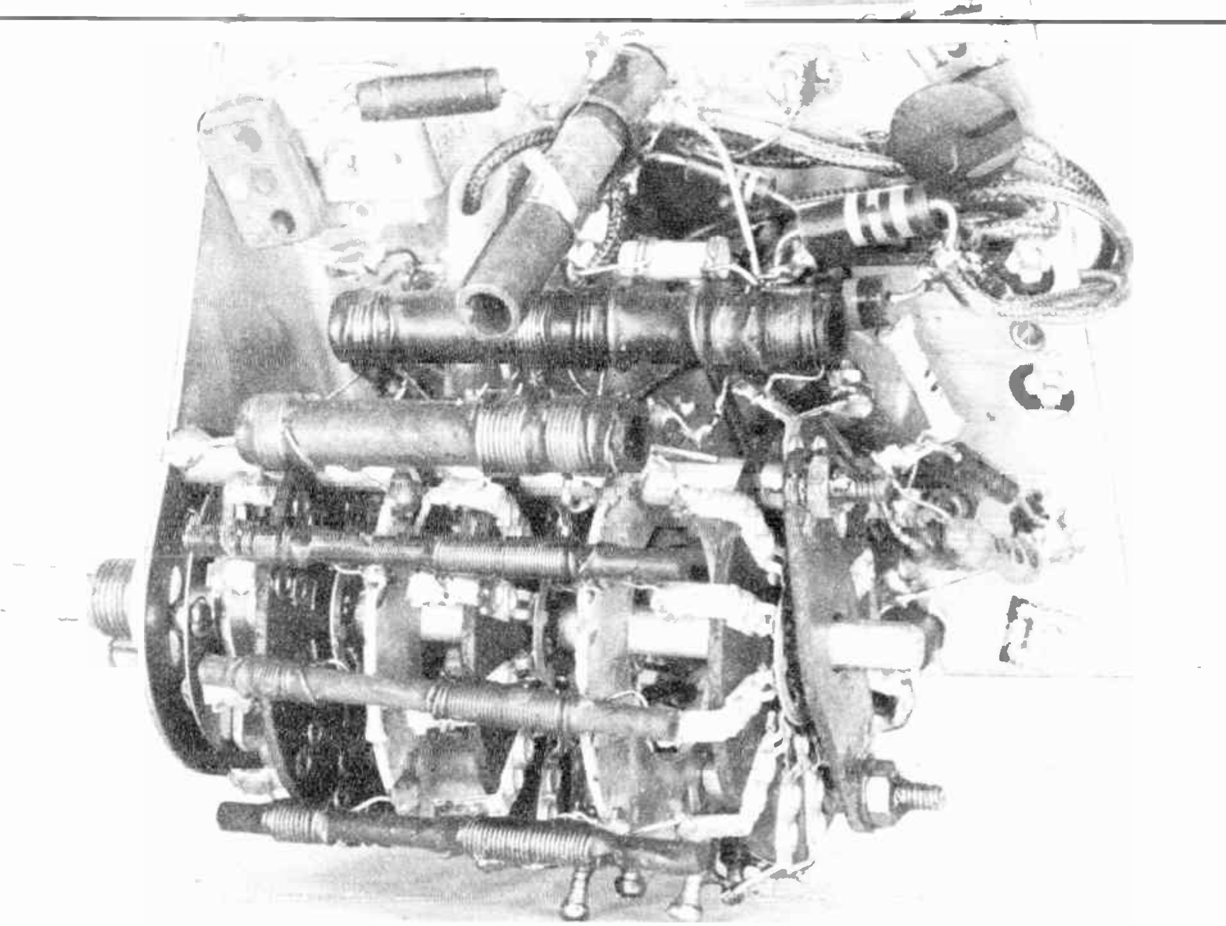

Fig. 9. Tuning inductors are on stationary forms, with channel selection connections made by a rotary switch.

are accessible with the chassis removed from its cabinet.

In the lesson on "Inductors For Television And Radio" is shown a tuner whose channel inductors are mounted on the receiver chassis near a rotary selector switch with interconnections through wire leads. Within the inductor coil forms are movable cores whose threaded rods or screws extend through the chassis are accessible from above for alignment.

TAPPED INDUCTORS WITH SELECTOR SWITCHES. In the lesson on "Inductance Tuning" is explained in detail the method of channel selection often called incremental tuning. Total or maximum inductance in a number of series-connected sections is sufficient for resonance at lowest channel frequencies, with sections shorted out for tuning to successively higher channel frequencies. Inductor sections for any one tube circuit are connected to terminals around the outside of a rotary switch wafer. It would be a good idea to read that earlier lesson to refresh your memory on just how this system operates.

Circuits for a complete tuner with incremental tuning for r-f amplifier and mixer, and with separate channel inductors for the r-f oscillator, are shown by Fig. 10. Segments of the selector switch, shown shaded, are in positions for reception of channel 13. Switch A tunes the r-f amplifier plate, shorting all sections of the inductor except Lp for reception in this channel. Switch segment B shunts inductors La across the antenna input coupler for all high-band channels. Switch segment C tunes the mixer grid circuit, with only the inductance at Lg active for channel 13. Tungues on switch segments D and E connect separate oscillator tuning inductors

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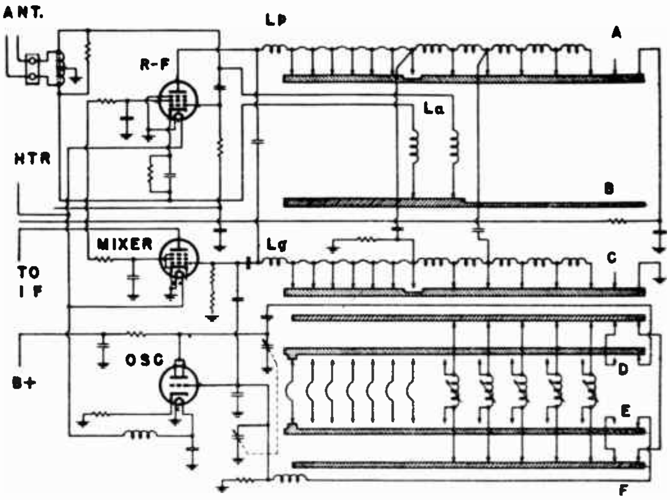

Fig. 10. Incremental tuning for r-f and mixer, with separate oscillator coils.

between plate and grid of the oscillator triode. For high-band tuning the oscillator inductors for all low-band channels are shorted together by switch segments shown above D and below E. Switch segments move to the right, in the diagram, for tuning to lower channels. This removes short circuits from successive sections of r-f and mixer inductors, while making connections to required oscillator inductors.

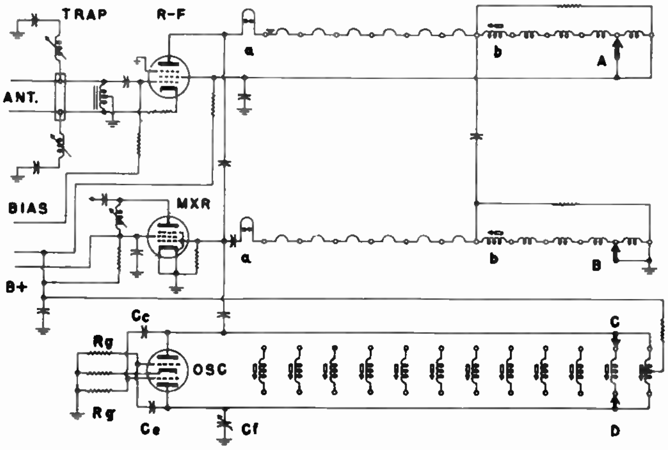

Fig. 11. A push-pull oscillator, with incremental tuning for r-f and mixer circuits.

Fig. 11 shows connections in a tuner having incremental inductors for the r-f plate and the mixer grid circuits, and individual channel inductors for a push-pull r-f oscillator. Switch A shorts successive sections of the r-f plate inductor when tuning to higher channels, while switch B does the same thing for the mixer grid inductor. Switches C and D make connections to the two ends of individual oscillator inductors for each channel. Alignment adjusters at a-a are for high-band tuning, and those at b-b are for low-band tuning of r-f plate and mixer grid circuits. Each oscillator coil has its own alignment adjustment. At Cf is the fine tuning control.

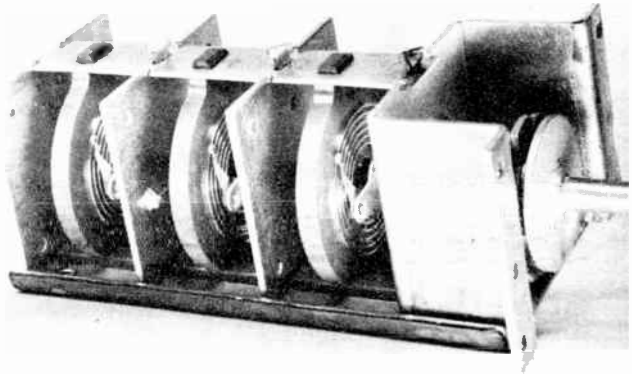

Fig. 12. Spiral inductors and contact brushes in a three-circuit Inductuner.

INDUCTUNERS. Fig. 12 is a picture of a unit whose trade name is "Inductuner". Three stationary inductors consist of flat metallic strips formed into spirals and partially embedded in discs of low-loss insulation. On the exposed edges of the spirals rest three contact brushes which are rotated together by being carried on a shaft of insulating material extending lengthwise. This shaft is rotated from the tuning dial through gearing in the compartment at the right in the picture.

With a brush at or near the outer end of a spiral inductor there is maximum inductance, slightly less than one microhenry. With the brush rotated to reach the inner end of the spiral, inductance is reduced to about 1/40 microhenry. This change of inductance, working with capacitances of tubes, wiring, and alignment capacitors, allows continuous tuning through the low and high television bands, also the f-m broadcast band. There is "skip tuning" in the large change of frequency between the top of the f-m broadcast band and the low end of television channel 7.

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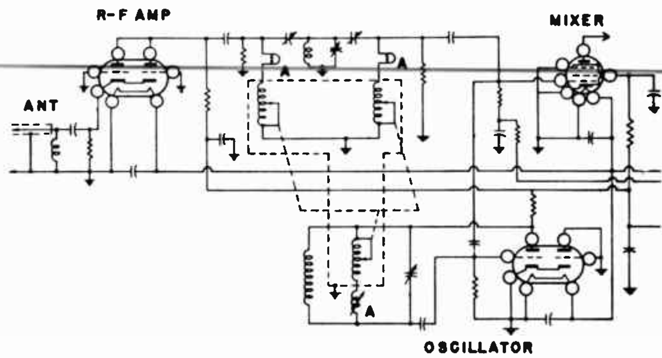

Fig. 13. Circuit connections for a three-circuit Inductuner.

Fig. 13 shows one circuit in which the three-section Inductuner has been used. Inductor elements A-A-A are in the plate circuit of the r-f amplifier, the grid circuit of the mixer, and between plate and grid of the oscillator. The external coil in parallel with the oscillator inductor reduces effective inductance, as required for maintaining oscillator frequency higher than carrier frequencies. Small adjustable alignment inductors are in series with each variable unit. These series inductors are loops or one or two turns of wire. Adjustable alignment capacitors couple r-f plate and mixer grid circuits.

In other applications of the three-circuit Inductuner one section is used between antenna and r-f grid, a second section in the r-f plate circuit, and the third for the r-f oscillator. The section on the r-f plate forms a tuned impedance coupling feeding to the mixer grid through a coupling and blocking capacitor.

There are also four-section or four-circuit spiral inductor units. Connections usually are similar to those of Fig. 13, with the addition of the fourth tuning unit between antenna and grid of the r-f amplifier.

MOVABLE CORE TUNERS. In the lesson on "Inductance Tuning" is a picture of a tuner in whose inductors are movable cores for channel selection. There are three pairs of inductors. One pair tunes the plate circuit of the r-f amplifier, another the grid circuit of the mixer, and the third is for the r-f oscillator. One inductor of each pair is switched into the tube circuits for low-band tuning, and the other one for high-band tuning. There may be continuous tuning in each band, although the unit pictured has stops on the tuning shaft mechanism for each channel position.

In other designs of movable core tuners the bar through which thread small screws attached to the cores is raised and lowered by two cams, one at the front and the other at the rear of the tuner, with the selector shaft extending from one to the other through the frame. There are pairs of coils for low-band and high-band tuning of r-f plate, mixer grid, and oscillator circuits. Trimmer capacitors are provided for alignment adjustments on all tuned circuits.

A few movable core tuners have been adapted for f-m broadcast reception by switching in parallel with the low-band inductors an extra coil. This paralleled coil reduces the combined or effective inductance sufficiently to extend the tuning range from the top of channel 6 into the f-m band of 88 to 108 mc.

In still other designs the movable cores are brought into correct positions for each channel by pressing one of twelve push buttons. The button mechanism also accomplishes band switching. Screw adjustments allow limiting the distance that each button moves one of the tuning cores. Since this is a step tuner, with fixed settings for each channel, there is a fine tuning capacitor on the oscillator circuit.

Most of the movable core tuners have a pentode r-f amplifier and a twin triode for oscillator and mixer. Some have separate twin triodes for oscillator and mixer, with one section of each triode used for the low band and the other section for the high band.

Most tuners of the movable core type have circuits of the general style shown by Fig. 14. Switches for selecting either the low band or the high band are shifted as the channel selector dial is moved between positions for channels 6 and 7. At a across each of the three low-band inductors is a trimmer capacitor used during alignment. Trimmer capacitors b, in series with the high-band inductors, are used during alignment of the high band. There is no fine tuning capacitor,

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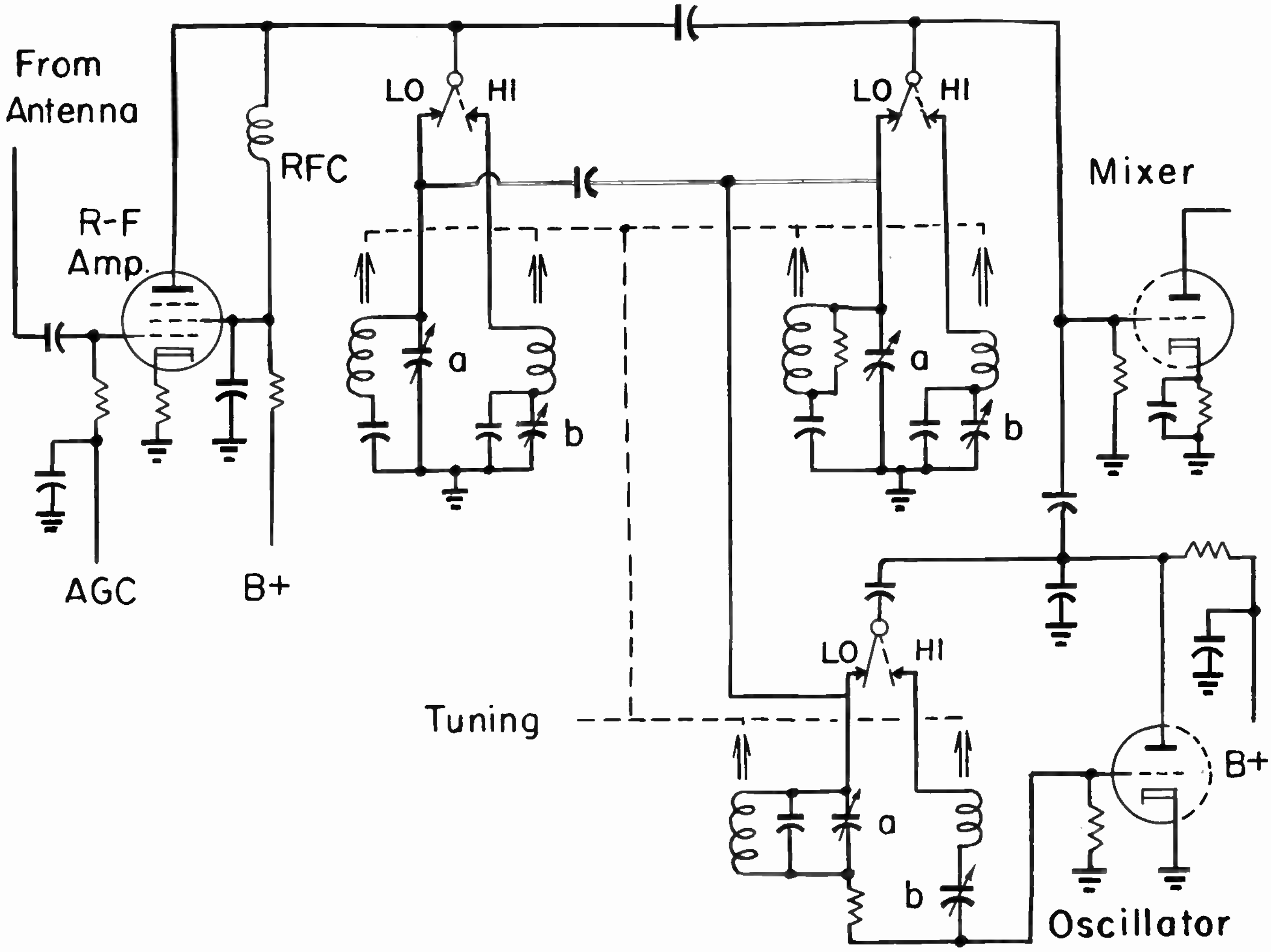

Fig. 14 Circuit connections for one style of movable core tuner.

since this unit tunes continuously through either band.

VARIABLE CAPACITANCE TUNERS. In some of the earlier tuners using variable capacitors and fixed inductors for channel selection are three twin triodes for r-f amplifier, mixer, and r-f oscillator. There are push-pull circuits for r-f plate, mixer grid, and oscillator. Separate inductors and variable capacitors are used for the low band and for the high band in each tuned circuit. The six variable capacitors are rotated together by the selector dial. The band switch is operated when the dial is moved between its positions for channels 6 and 7.

Some of the later designs in variable capacitance tuners have a pentode r-f amplifier and a twin triode for oscillator and mixer. There are only four variable capacitors. One capacitor tunes the r-f plate, another the mixer grid, and two more are used for tuning the oscillator in either the high band or the low band. In some of these types there is an additional variable capacitor for tuning the coupling between antenna and r-f grid.

Still other variable capacitance tuners have two r-f stages in cascade, using two pentodes. A twin triode is used for oscillator and mixer functions. One of these tuners, in which are only three variable capacitors, is pictured by Fig. 15 as it appears from underneath the chassis with the tuner shield removed. The variable capacitor toward the front or shaft end of the tuner, at the left in the picture, tunes the first r-f plate circuit. The middle capacitor tunes the second r-f plate circuit. The variable capacitor toward the rear tunes the r-f oscillator circuit. There is no fine tuning capacitor, because

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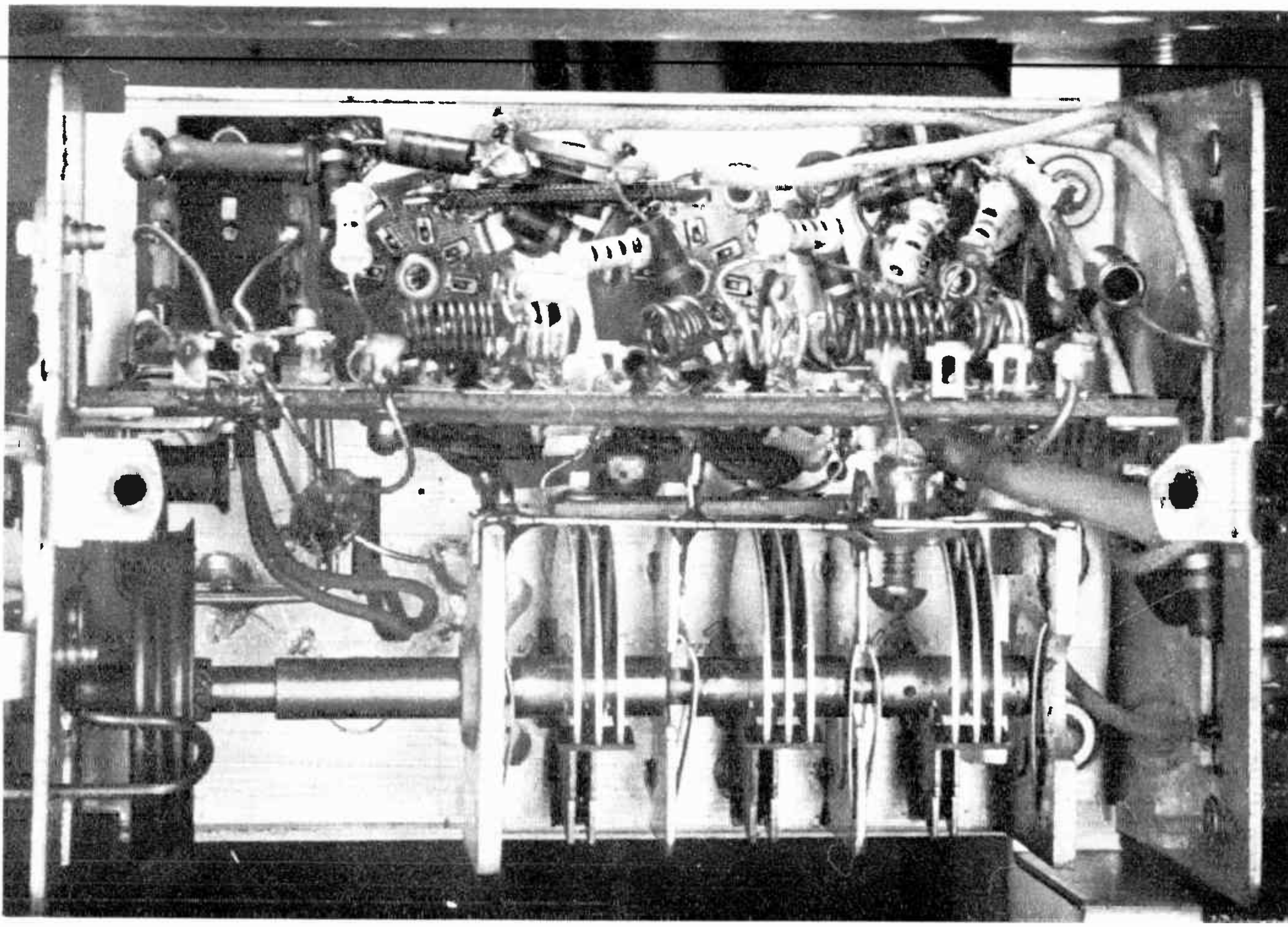

Fig. 15. Bottom view of a tuner having three variable capacitors for channel selection.

thus unit tunes continuously through each band. Band switching is by means of a knob on a shaft that is concentric with the shaft for variable capacitors.

Inductor coils whose turns are squeezed or spread for alignment are accessible from either the bottom or one side of this capacitance tuner. A side view, with the tuner mounted in its receiver chassis, is shown by Fig. 16. Slug adjustment screws for trimmer capacitors used during alignment are accessible on top of the tuner frame. It is generally true of variable capacitance tuners that alignment adjustments are quite easily reached from the bottom, one side, and the top of the unit.

With an entirely different method of capacitance tuning there are three fixed inductors, one for the r-f plate circuit, a second for the mixer grid circuit, and a third for the r-f oscillator circuit. Each inductor is tuned for any desired channel by connecting to it a mica-dielectric trimmer capacitor which is aligned to provide whatever capacitance is required for resonance at the channel frequencies. The compression type mica capacitors are connected into the tube circuits by twelve push buttons, one for each channel, which may be seen at the top of Fig. 17.

Of the thirty-six trimmer capacitors visible in the picture, the twleve in the row extending from left to right nearest the push buttons tune the oscillator circuit. The twelve in the middle row tune the mixer. Trimmers in the lower row, farthest from the buttons, tune the r-f amplifier. A fine tuning capacitor is adjusted by the knob at one end of the row of buttons. Sockets for r-f, mixer, and oscillator tubes may be seen at one side of the capacitor assembly.

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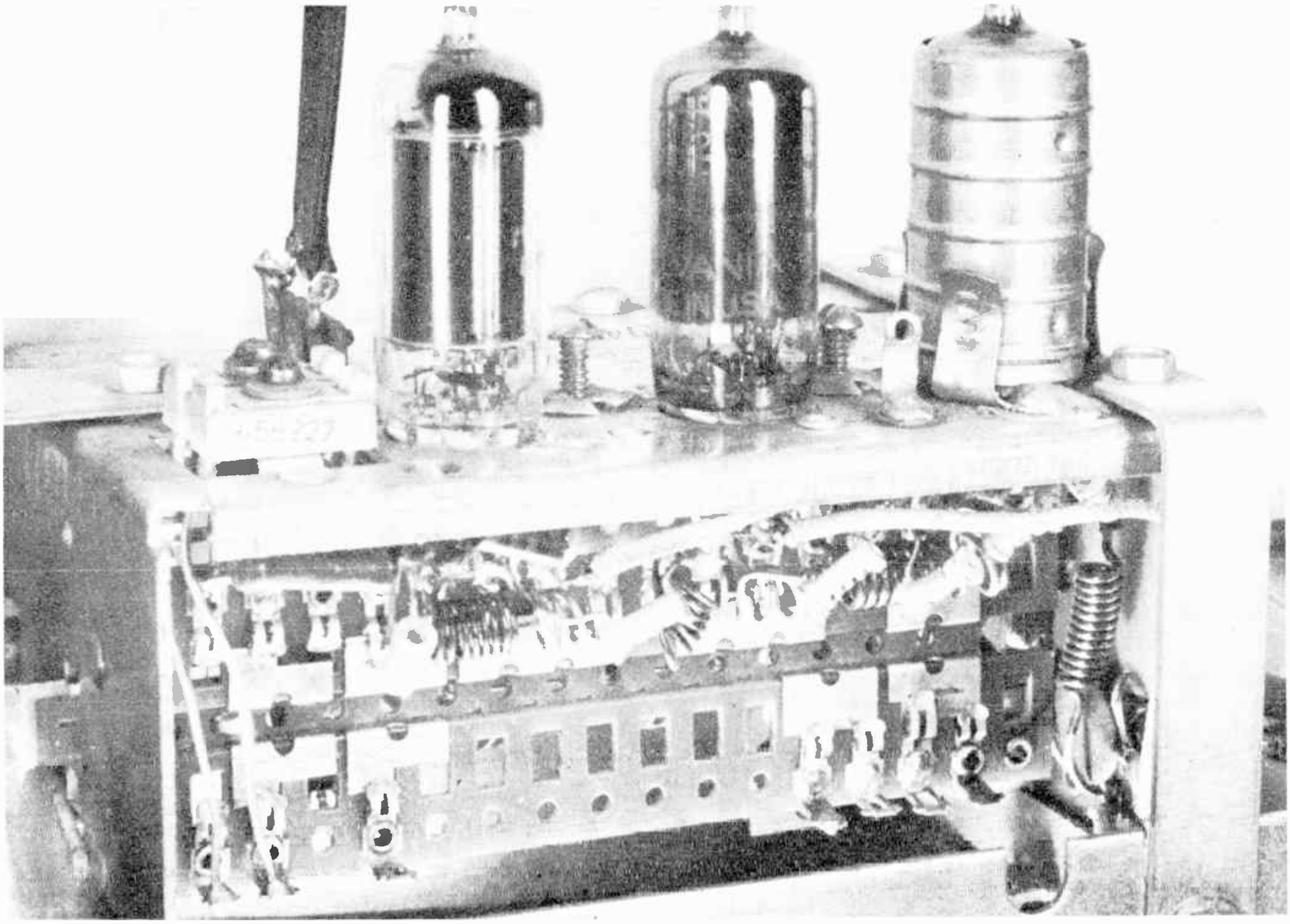

Fig. 16. This is a side view of the capacitance tuner illustrated by Fig. 15.

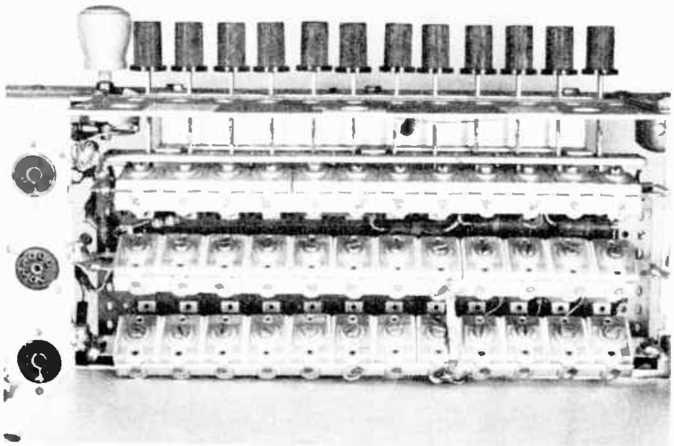

Fig. 17. Thirty-six adjustable capacitors allow alignment of each circuit for each channel.

Each of the trimmer capacitors has its own screw adjustment for alignment. Screw heads for oscillator trimmers are accessible through holes in the tuner frame which are in line with push buttons for the respective channels. Adjusting screws for r-f amplifier and mixer trimmers are accessible from on top of the tuner with the chassis out of its cabinet.

The push button capacitance tuner appears from the bottom as in Fig. 18, where the twleve switch mechanisms are visible. The sixth button from the left is depressed to close its capacitor circuits for channel tuning. Switches are held closed by a locking bar, against tension of small coiled springs. Pressing any one button releases the switch for any other button previously pressed for tuning. Each switch has three sections that simultaneously make connections for the three capacitors that tune r-f, mixer, and oscillator circuits for any one channel.

In another push button capacitance tuners the twelve channel buttons are in two rows,

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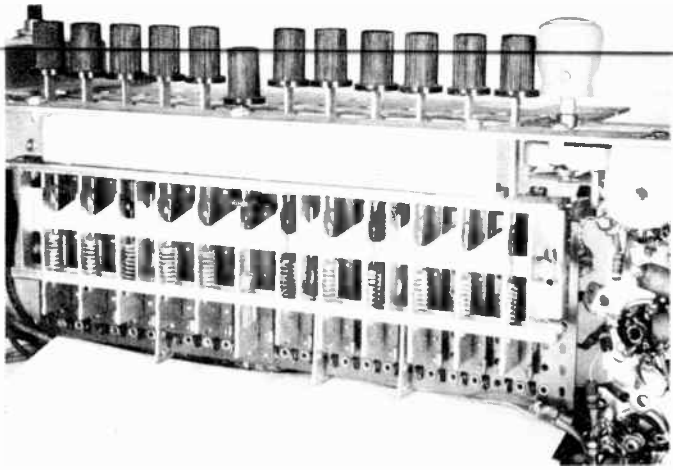

Fig. 18. Switch mechanism of the push button capacitance tuner.

one row for each band. Above each high-band button and below each low-band button are holes through which may be reached the respective oscillator trimmer screws during alignment. This tuner uses four tubes. One pentode is the high-band r-f amplifier. Another pentode is the low-band r-f amplifier. Two sections of one twin triode act respectively as high-band and low-band mixers. Two sections of another twin triode act as high-band and low-band oscillators.

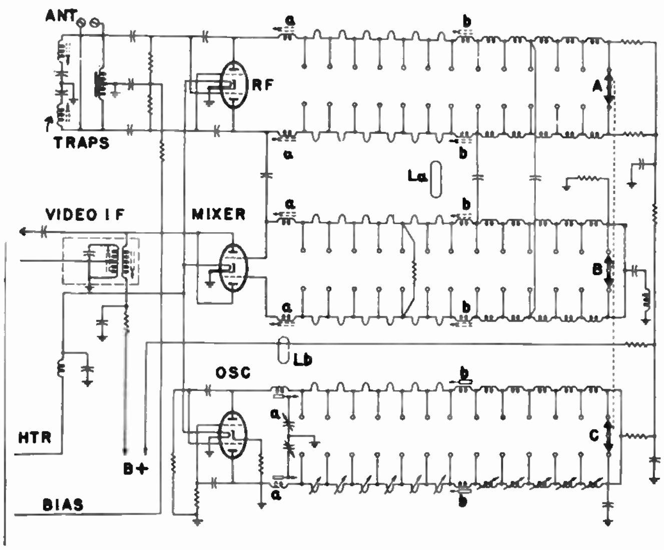

Fig. 19. Circuits of a tuner having shorted quarter-wave resonant lines.

RESONANT LINE TUNERS. Circuit connections are shown by Fig. 19 for a tuner employing quarter-wave shorted resonant lines for r-f amplifier plates, mixer grids, and oscillator plates. All three tubes are twin triodes. Each of the three resonant lines consists of two tapped inductors made up of loops and small coils in series around the edges of wafers in a rotary selector switch. The lines are progressively shorted for channel tuning by tongues on rotor segments of the switches. Parts of the lines between successive taps may be straight wires or straps, small loops, or coils of several turns, all depending on how much the electrical length of line is to be varied between channels.

Rotor tongues for r-f tuning are represented at A, those for mixer tuning at B, and for oscillator tuning at C. The two tongues or segments on switch wafers for each resonant line are tied together to act as a single shorting bar. The shorting bars are shown in positions for reception of channel 2. As the bars move to the left on the diagram, as the channel selector switch is operated, successive portions of each resonant line are shorted out for tuning to higher and higher frequencies.

When the shorting bars reach taps at the extreme left, for tuning channel 13, the remaining unshorted portions of the resonant lines consist only of inductors marked a. These inductors are small loops which are adjusted for alignment of channel 13 and all other high-band channels. To bridge the large change of frequency between channels 7 and 6 there are adjustable inductors at points marked b. These inductors are adjusted for low-band alignment. The principles and methods of adjustment are much the same as explained for incremental tuning in the lesson on "Inductance Tuning".

At La on the diagram is a link circuit for coupling the output of the r-f amplifier to the mixer grid. At Lb is a link for coupling the r-f oscillator output to the mixer grid. A dual fine tuning capacitor is connected from each oscillator plate line to ground.

CARE OF TUNERS. When tubes are removed from a tuner for any reason, be sure to remember which tube goes back in which socket if there is any chance of confusion. Slight differences between internal capacitances of tubes of the same type can cause

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large shifts of resonant frequencies in tuner circuits.

If, when a replacement tube is used in a tuner, some or all channels are difficult to tune, or if a fine tuning adjustment no longer has enough range, try another new tube. If you have enough tubes of the correct type, try to find one which allows satisfactory reception without the need for any realignment of tuner circuits.

Troubles with tuners, in the most probable order of occurance, include defective tubes, noise due to mechanical defects or dirt, poor electrical contacts, defective capacitors, defective resistors, and defective inductors. Least likely of all is incorrect alignment of r-f and mixer stages unless the tuner has been worked on by a service man who lacked know-how or proper equipment, or both.

Noise may result from microphonic effects, from loose shields or other parts, from rubbing of shafts or other parts which should have clearance, from poor contacts of tube pins in sockets, or from dirty switch contacts. How such troubles are located and remedied is explained in the lesson on "Noise In Television Pictures". Tuner switch contacts should be cleaned in any of the ways described in that lesson.

Contact cleaning liquids which leave a film of lubricant may be advantageous for tuners in which a number of rotary switch sections, each with many contact surfaces, operate together. It is possible also to use a special variety of switch contact oil, available from many distributors and supply houses. This oil should be applied with a small camel's hair brush. Shaft bearings and detent mechanisms may be lubricated with Vaseline. It is worth mentioning that a lost detent ball may be replaced with a steel ball of similar size for a bicycle ball bearing, obtainable from a bicycle repair shop.

Tuner parts and surfaces which have collected dirt and dust may be wiped clean with a soft cloth moistened in carbon tetrachloride. Wind a piece of cloth on the end of a small pick or wire to reach out-of-the-way surfaces. Deposits of rosin which remain after soldering may be removed with alcohol.

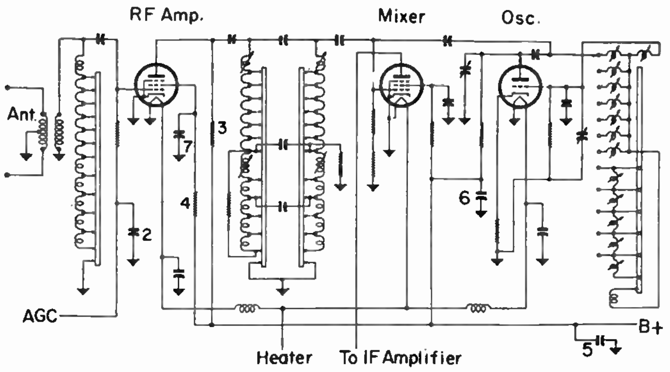

Fig. 20. With the help of a service diagram, like this one, it is possible to test most of the parts in a tuner.

<u>TESTS OF TUNER PARTS.</u> Many of the capacitors, resistors, inductors, and circuit connections in tuners may be tested by using an ohmmeter, while the tuner still is completely assembled. It is necessary to have a circuit diagram. The diagram of Fig. 20. will be used to illustrate a few examples. Most often it will be convenient to attach one ohmmeter lead to a lug on a tube socket or to a pin opening on top of the socket while using the other lead at various test points. As always is true when using an ohmmeter for circuit testing, it may be necessary to temporarily disconnect leads which go from the tuner to external B-plus lines, agc lines, heater lines, and to the first i-f amplifier. Be sure to pull the power cord plug during all tests.

On the service diagram locate circuits which commence at any tube element and pass through only one capacitor, one resistor, or one inductor on the way to some point which may be reached for testing. Then connect the ohmmeter to the two ends of this circuit while testing the elements. Select circuits in which elements to be checked are in series with one another, not in parallel.

One or more capacitors in series should cause the ohmmeter to indicate an open circuit, unless the capacitors are shorted or very leaky. Resistors without capacitors in series should give appropriate resistance readings. Inductors without capacitors in series should give indications of small re-

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sistance or of resistance too little for measurement.

1. To the grid or grid circuit of the first i-f amplifier.

A few tests which might be made on the tuner of Fig. 20 are as follows:

1. Between r-f amplifier grid and agc line check the grid resistor for this tube.

2. Disconnect the agc line and test between r-f grid and ground. The indication should be an open circuit unless there is a short or severe leakage in capacitor 1 or capacitor 2.

3. Disconnect the B-plus line and test between r-f amplifier plate and this line to check resistor 3.

4. Test from r-f amplifier screen to the B-plus line to check resistor 4.

5. A test from r-f plate to ground should show open. If there is resistance equal to that of resistor 3 it indicates a dead short in capacitor 5 or 6.

6. Resistance from r-f plate to ground equal to the sum of resistances at 3 and 4 would indicate a dead short in capacitor 7.

We might continue similarly throughout all the tuner circuits, working from base pins of each tube to various test points. If you understand the elementary principles of series circuits all useful tests are easily figured out.

Tests from various points to ground, the tuner frame, will indicate opens or high resistances at ground connections. Then you would look for poor soldered joints, loose wires, or broken leads. When resoldering defective joints in tuner circuits don't add excessive quantities of solder. At some places this might alter the small capacitances or the lead inductances which are so important at very high frequencies.

TUNER REPAIRS. To make repairs on wiring or to replace parts it almost always is necessary to take the tuner out of the receiver chassis. Before removing a tuner identify these leads from the tuner to external circuits.

2. To the agc circuit. You can identify this circuit on the chassis by the fact that other leads will run directly or through resistors to the grids of one or more i-f amplifiers.

3. To B-plus supply lines. Other leads from a B-plus line usually go through resistors to screens and plate loads of some or all the i-f amplifiers. Sometimes the tuner B-plus line comes from other points than the i-f amplifier. There may be more than one B-plus lead for the tuner, supplying different positive voltages.

4. To the ungrounded side of a parallel heater line, or to a series heater circuit. Heater lines go also to heaters of other tubes on the main chassis.

Make a sketch showing the color coding of all these external leads, where they come out of the tuner or connect to its terminal strip or strips, and to what points they connect on main chassis wiring. Then disconnect the leads at their tuner ends or at chassis ends, whichever is more convenient.

Make sure that the antenna transmission line on the tuner is disconnected from transmission line terminals on the main chassis or the cabinet. A short length of transmission line usually remains connected to the tuner, and is disconnected from terminals at the other end of this length.

Tuners ordinarily are held in place by screws passing through holes in the main chassis into threaded holes or brackets on the tuner. Some tuners are supported by brackets or box-like structures attached to the receiver chassis. The brackets or boxes may remain on the tuner or on the chassis. Methods of mounting will be apparent upon careful inspection. With screws or brackets removed, the tuner usually comes out through the bottom of the receiver chassis. Put all screws and brackets back where they belong, so that there will be no questions as to proper replacement.

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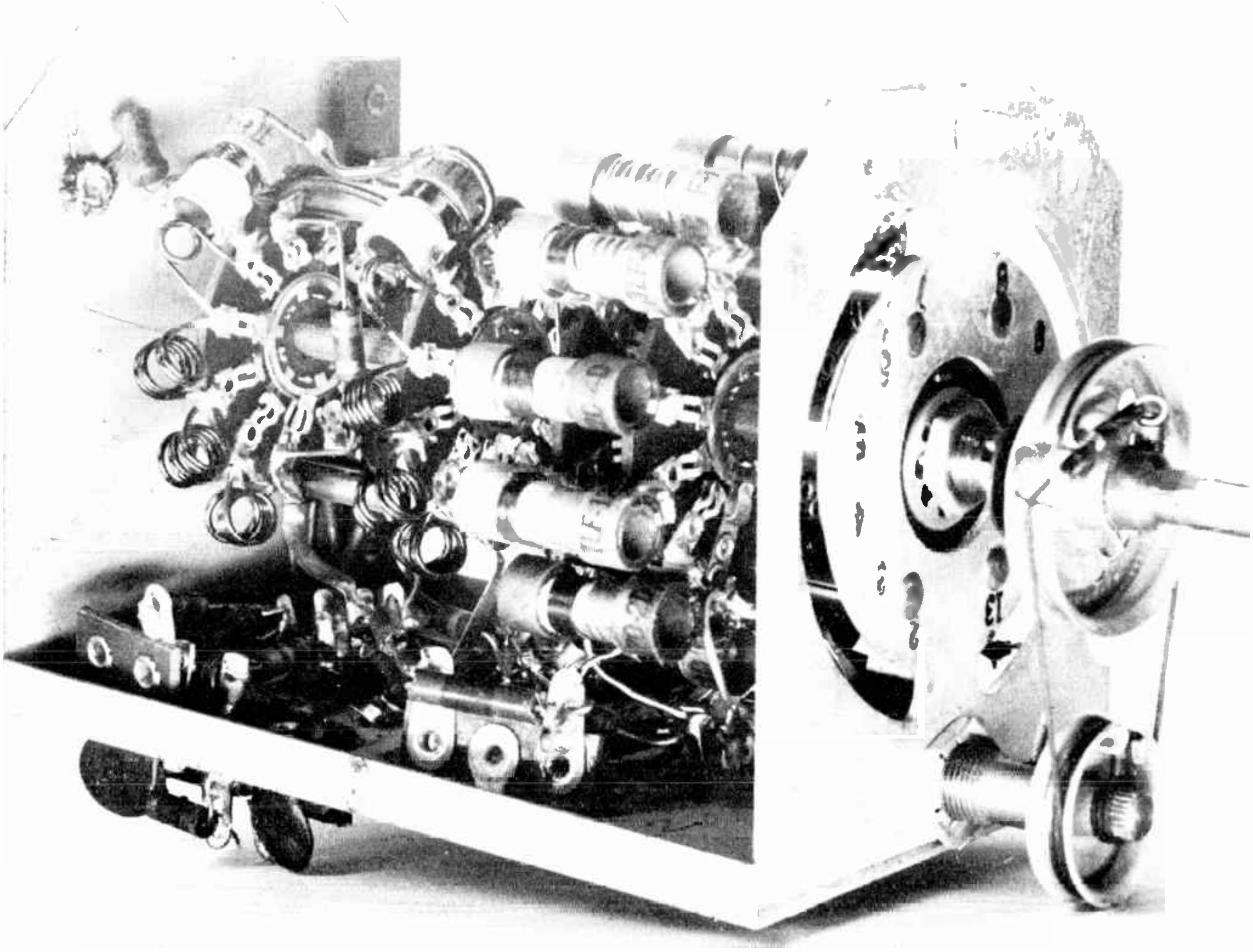

Fig. 21. Most of the inductors, capacitors, and resistors are fairly accessible.

Many tuners are so constructed that most of the small parts and connections are accessible with the tuner out of the receiver chassis. An example is pictured by Fig. 21. Other tuners require removal or loosening of a channel selector switch assembly before small parts can be reached. Switch removal is likely to be a difficult and time-consuming job, and often proves to be even more difficult when it comes to reassembly. A channel selector switch removed from its tuner frame is shown by Fig. 22.

All lead and strap connections between a switch assembly and parts on the tuner frame must be carefully unsoldered and positively identified for later replacement. Every selector switch presents problems of its own, and they have to be solved by painstaking examination to determine best procedures before disconnecting the leads.

It is well to keep in mind that every tuner must have been assembled part by part, and it can be disassembled in reverse order. But some parts may have been riveted or sweat soldered in place during assembly, or so many joints may have been soldered after most parts were in place that it is difficult to get all these joints free at the same time, to allow removal of parts of the assembly.

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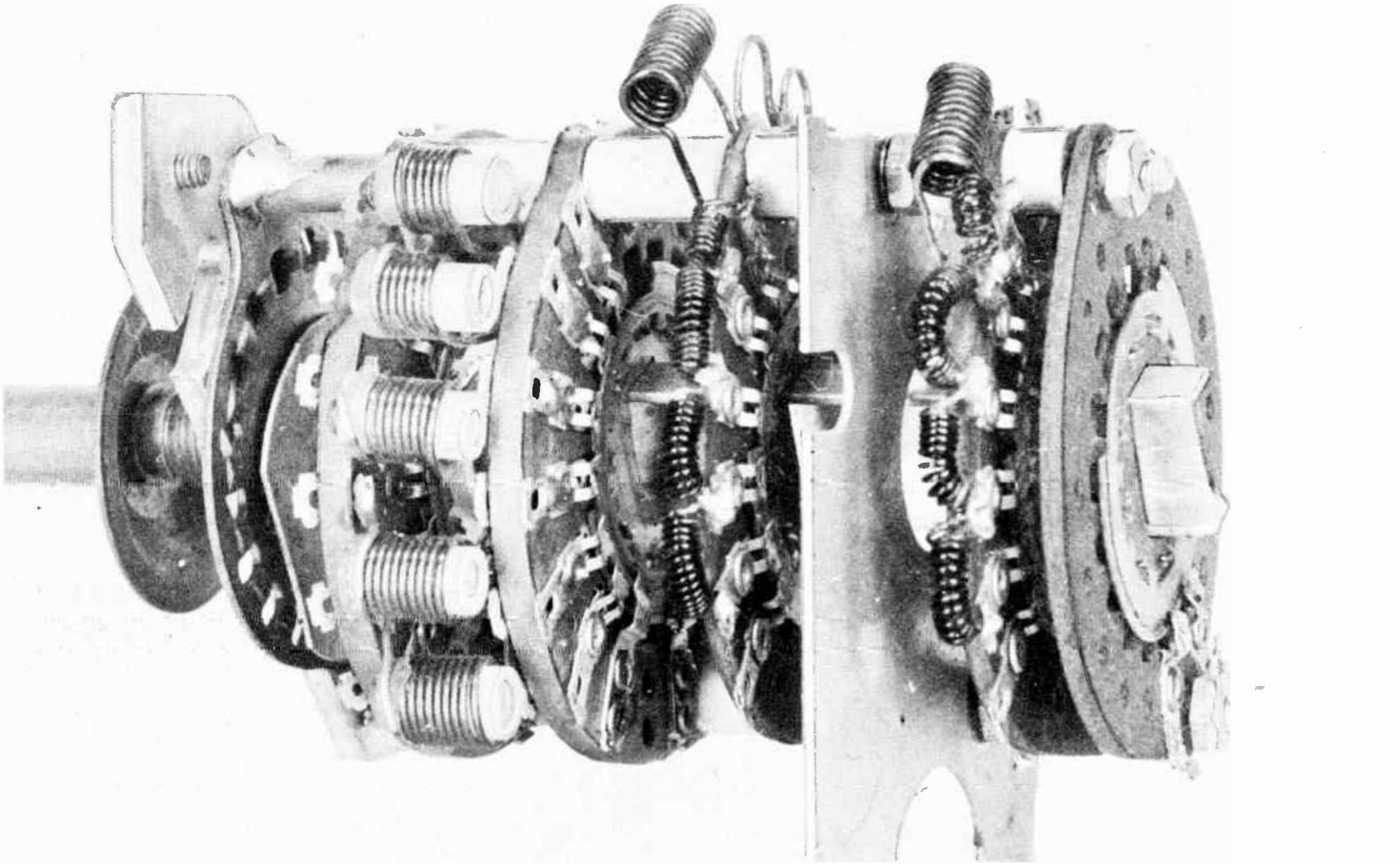

Fig. 22. All of the channel inductors remain on this rotary switch when removed from the tuner frame.

A few tuners have some parts so inaccessible that you would spend far more time getting at them than could be charged for on a bill for service. The procedure then is to install a new tuner, or return the original one to a factory service department for repair or replacement. In fact, when tuners require major repairs, and are difficult to work on, the most profitable procedure for you and most satisfactory for the set owner is to make a complete replacement.

When installing new capacitors, resistors, and inductors in tuners it is essential to use parts not only having identical electrical characteristics, but also of the same dimensions to avoid altering capacitances to ground. This refers to such parts as shown underneath a tuner shelf by Fig. 23. Cut new leads to the same lengths as originals. Install new components in the same positions as old ones. Dressing of small parts and leads is critical in tuners. Watch carefully for temperature compensating capacitors, and don't replace them with non-compensating types.

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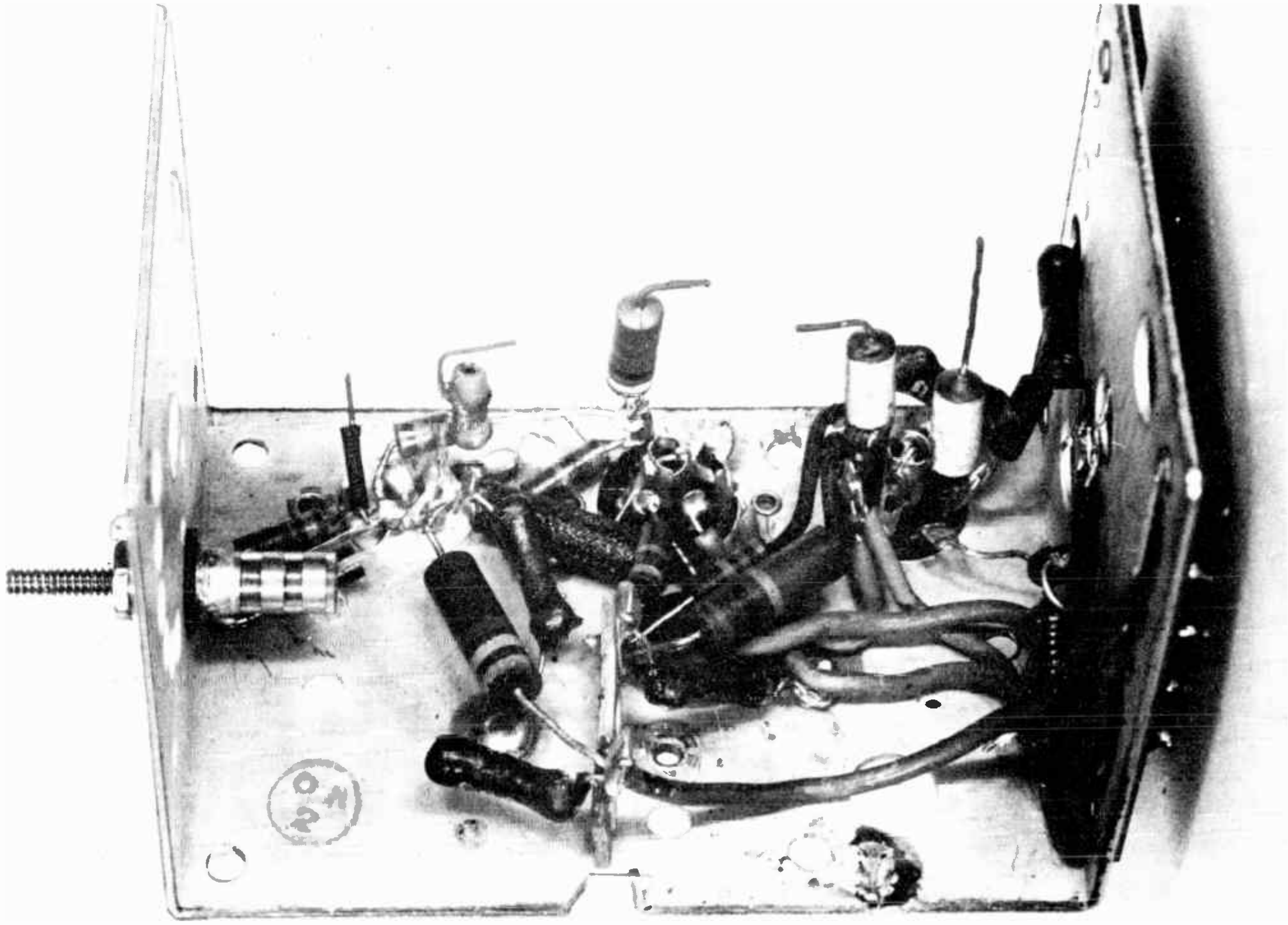

Fig. 23. Connections for parts in a tuner are made with short, direct leads.

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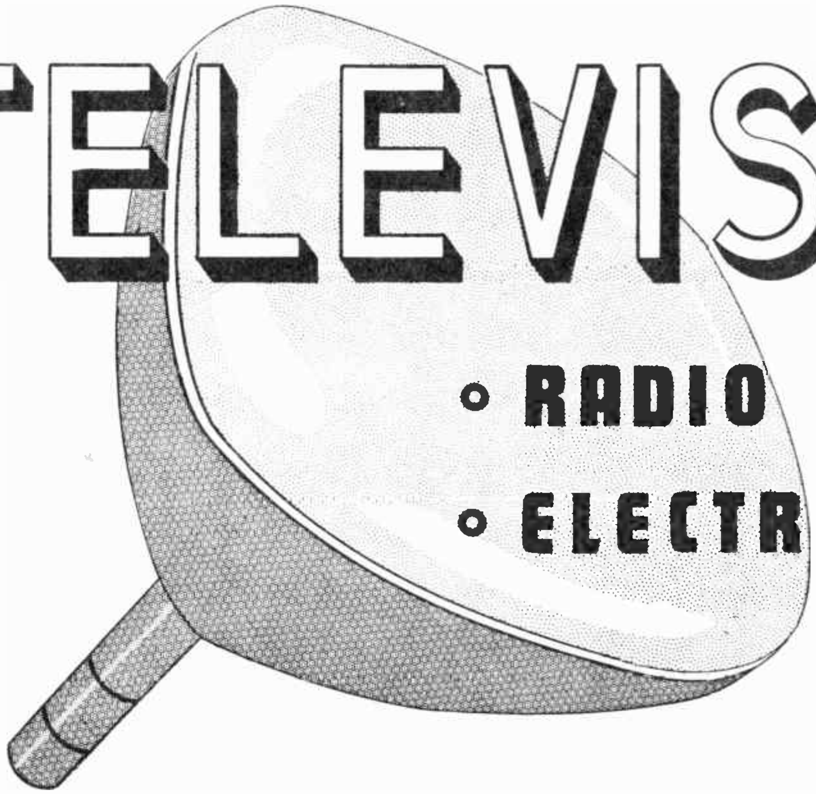

• RADIO
• ELECTRONICS

LESSON 81 — TUNER ALIGNMENT

Coyne School

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Lesson 81

TUNER ALIGNMENT

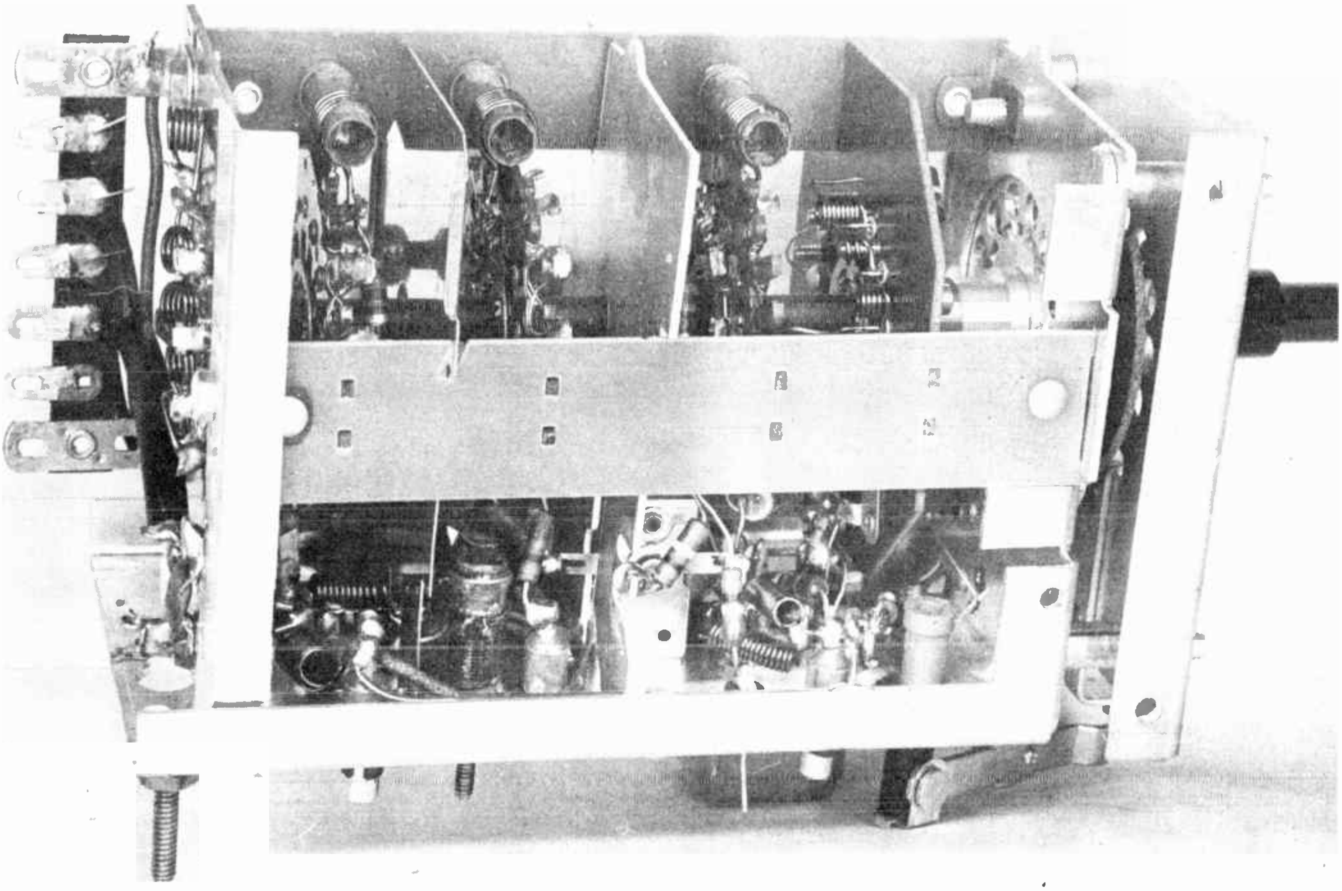

Fig. 1. A tuner in which channel selection is by means of rotary switches connected to series inductors for each resonant circuit.

Tuner alignment usually is handled as two separate operations, although both may be performed with a single setup of test equipment. One operation consists of adjusting the r-f oscillator circuits, the other of adjusting antenna, r-f amplifier, and mixer circuits. The entire operation of adjusting antenna, r-f amplifier, and mixer circuits often is referred to as r-f alignment.

Oscillator alignment is required quite often, because only a slight change of oscillator frequency will throw video and sound carriers onto wrong parts of the r-f response, and the corresponding intermediate frequencies to wrong points on the i-f response. A fine tuning adjustment may not have sufficient range to compensate for change of oscillator frequency, and reception becomes difficult or impossible on some or all channels.

R-f alignment seldom should be needed unless parts have been damaged and replaced or adjusters have been tampered with, or replacement tubes have characteristics decidedly different from originals. This is because r-f circuits tune rather broadly, and usually will handle all carrier frequencies in a channel even when not perfectly aligned.

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R-f alignment and oscillator alignment by means of test instruments require that these instruments be of high accuracy at all carrier frequencies. Marker generators should be crystal controlled, or crystal calibrated at frequencies close to those actually used. TV stations transmit on exact frequencies, and you must be able to duplicate these frequencies within a small fraction of one per cent.

Sweep generator outputs must be free from humps and dips, peaks and valleys, when sweeping any one channel. Sweep width must be at least 10 mc and preferably more, a width not reached on all channels by some instruments.

The oscilloscope must have high vertical gain when the scope is used at the output of the r-f amplifier in a tuner. This output is at the grid of the mixer, and ahead of this point there usually is only one stage of r-f amplification. If sweep generator input must be made too great in attempting to overcome lack of gain in the scope, alignment will be incorrect.

Before undertaking tuner alignment make sure it is needed, in this manner:

1. Try actual picture and sound reception on all active channels to determine whether there is trouble on only some channels or on all. This will indicate what steps are necessary, if any, as described in following pages.

2. Check the action of all controls used by the set operator. If fine tuning must be varied excessively between channels, but then will allow good reception, it is probable that alignment is needed only for the oscillator, not for the r-f section.

3. When testing a set in the customer's home, examine the antenna installation, the transmission line, and antenna connections at the cabinet, chassis, and tuner.

4. Try new tubes in the tuner, one at a time. If there is decided improvement, nothing more may be needed than a tube and a check of oscillator alignment.

5. Inspect the tuner for signs of mechanical damage, of burnouts, and of tampering. If there is damage, or if further tests indicate need for complete realignment, it may be advisable to send the complete tuner to the factory or an authorized service station for repair, exchange, or replacement. A new or repaired tuner will come to you completely aligned, and usually with new tubes.

PRELIMINARY STEPS. When preparing to align a tuner with test instruments it is necessary to take a few preliminary steps and to observe certain precautions, just as when preparing to align an i-f section. The most important items are as follows:

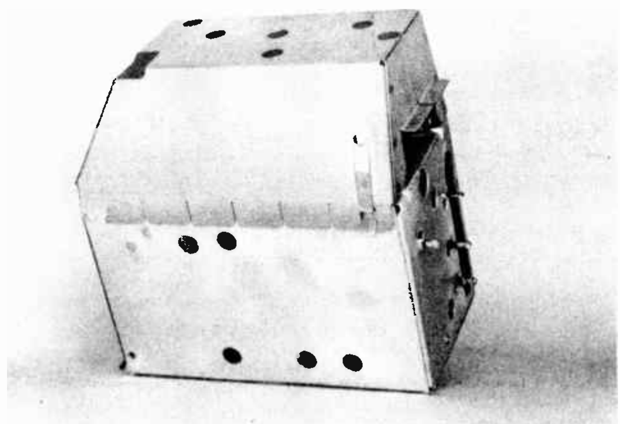

Fig. 2. These are shields which almost completely enclose a tuner while in operation.

1. All shields normally used on the tuner and its tubes should remain in place during alignment, if this is possible. Fig. 2 shows shields for the tuner of Fig. 1. In the top shield are six holes, and in one side of the bottom shield are five more. These holes admit alignment tools while the shields remain in place.

When alignment must be made with shields removed, later replacement of the shields will add capacitances and may alter effective inductances, usually with a drop of resonant frequencies. It may be necessary to align for frequencies somewhat higher than wanted during operation. Check performance with shields replaced, and make readjustments if necessary.

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LESSON 81 – TUNER ALIGNMENT

2. Most methods of tuner alignment require connection of a sweep generator to antenna terminals on the tuner or on the short transmission line on the tuner. Make sure that an outdoor, indoor, or built-in antenna is disconnected. It is essential that sweep generator output be correctly matched to tuner input with a pad such as described in the lesson on "Sweep Generators For Alignment".

3. No matter to what point on the tuner or chassis circuits an oscilloscope is connected during alignment, do not forget to have in series with the vertical input, at its probe end, a fixed resistor of 10K to 30K ohms for isolating the cable capacitance from the measured circuit. Fuzzy traces are avoided by connecting a fixed capacitor to ground from the cable side of the series resistor, just as when using a scope for i-f alignment.

4. When an oscilloscope or VTVM used as output indicator is connected to any point following i-f or video amplifiers affected by the contrast control, keep this control turned at least as high as for normal reception.

5. Should oscilloscope traces show effects of horizontal sync in the form of small irregularities crawling along trace lines, shut off the sync voltage by removing the horizontal sweep oscillator or horizontal output tube during alignment.

6. To avoid possibility of high-voltage shock, the horizontal output amplifier may be removed from sets in which high voltage is produced by flyback action, or the high-voltage oscillator may be removed from an r-f type high-voltage supply.

7. Use only non-metallic alignment tools, containing no metal whatever. Tuning wands usually introduce too much stray capacitance to be used for tuner alignment.

8. Be sure to turn the receiver channel selector to the same channel for which signal generators are tuned during each step of alignment.

9. Before commencing adjustment, be sure to let receiver and all test instruments warm up for at least 15 to 20 minutes.

10. Bring any kind of response curve onto the screen of the scope and watch for changes of curve shape while resting your hand on each test instrument, on the receiver chassis, and on cables for generators and scope. Curve distortion may indicate lack of sufficient bonding or grounding between instruments and receiver, or poor matching of sweep generator output to receiver or tuner input, or it may indicate excessive output from sweep generator, marker generator, or both.

TUNER ADJUSTMENTS. It is not always easy to locate alignment adjustments in tuners, nor to determine the functions of particular adjusters when located. The truth of this statement is apparent when you examine photographs of tuners in this and other lessons. It is, however, possible to arrive at a general classification of alignment adjustments used in most tuners.

Look first at Fig. 3. Inductors or coils shown by broken line symbols indicate any kinds of couplings between antenna and r-f grid, and between r-f plate and mixer grid. Similarly, the r-f oscillator might have any kind of tuned plate-grid circuit. We are interested now only in alignment trimmer capacitors marked with letters.

At A is a trimmer for the r-f grid circuit. It sometimes is called an antenna trimmer. This trimmer might be connected anywhere on the r-f grid circuit. At P is a trimmer for the r-f plate circuit, sometimes called merely the r-f trimmer. At G is a trimmer for the mixer grid circuit. At O is a trimmer in parallel with the fine tuning capacitor on the oscillator circuit.

Alignment trimmers in some or all the positions shown are found on many tuners which have separate inductors for each channel, including turret tuners and tuners with stationary inductors connected through a rotary switch. Such trimmers are used also on tuners which have variable capacitors for tuning, and on those having movable-core inductors for channel selection.

The primary purpose of trimmer capacitors shown by Fig. 3 is to allow compensation for differences of internal capacitances

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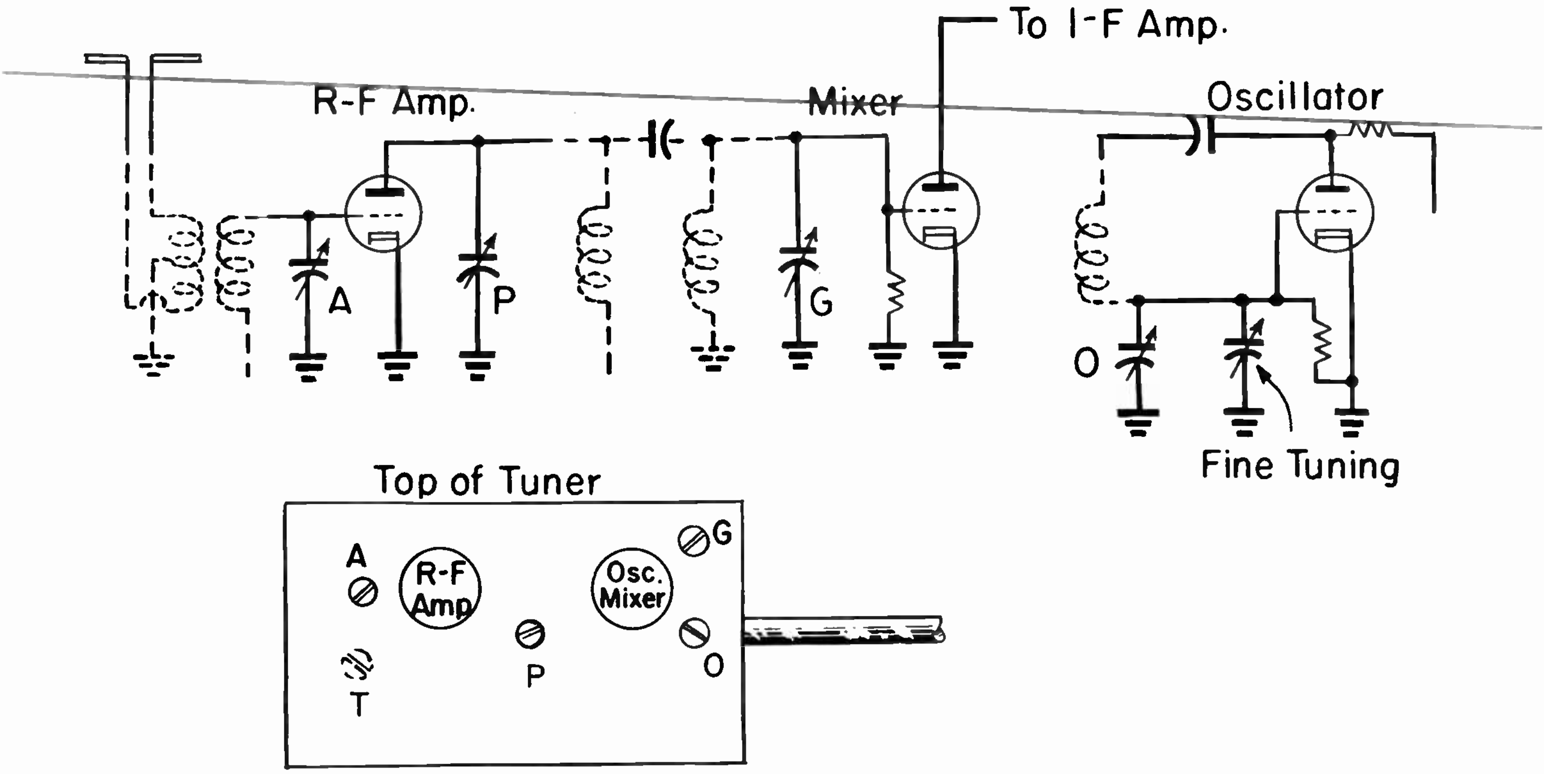

Fig. 3. Trimmer capacitors for overall alignment adjustments of tuner circuits.

between original and replacement tubes, and for slight changes of circuit capacitances and inductances that occur with aging. When a replacement tube has slightly different internal capacitances, it should be possible to restore correct alignment by adjusting one or more trimmer capacitors, without disturbing any other adjustments in tuned circuits.

The sketch at the lower part of Fig. 3 illustrates one arrangement of trimmer adjustment screws on top of a tuner frame. Adjusters lettered A, P, G, and O are for trimmers similarly lettered on the circuit diagram. In many tuners there is no trimmer paralleling the fine tuning capacitor, and adjuster O would not appear. In some tuners there is a trap for reducing interference from a-m transmitters operating at frequencies in or near the i-f range of the receiver. The adjuster for such a trap might be at T, on top of the tuner.

Tuners with series inductors tapped for channel selection, or with incremental tuning, have circuits generally similar to those of Fig. 4. Resonant line tuners have inductors on this order, although it takes a pair of inductors for each tuned line. On tuners such as illustrated by Fig. 4 there may be only a single trimmer capacitor, O, paralleling the fine tuning capacitor, or there may be no trimmers at all.

Loops or small coils which are spread or squeezed for high-band alignment may be at a-a-a-a. Relatively large inductors for low-band alignment usually are at b-b-b-b. These latter often have adjustable cores, but sometimes are designed for spreading or squeezing of turns during alignment.

Many tuners with tapped inductors have additional trimmer capacitors; at A for the r-f grid or antenna circuit, at P for the r-f plate circuit, and at G for the mixer grid circuit. When these three trimmers are present there usually is no provision for adjustments marked a, the trimmers would be used for high-band alignment and the adjustable inductors at b for low-band alignment. All the trimmer adjustments, also a trap adjustment T, may be on top of the tuner as in diagram 1 of Fig. 5, with low-band inductor adjustments accessible from one side of the tuner.

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LESSON 81 – TUNER ALIGNMENT

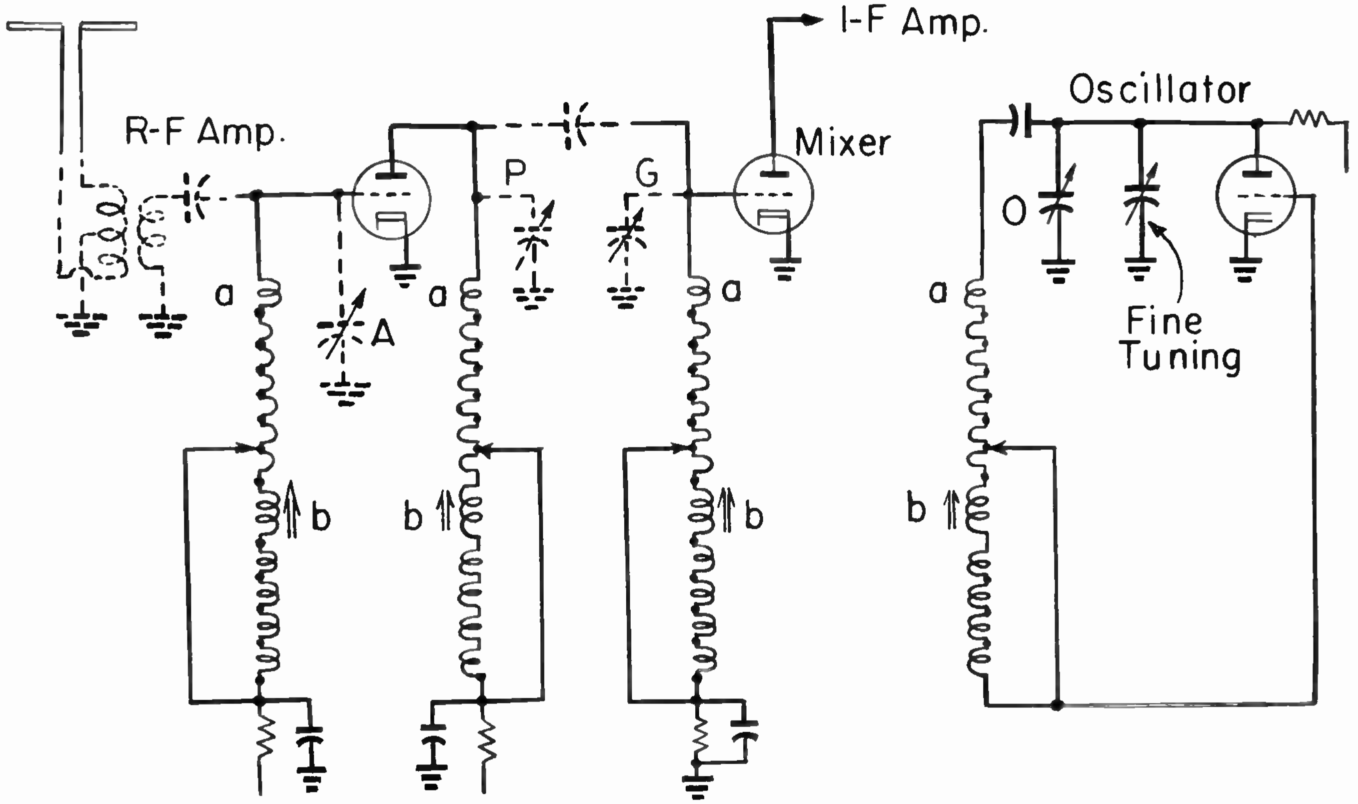

Fig. 4. Overall trimmer capacitors and band alignment inductors in a tuner having tapped series inductors for channel selection.

In addition to trimmer capacitors, some tuners have adjustable inductors directly in series with the r-f grid, r-f plate, mixer grid, and oscillator grid. These inductors are used for high-band alignment. Screw heads for adjustable cores in the four inductors just mentioned appear in diagram 2 of Fig. 5 on top of a tuner; at La for r-f grid, at Lp for r-f plate, at Lg for mixer grid, and at Lo for the oscillator. At C-C of this diagram are trimmer capacitor adjusters for varying the coupling between r-f plate and mixer grid. Any adjustable coupling between these two elements in a tuner is for varying the bandwidth of the frequency response. The other trimmer capacitors are used for low-band alignment.

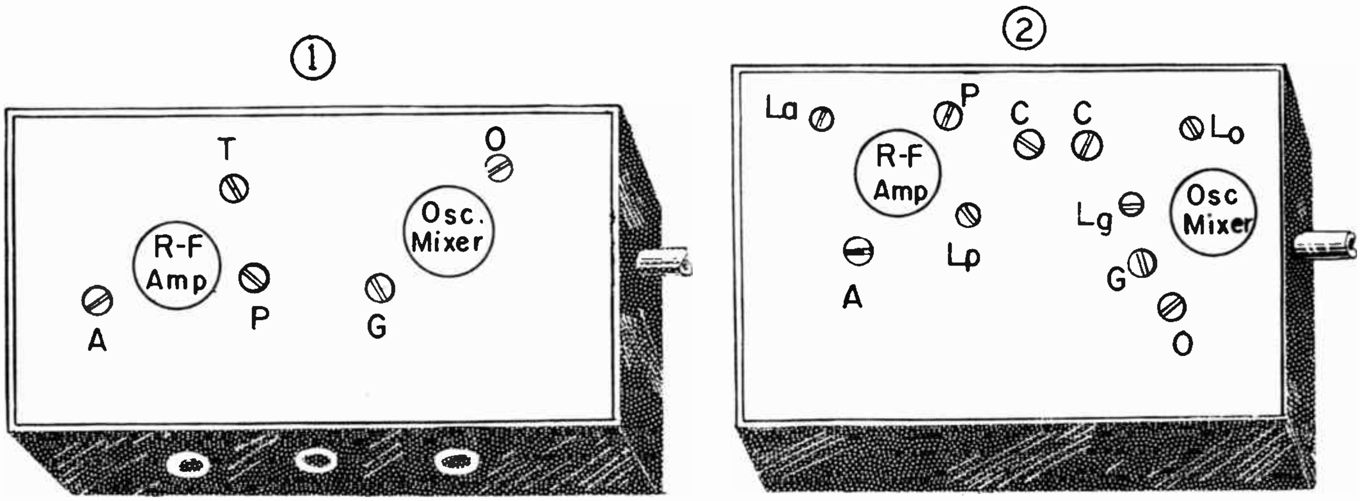

Fig. 5. Arrangements of alignment adjusters on the tops of tuners.

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Positions of alignment adjusters on the tops of tuners in Figs. 3 and 5 illustrate the wide variety of arrangements which may be found. These diagrams, which are merely a few samples, show that you cannot positively identify any certain alignment adjuster by its position on a tuner unless you are familiar with the unit or have a diagram applying to the specific tuner.

In a few tuners there are individual movable core adjustments or trimmer capacitors for each channel, or for pairs of channels, on tuned circuits for r-f amplifier, mixer, and oscillator. Such tuners are illustrated in other lessons. On a great many tuners, perhaps the majority, are individual channel adjusters only for the r-f oscillator. These oscillator adjusters most often are reached through an opening or openings in the front of the tuner frame. Along with the individual channel adjusters for the oscillator may be r-f and mixer adjustments for the high band and for the low band, but not for individual channels, or there may be only overall adjusters for r-f and mixer circuits.

Any alignment inductors may have movable cores whose adjustment screws are accessible from top or sides of a tuner. In other cases some or all of the inductors are aligned by spreading or squeezing turns, or by employing any of the other methods described in the lesson on "Inductance Tuning".

OSCILLATOR ALIGNMENT. When preparing for oscillator alignment take the preliminary steps and observe precautions mentioned in preceding pages. In addition, if there is a fine tuning control, keep it at midposition unless instructions say otherwise.

Oscillator alignment is simplified when you keep clearly in mind just what is happening on the i-f response, as illustrated by Fig. 6. In both diagrams the correct positions for sound and video intermediates are shown by full lines. Sound is far down on the low-frequency side, possibly in the dip formed by a trap, while video is about half way down on the high-frequency side of the response.

When oscillator frequency is made too low, both intermediates will shift to the broken-line positions of the left-hand diagram. Sound now is so low on the gain curve as to have practically no amplification, and audio output will be weak or absent. Video is so high that pictures will lack detail while being excessively bright.

When oscillator frequency is made too high the intermediates move to the broken-line positions of the right-hand diagram. Sound is so strongly amplified that, with an intercarrier system, sound bars are likely to appear on pictures. Video is so low that it will be difficult or impossible to hold either horizontal or vertical sync. With dual sound

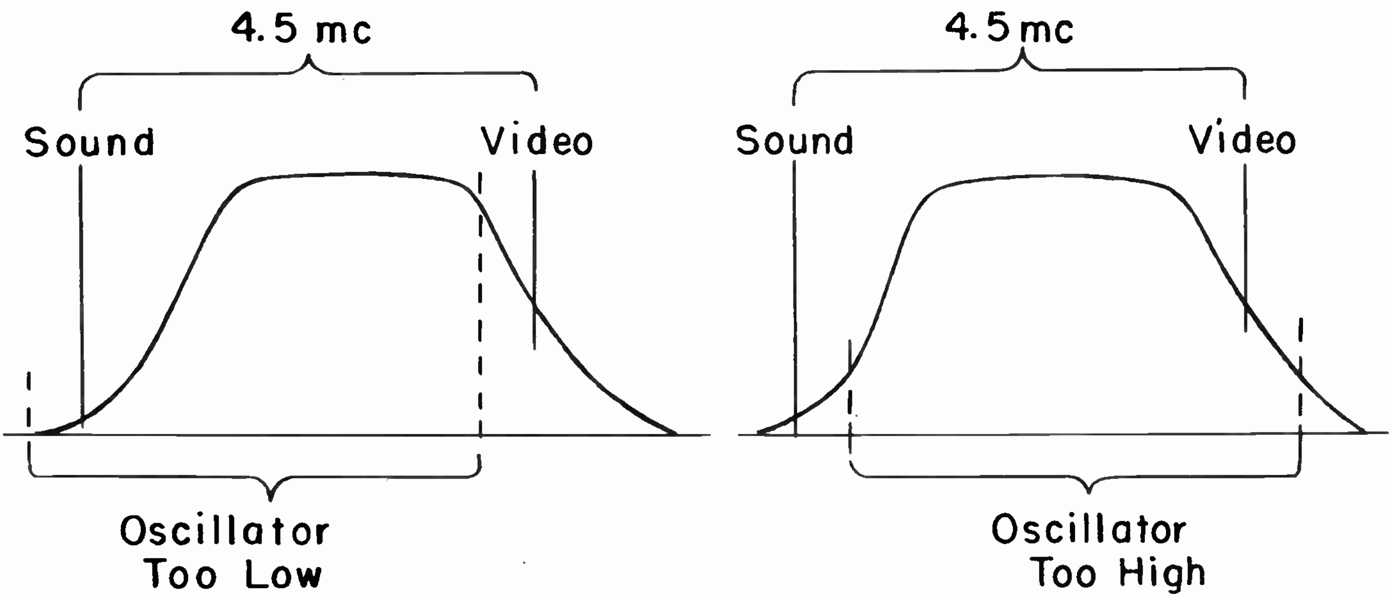

Fig. 6. Changing the r-f oscillator frequency moves the intermediate frequencies to different positions on the response curve.

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systems either of the misadjustments of oscillator frequency would throw the sound intermediate outside the pass band of the sound i-f amplifier, and there would be no audio output.

Effects illustrated by Fig. 6 would occur on all channels with misadjustment of a fine tuning control. They would occur on all channels also when there is misalignment of a trimmer capacitor which parallels a fine tuning capacitor. They occur on any one channel when an oscillator adjuster for that channel is wrongly aligned.

When oscillator alignment is correct in receivers having a dual sound system, the sound intermediate frequency will fall at or very close to the center of the sound i-f amplifier pass band. This condition may be identified by connecting a VTVM or scope to the audio output of the sound demodulator. If the video intermediate is not at its correct position on the i-f response when the sound intermediate is correct, the i-f amplifier must be realigned to place the video intermediate where it belongs. This and other details of alignment with dual sound systems will be considered later. Until then, our instructions for oscillator alignment will apply specifically to receivers having an intercarrier sound system.

To determine whether a receiver uses dual or intercarrier sound proceed thus:

Tune in a program, then vary the fine tuning control or a control for continuous channel tuning.

If sound is good at one position of this control, but almost disappears with the control varied in either direction, the set probably uses dual sound.

If sound is lost when pictures are good, and pictures are poor when sound is best, there almost certainly is a dual sound system.

Should altering the fine tuning or a continuous tuning selector affect picture quality or sync before there is much change of audio quality or volume, the receiver doubtless has an intercarrier sound system.

We now shall proceed to outline methods commonly employed for oscillator alignment. No matter what method is selected, if the tuner has tapped series inductors or is of the incremental type, alignment should begin with channel 13 and go progressively to channel 2, or should begin with adjustments for the high band rather than for the low band. This is because almost all such tuners are so constructed that alignment of any one channel effects alignment of all lower channels.

<u>Sound Bars As Alignment Indicator.</u> An approximate oscillator alignment may be made without instruments, as follows:

<u>1.</u> Tune in a program or a station test pattern. If there is a fine tuning control, set it at mid-range.

<u>2.</u> Experiment with the oscillator alignment until finding a position at which sound bars appear with adjustment in one direction, and disappear with opposite adjustment. This adjustment may be for one channel, for either high band or low band, or overall.

<u>3.</u> Vary the oscillator adjustment to a point at which sound bars just commence to appear. Then turn the adjustment only far enough the opposite way to make sound bars disappear.

<u>4.</u> Tune in other stations. Get the best possible picture on each. If sound bars appear, make a slight readjustment of oscillator alignment to get rid of the bars.

<u>Oscilloscope To Video Detector Load For Alignment.</u> The following method of oscillator alignment requires (a) a sweep generator, (b) a marker generator capable of tuning accurately to video carrier frequencies of channels, and (c) an oscilloscope which need not have high vertical sensitivity. The setup is shown by Fig. 7. It is necessary that the i-f section be satisfactorily aligned before using this method of r-f oscillator alignment.

<u>1.</u> Connect the sweep generator through a matching pad to the antenna terminals of the tuner or receiver.

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2. Connect the high side of the marker generator through a small capacitor, about 2 to 5 mmf, to either antenna terminal. Connect the low side to tuner frame metal or to B-minus.

3. Connect the oscilloscope vertical input across the video detector load, in the same manner as for i-f alignment.

4. If there is a fine tuning control place it at mid-range, and leave it there.

5. Tune the marker generator precisely the video carrier frequency of the channel to be first aligned. Set the channel selector for the same channel.

6. As shown by Fig. 7, altering the adjustment of oscillator frequency will move the entire response curve to the right or left on the screen of the scope, but the marker pip will remain in fixed position crosswise of the scope screen.

7. Adjust oscillator frequency to move the response curve in relation to the video marker pip until this pip is at a point of 50 to 60 per cent of peak gain, and is on the low-frequency slope of the response. Note that the video marker appears on the low-frequency side of the response, whereas with sweep and marker to the mixer for i-f alignment the video marker would appear on the high-frequency slope.

8. Tune the marker generator precisely to the sound carrier frequency of the channel being aligned, and note the position of the sound marker on the response. The sound marker should be far down on the high-frequency slope of the response, or in a dip caused by a trap or traps for accompanying sound. If the sound marker is not in this position when the video marker is correctly placed, the i-f section is not correctly aligned, or possibly the r-f circuits in the tuner are misaligned.

Zero Beats For Oscillator Alignment. A popular method of r-f oscillator alignment makes use of zero beating between video carrier and video intermediate frequencies. The instrument setup is shown by Fig. 8. There is (a) a sweep generator, (b) a marker generator capable of tuning accurately to

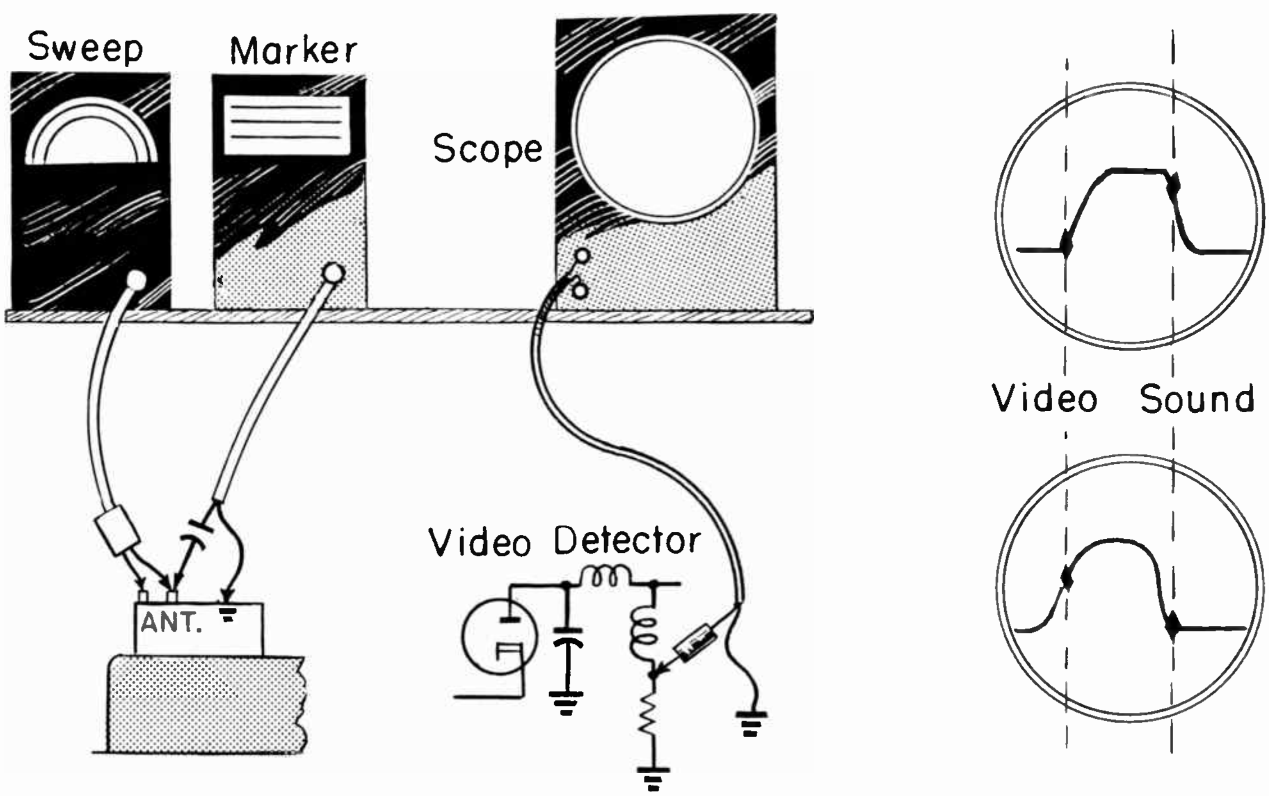

Fig. 7. R-f oscillator alignment with an oscilloscope at the video detector load.

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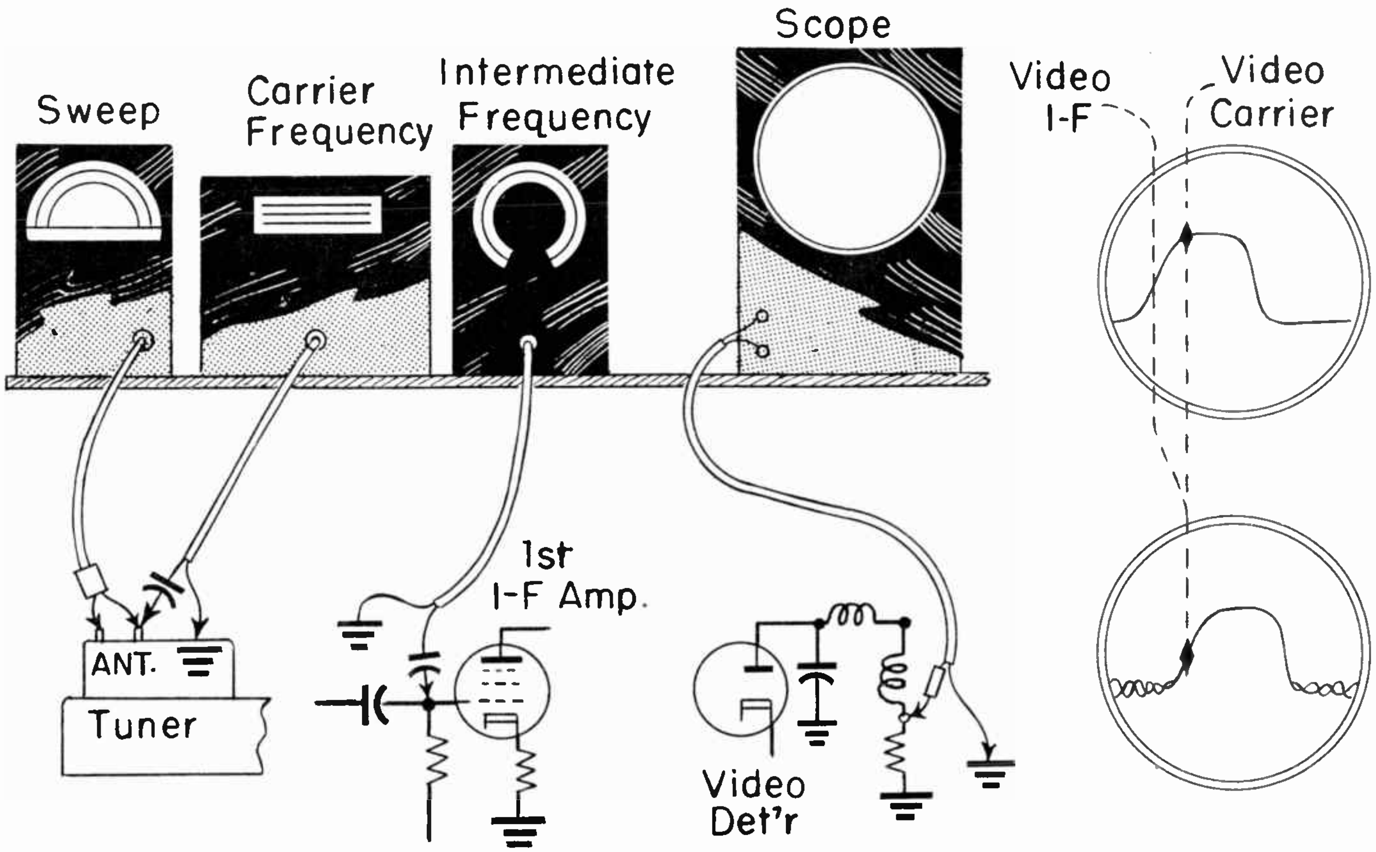

Fig. 8. R-f oscillator alignment by zero beating of carrier and video intermediate frequencies.

carrier frequencies, (c) a second marker generator which tunes accurately to intermediate frequencies, and (d) an oscilloscope of moderate vertical sensitivity. Steps are as follows:

1. Connect the sweep generator through a matching pad to the antenna terminals of tuner or set.

2. Connect the carrier-frequency marker generator to either antenna terminal through a capacitor whose value may have to be as great as 50 mmf, but preferably is smaller. Connect the low side to tuner frame metal or to B minus in the tuner.

3. Connect the i-f marker generator high side to the grid of the first i-f amplifier through a capacitor of not more than 10 mmf. This connection may be made otherwise to an ungrounded shield or a metal coupling band on the envelope of the first i-f amplifier tube. Connect the low side of this generator to tuner frame metal or to B-minus.

4. Connect the vertical input of the scope to the video detector load, in the same manner as for i-f alignment.

5. Tune the carrier-frequency marker accurately to the video carrier frequency of the channel to be first aligned. Adjust the sweep generator to sweep this channel

6. Tune the i-f marker generator accurately to the video intermediate frequency of the receiver.

7. The two marker pips should appear on the low-frequency slope of the response. Adjusting the oscillator frequency will move the response curve bodily to the left or right. The i-f marker will move with the response, remaining at its original position on the curve. The carrier marker will not move with the response, but will remain at a fixed point crosswise of the scope screen. It is apparent that oscillator frequency adjustment will move the response curve and i-f marker to a position where the i-f marker coincides

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with the stationary carrier-marker. This indicates a correct alignment of oscillator frequency.

Sketches of responses in Fig. 8 show how the two markers at first may be separated, then how oscillator frequency adjustment will bring them together. When the markers come together there will be a zero beat effect, and both sides of the response curve will break up into a number of waves. These waves or wriggles on the response are clearly evident even though the marker pips are too faint to be identified. Before making a final adjustment you should try varying a fine tuning control or an oscillator adjustment to become familiar with this indication of zero beat.

The shape of the response curve is of no importance, so long as the condition of zero beat can be identified. That is, alignment will be just as accurate even though the response curve is distorted by marker generator connections and voltages.

8. Repeat the oscillator adjustment by obtaining zero beat for all other channels, or for the high band and then for the low band in case there are adjusters only for the two bands.

This method of zero beating will work just as well when you set the marker generators for the sound carrier of a channel and for the sound intermediate of the receiver. The two markers then will appear on the high-frequency slope or end of the response.

OSCILLATOR ALIGNMENT WITH DUAL SOUND SYSTEMS. If a receiver has a dual sound system it is desirable to align the r-f oscillator by using the output of the sound demodulator, because small variations of oscillator frequency are easily noted by their effects in the narrow frequency response of the sound system. It is essential that all sound i-f amplifiers and the demodulator circuits be correctly aligned before making adjustments on the r-f oscillator. Several methods will be described.

Speaker As Output Indicator. This method requires a tone- or audio-modulated signal generator capable of tuning accurately to sound carrier frequencies. The output indicator may be a speaker. Otherwise the indicator may be an output meter connected to the speaker voice coil or to the audio output amplifier plate circuit just as for alignment of a-m sound receivers. Proceed as follows:

1. Connect the high side of the generator through about 1,000 mmf to either antenna terminal of the tuner or set. Connect the low side to tuner frame metal. With the generator output modulated for an audible tone, tune precisely to the sound carrier frequency of the channel first aligned.

2. Listen to the speaker while adjusting the r-f oscillator for maximum volume, or adjust for maximum reading on an output meter. Keep the receiver volume control near its maximum setting. Reduce the generator output as alignment proceeds.

VTVM As Output Indicator. This method requires a vacuum tube voltmeter, also an unmodulated signal generator capable of tuning accurately to sound carrier frequencies. It is difficult or impossible to make an oscillator alignment on receivers having the series plate-cathode B-supply system. Sound circuits usually are at high positive voltage, and the VTVM must be used on such a high range that small variations of voltage cannot be read with accuracy. With other B-supply systems proceed thus:

1. Connect the high side of the signal generator to either antenna terminal, direct or through about 1,000 mmf, and connect the low side to metal of the tuner frame. Tune the generator accurately to the sound carrier frequency of the channel aligned.

2. With the VTVM on its d-c function connect the high side to the audio output point of the sound demodulator circuit, as when aligning the secondary of the demodulator transformer. Connect the low side to chassis ground or B-minus.

3. Adjust the oscillator alignment for zero VTVM reading which occurs between positive and negative indications. Repeat this on all channels.

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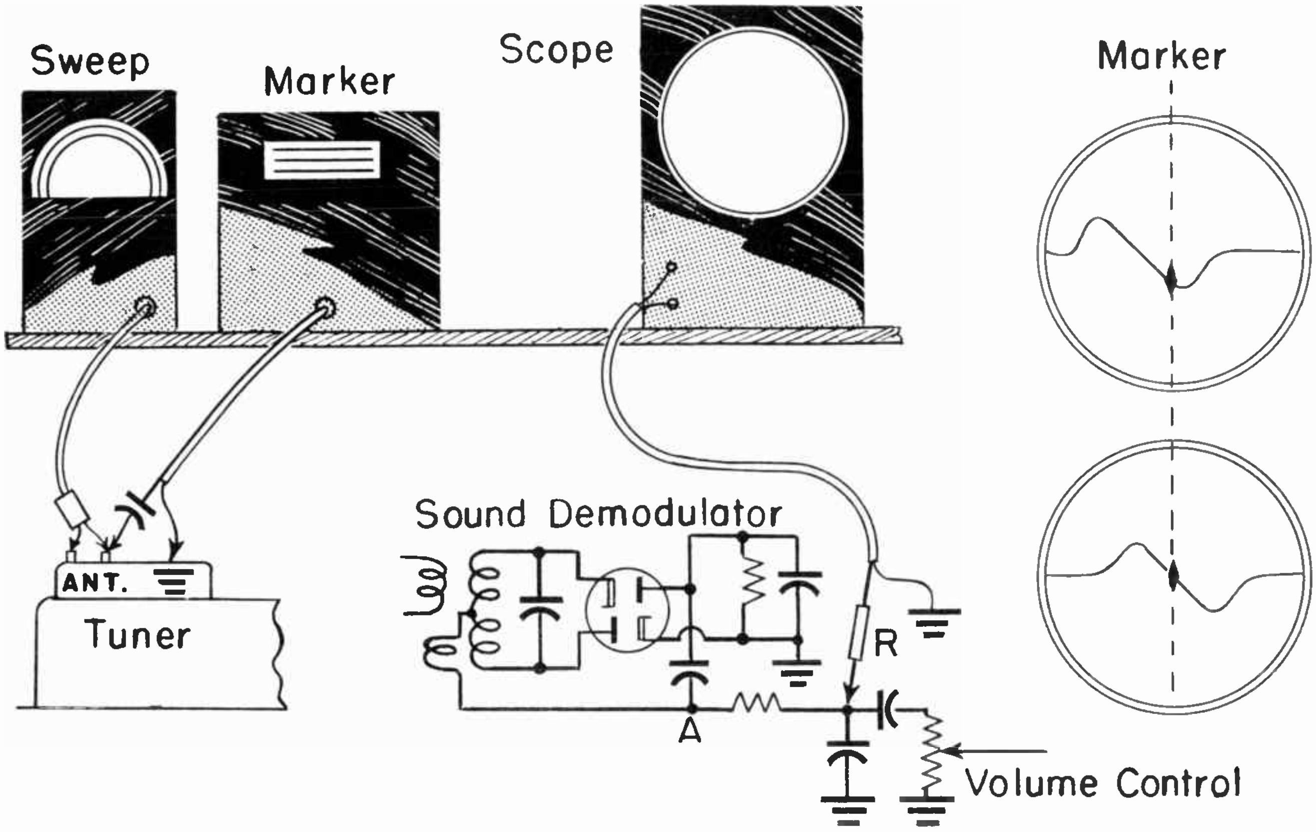

Fig. 9. R-f oscillator alignment with an oscilloscope at the audio output of the demodulator in a dual sound system.

Oscilloscope As Output Indicator. The method of r-f oscillator alignment illustrated by Fig. 9 makes use of a sweep generator, a marker generator for sound carrier frequencies, and an oscilloscope for output indicator. The procedure follows:

1. Connect the sweep generator through a matching pad to antenna terminals of the tuner or receiver. Use a narrow sweep, something less than one mc, as when aligning a sound demodulator with the oscilloscope.

2. Connect the marker generator high side to either antenna terminal through a capacitor of not more than 5 to 10 mmf. Connect the low side to ground or B-minus.

3. Connect the vertical input of the oscilloscope to the audio output or balanced output of the sound demodulator, as for aligning the secondary of a demodulator transformer. In series with the high-side scope lead use, at R, a resistor of 10K to 20K ohms or, if traces are more distinct, use at this point a capacitor of about 1,000 mmf. Instead of connecting the scope just ahead of the volume control, as in the diagram, it may be connected at point A.

4. With the selector at the channel to be first aligned, adjust the sweep generator to bring an S-curve onto the screen of the scope.

5. Tune the marker generator to the exact sound carrier frequency of the channel being aligned.

6. Adjust r-f oscillator frequency to bring the S-curve into such position that the marker is at the center of the long slope on this curve. Changes of oscillator frequency will move the curve to right or left, with the marker remaining fixed.

OVERALL RESPONSE. An excellent way to determine whether a tuner is in good or poor alignment is to observe the combined frequency response of the tuner and the i-f amplifier section of the receiver. This is done by connecting sweep and marker generators to the antenna terminals of the tuner

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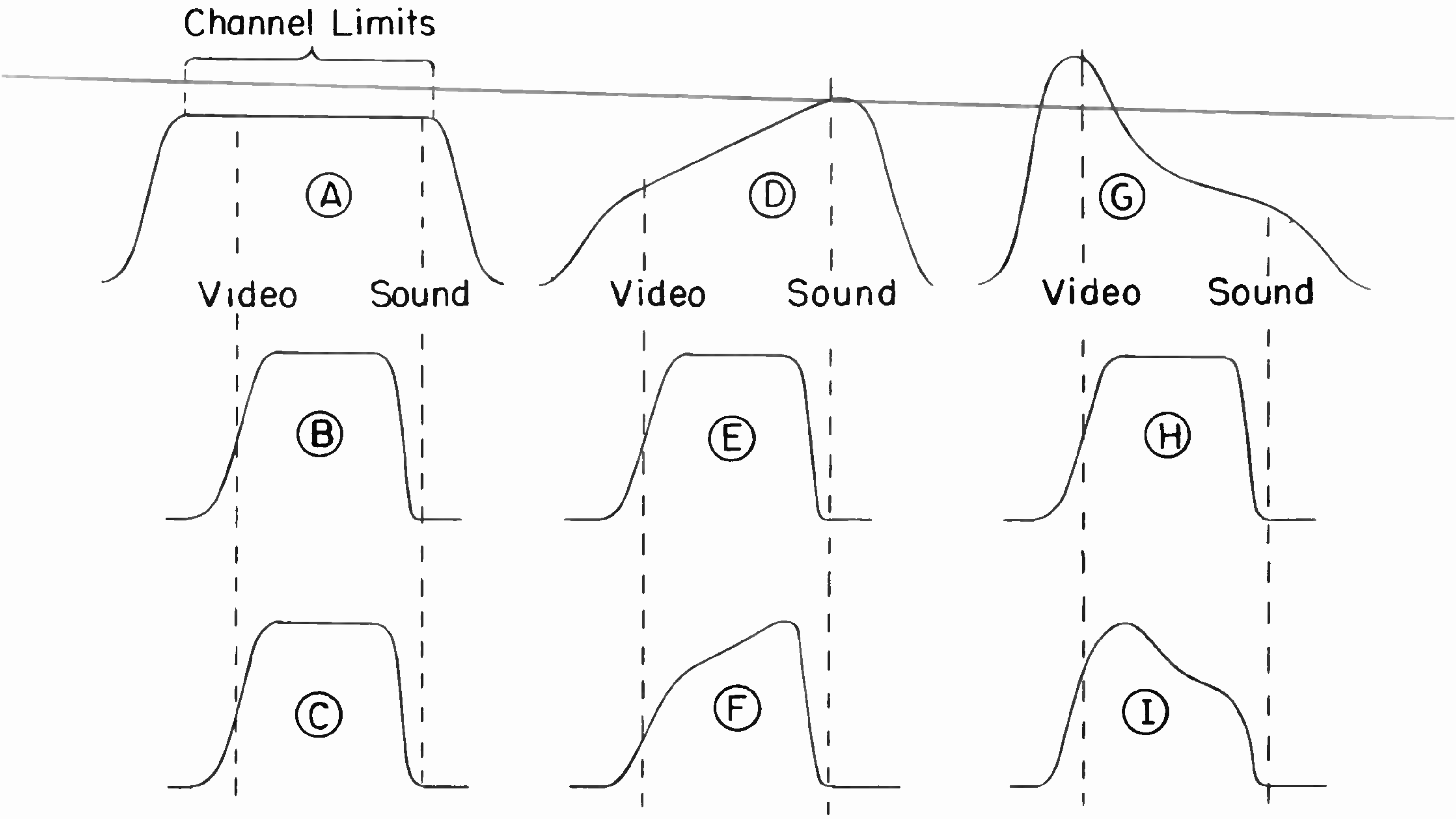

Fig. 10. How tuner alignment affects the shape of i-f responses.

or receiver, and the oscilloscope to the video detector load, just as in Fig. 7.

What happens is illustrated, in principle, by Fig. 10. Were a tuner perfectly aligned its response, alone, would be flat or of uniform gain throughout a band width at least as great as the six megacycles of one channel. This is shown at A. Assume that this tuner feeds an i-f amplifier section whose response is shown at B. Since all channel frequencies will be at the same level when fed to the i-f amplifier, the response at the video detector will be of the same shape as the i-f response, and will be as at C.

Supposing next that the tuner response is as shown at D, with a decided tilt. The i-f amplifier response still is the same as before, and is shown at E. Now some of the channel frequencies are amplified more than others in the tuner, the i-f section does not receive equal voltages at all frequencies, and response at the video detector will be as at F. Here we see the tilt due to tuner misalignment.

In another case the tuner response might be peaked at one side, as at G. Still there is no change of i-f response which, considered by itself, is shown at H. But overall response, I, observed at the video detector, carries a peak which is due to misalignment of the tuner.

When making actual tests of this nature we go through the following steps.

1. Observe the i-f response by itself, with sweep and marker generators connected to the mixer grid circuit, and scope to the video detector load. If i-f alignment is not satisfactory, make it so before including the tuner in your test setup. Then remember the shape of the i-f response or, better, make a sketch.

2. Connect sweep and marker generators to the antenna terminals, observing all the precautions mentioned earlier.

3. Sweep each of the twelve channels while comparing overall responses with the response of the i-f amplifier alone.

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4. On each channel tune the marker generator to video and sound carrier frequencies of that channel. Note positions of the marker pips on the overall responses for each channel.

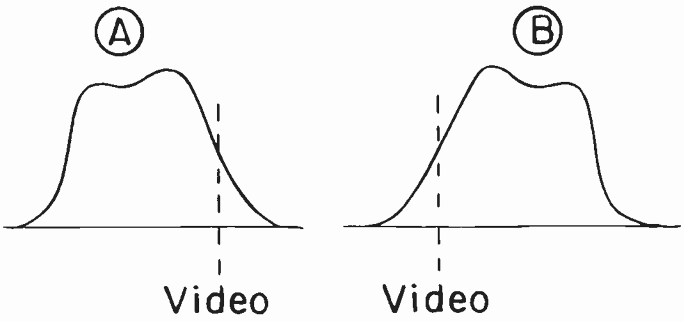

Fig. 11. Response curves are turned side for side when changing the generators from mixer grid to antenna terminals.

5. When recording your observations of channel responses keep in mind that right- and left-hand sides of the i-f response, with generators at the mixer grid, will be reversed when the generators are connected to the antenna terminals. For example, if the i-f response appears as at A of Fig. 11 when the generators are at the mixer grid, the corresponding response with generators at the antenna terminals will be turned side for side, as at B.

6. After observing overall responses on all channels you may draw these conclusions with reference to tuner alignment:

a. When responses on all channels look almost exactly the same as the i-f response, except for right and left reversal, and when video and sound marker pips fall at proper points on all channel responses, the tuner is correctly aligned.

b. If channel responses don't look just like the i-f response, but all channel responses are like one another, the tuner is not perfectly aligned but it has the same error on all channels. Tuner alignment probably can be corrected by using one or more overall adjusters such as shown in Figs. 3 and 4.

c. Should responses for various channels differ materially from one another, tuner alignment is not the same for all channels. It may be satisfactory for some channels, but not for others. Correction will require tuner adjustments for individual channels. Overall adjustments cannot make different corrections for different channels, although they might bring about a compromise fairly satisfactory for all channels.

When conditions are as in preceding paragraphs b and c, do not attempt to improve overall responses by realigning the i-f amplifier stages while generators are connected to the antenna terminals and feeding through the tuner to the i-f amplifier. If, however, the tuner appears correctly aligned, as in paragraph a, there is no objection to making slight readjustments on the i-f stages to improve overall response. These i-f adjustments then will affect all channels alike.

R-F ALIGNMENT OF TUNER. R-f alignment usually is carried out with sweep and marker generators connected to the antenna terminals, and with the oscilloscope connected to the mixer grid circuit. Although it may be fairly simple to make an alignment once you have a true r-f response on the scope, there are many difficulties in the way of obtaining a response that represents actual performance of the tuner under normal reception conditions.

It must be kept in mind that you are working with only one or possibly two staggered stages of amplification between input and output. When input from the sweep generator is kept low enough to avoid overloading tuner tubes, output at the mixer grid is so weak as to require extreme vertical sensitivity in the oscilloscope. Many service shops use a preamplifier on the scope vertical input, thus increasing effective sensitivity anywhere from 30 to about 500 times. This is not too difficult, since the preamplifier need be designed to handle only the 60-cycle sweep, not carrier frequencies.

Because you will be working with 60-cycle sweep the matter of 60-cycle stray field pickup is serious. The least bit of stray 60-cycle voltage is greatly amplified in the scope, and in a preamplifier if used. The result is that forward and return traces do not track, one will ride high and the other low on the screen of the scope. Retrace blanking helps, but then the remaining for-

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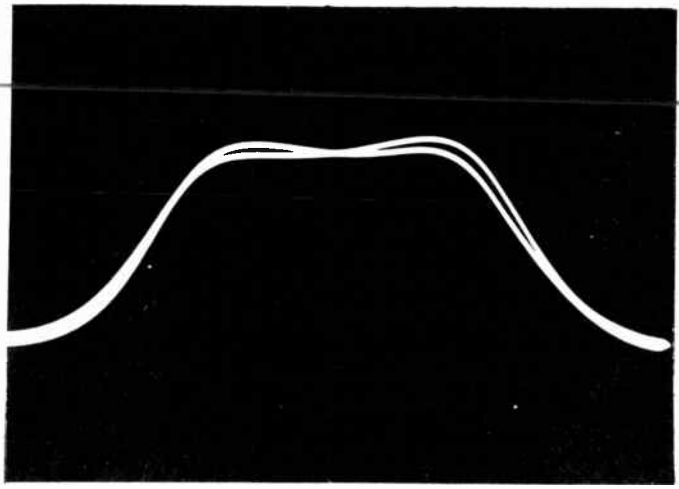

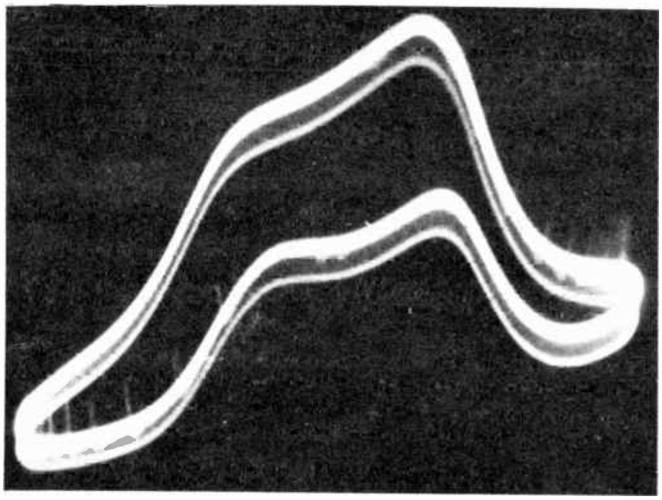

Fig. 12-B

Fig. 12. Stray field pickup seriously distorts the r-f response as seen on the scope.

ward or return trace rides a curve which makes it look quite unlike a normal response curve. At A of Fig. 12 is a good response. At B is the response from the same tuner with stray 60-cycle voltage getting into the scope vertical input. This latter trace was affected also by pickup of horizontal sync and sweep pulses.

To prevent pickup of stray field voltages the vertical input prod or probe must be shielded to within at least a half-inch of its connection to the mixer grid circuit. Series resistors and bypass capacitors, for preventing fuzzy traces, also must be shielded.

Another difficulty occurs because, at carrier frequencies, effects of even the smallest added capacitances and inductances cause large changes of frequency response. When instrument cable clips or prods are used at socket lugs of tuner tubes the clips or prods must be kept well away from circuit wiring and parts. A prod within a half inch of tuner grid or plate circuit wiring can cause complete detuning.

Unless suitable test point connections are built into the tuner it is advisable to make instrument connections on top of the tuner frame, with small bared wires wound around tube pins. Do not attempt to use test adapters for making instrument connections to tuner tubes. An ordinary adapter can throw tuning off as much as one whole channel.

The oscilloscope may be connected to the mixer grid or the grid return path without the need for a detector probe on the vertical input cable. This is because the mixer grid, with its highly negative bias, acts with the cathode in much the same manner as a diode detector to recover the outlines of frequency responses.

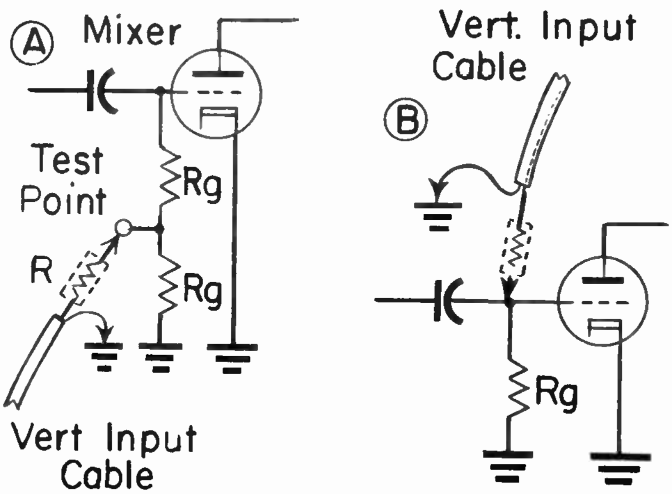

Fig. 13. Oscilloscope connections to a mixer grid test point, and directly to the mixer grid.

On many tuners the mixer grid return resistance is in two parts, as at A of Fig. 13. From between the resistors a connection is run to a test point on top of the tuner frame. This test point may be a wire loop, a straight wire, or sometimes a pin jack. For tuner alignment connect the high side of the oscilloscope vertical input to a mixer grid test

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point through a resistor, R, of 20K to 50K ohms. These test points are used also for applying sweep and marker voltages to mixer grid circuits during i-f alignment.

If the mixer grid return resistance is not tapped for a test point, the scope connection is made, as in diagram B, to the mixer grid through a resistor of about 100K ohms. Attach this resistor to a small bared wire wound around the grid pin of the mixer tube, so that cable connections remain on top of the tuner frame.

Any agc voltage normally applied to the r-f amplifier should be overridden or removed during tuner alignment. An override of $1\frac{1}{2}$ or 3 volts usually is satisfactory. If this prevents obtaining enough height on response traces, try grounding the agc bus. If there is an agc amplifier or control tube, remove that tube before grounding the bus.

Should slight changes of sweep generator output alter the shape as well as the height of the response, sweep generator output is too high. Sweep output must be reduced to a value which causes no limiting action or other distortion of the response.

If, with all previously mentioned precautions observed, you are unable to obtain a response curve high enough to show effects of adjustments, or can get no response curve of any kind, one or more of the following difficulties probably exist.

1. The oscilloscope does not have enough vertical gain.

2. The r-f amplifier stage in the tuner has too little gain to produce a good response curve with sweep voltage low enough to avoid distortion, and with the scope at maximum vertical gain.

3. The sweep generator does not sweep a frequency range wide enough to include both sides or both skirts of the r-f response. This condition is shown by the upper diagram of Fig. 14. When there is insufficient sweep width it may be possible to vary the center frequency of the sweep generator to bring either skirt of the response partially into view, as in the lower diagrams.

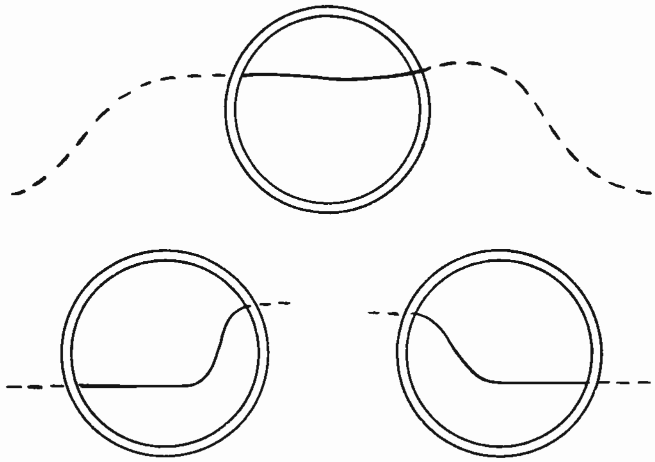

Fig. 14. When sweep width is too narrow, the entire response curve cannot be brought onto the screen of the scope.

In tuners not of fairly recent design the r-f response is exceedingly wide, especially in tuners having no channel tuning circuits between antenna and r-f grid. The wide response limits gain to small values, and the combination of wide response and small gain makes it difficult to obtain a useful response trace.

Oscilloscope To Mixer Plate Circuit. Frequency responses are much stronger at the plate than at the grid of a mixer, and often times a useful response curve can be taken from the mixer plate when one cannot be obtained at the grid. A trouble which must be overcome when using this method is the effect on response shape of inductances, capacitances, and resonances in the plate circuit or between the mixer plate and grid of the first i-f amplifier.

Another cause for false response is that a detector probe must be used on the vertical input of the scope when connected to the mixer plate circuit. Capacitances and inductances of the detector probe are likely to change the shape of a response. Sometimes there will be two separate responses, one due to capacitance and inductance of the probe. There is likely also to be stray field pickup with a poorly shielded detector probe, or when an isolating resistor is connected in series with the probe.

To prevent plate circuit resonant elements from affecting the response it is best to disconnect the mixer plate from the coup-

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ling between this plate and the grid of the first i-f amplifier, then connect the mixer plate to a resistance load in which there can be no resonant or trap effects. How this can be done depends on the design of circuits between mixer and first i-f amplifier.

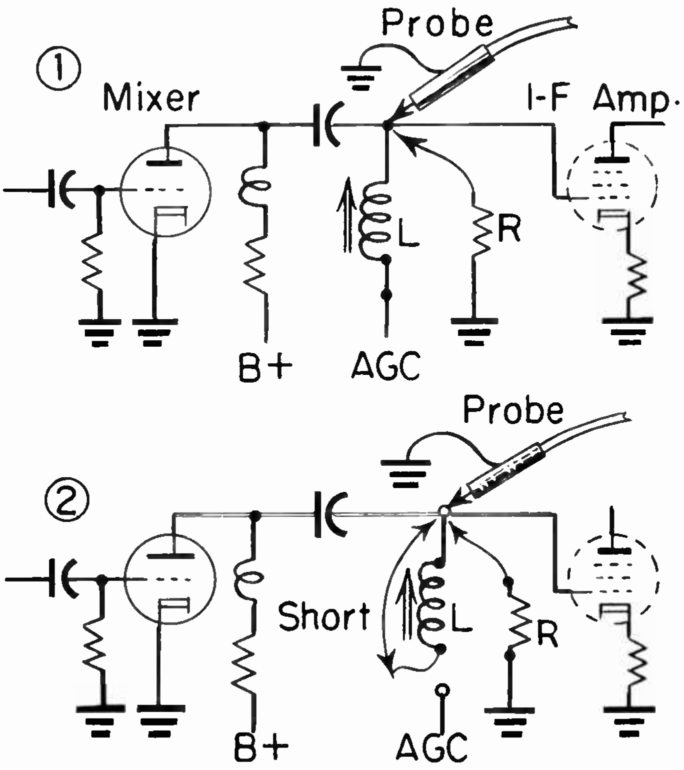

Fig. 15. Avoiding resonance effects in r-f to i-f couplings of the parallel feed type.

With coupling circuits such as those at 1 of Fig. 15, or anything generally similar, affects of coupler resonance can be greatly reduced by connecting at R a resistor of not more than 300 ohms, and by removing the first i-f amplifier tube. However, this small resistance load for the mixer plate lowers the gain and requires high sensitivity in the scope.

It would be better, as in diagram 2, to disconnect one end of the coupling inductor and short across the inductor with a piece of wire, then use at R a resistance of about 10K ohms. This fairly high load resistance for the mixer plate helps the gain, thus causing stronger responses. Instead of shorting the inductor it might be disconnected from the grid circuit, leaving resistance at R for a plate load.

In other cases there may be some kind of transformer coupling between mixer and i-f amplifier, as in the example at 1 of Fig. 16. Inductors La and Lb could be shorted with wires, decoupling capacitor Cd disconnected, and decoupling or dropping resistor Rd left as a load for the mixer plate. It might be well to remove the first i-f amplifier tube.

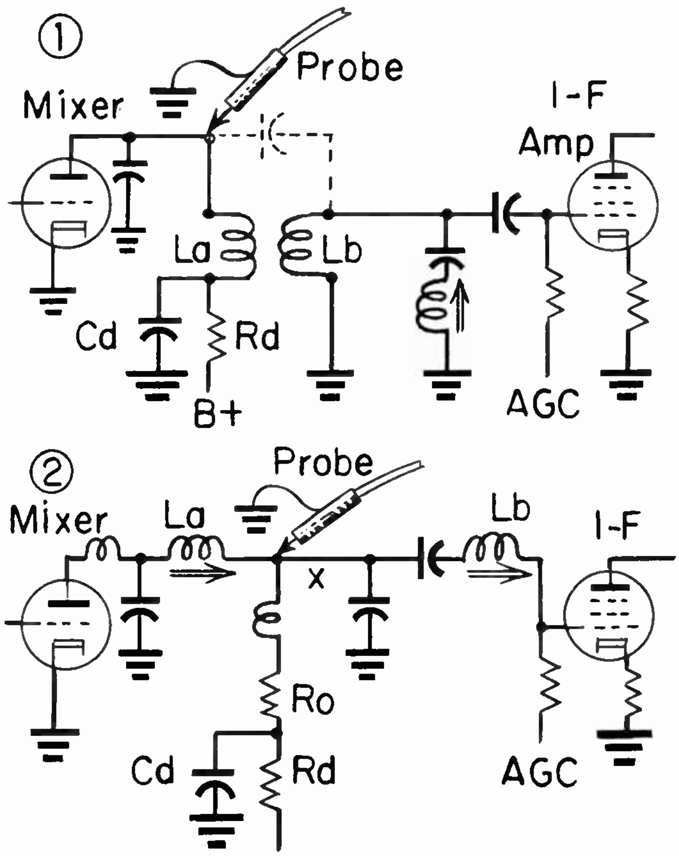

Fig. 16 Avoiding resonance effects when there is transformer coupling between mixer plate and i-f grid.

With mixer r-f coupling as in diagram 2 of Fig. 16 it would be possible to short inductors La and Lb, remove the first i-f amplifier tube, and connect the oscilloscope detector probe as shown. Resistor Ro, and an r-f choke in series, then would remain as a load for the mixer plate. Instead of shorting Lb it might be easier to open a connection at point X on the diagram.

Any number of additional examples might be examined, all varying according to the kind of coupling circuits between mixer and i-f amplifier. It always should be possible to

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devise suitable methods for obtaining responses by observing these four rules:

1. Disconnect or short out all tunable inductors and capacitors which originally connect to or are coupled to the mixer plate.

2. Make sure that there is a mixer plate load, or provide a load, consisting of non-inductive resistance or non-tunable impedance, possibly including an r-f choke.

3. Be sure to maintain B-plus voltage at the mixer plate, and do not get B-plus shorted to ground or B-minus.

4. Connect the oscilloscope detector probe to the high side of the mixer plate load mentioned in rule 2.

The detector probe used on the mixer plate circuit may be any type suitable for observation of frequency responses from any other points where it is necessary to demodulate a high-frequency voltage for application to the vertical input of the oscilloscope.

Turret tuners, incremental tuners, and other types often have the transformer or other coupling from mixer plate to i-f grid mounted on the tuner. Such a construction is shown by Fig. 17, where a shield can enclose the transformer. In other cases the mixer to i-f coupler may be a small movable-core unit mounted in a hole through the top of the tuner frame in the same manner that these units are mounted through holes in the main chassis when used between i-f stages.

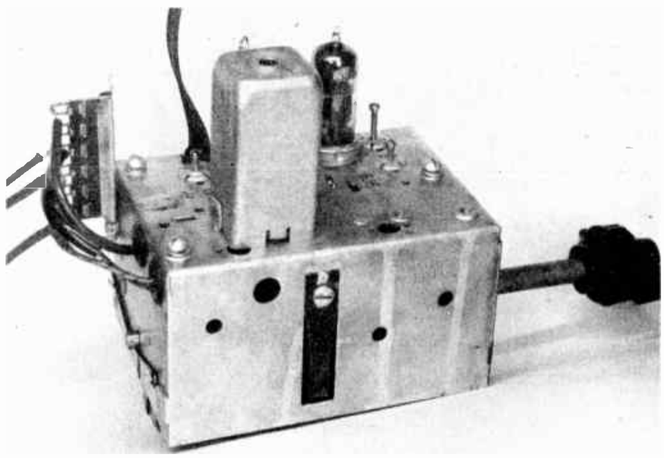

Fig. 17. Inside the shield on top of the tuner is a transformer for coupling the mixer plate to the grid of the first i-f amplifier.

Where the mixer to i-f coupling is part of the tuner it may be difficult to reach connections in the mixer plate circuit for attachment of the oscilloscope probe. The connections often may be reached by removing the shield for the transformer or coupler, or they may be accessible after removing the drum from a turret tuner.

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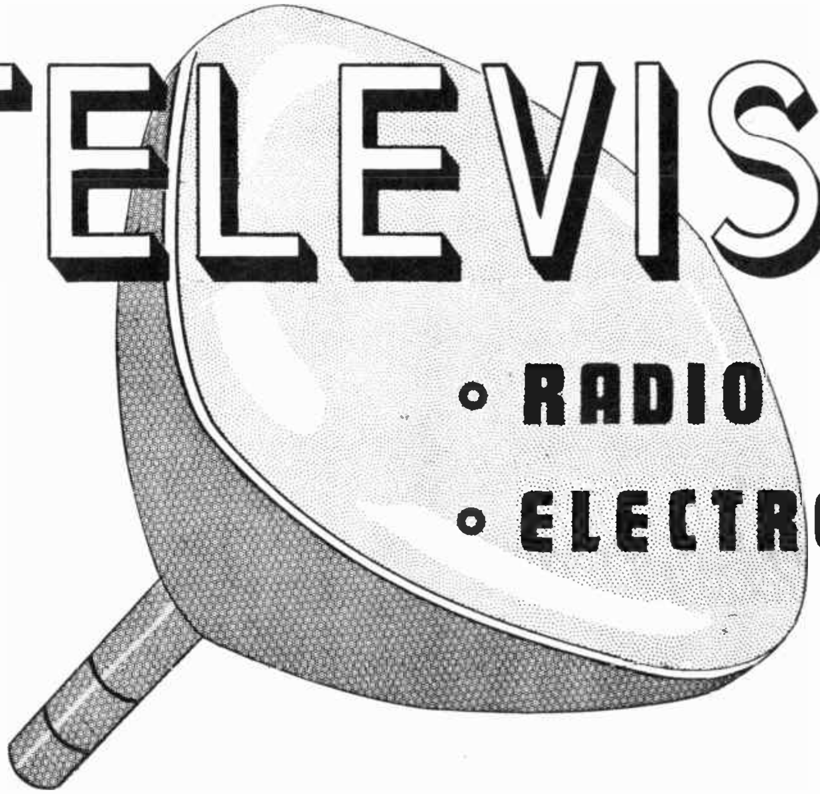

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Lesson 82

TUNER SERVICES

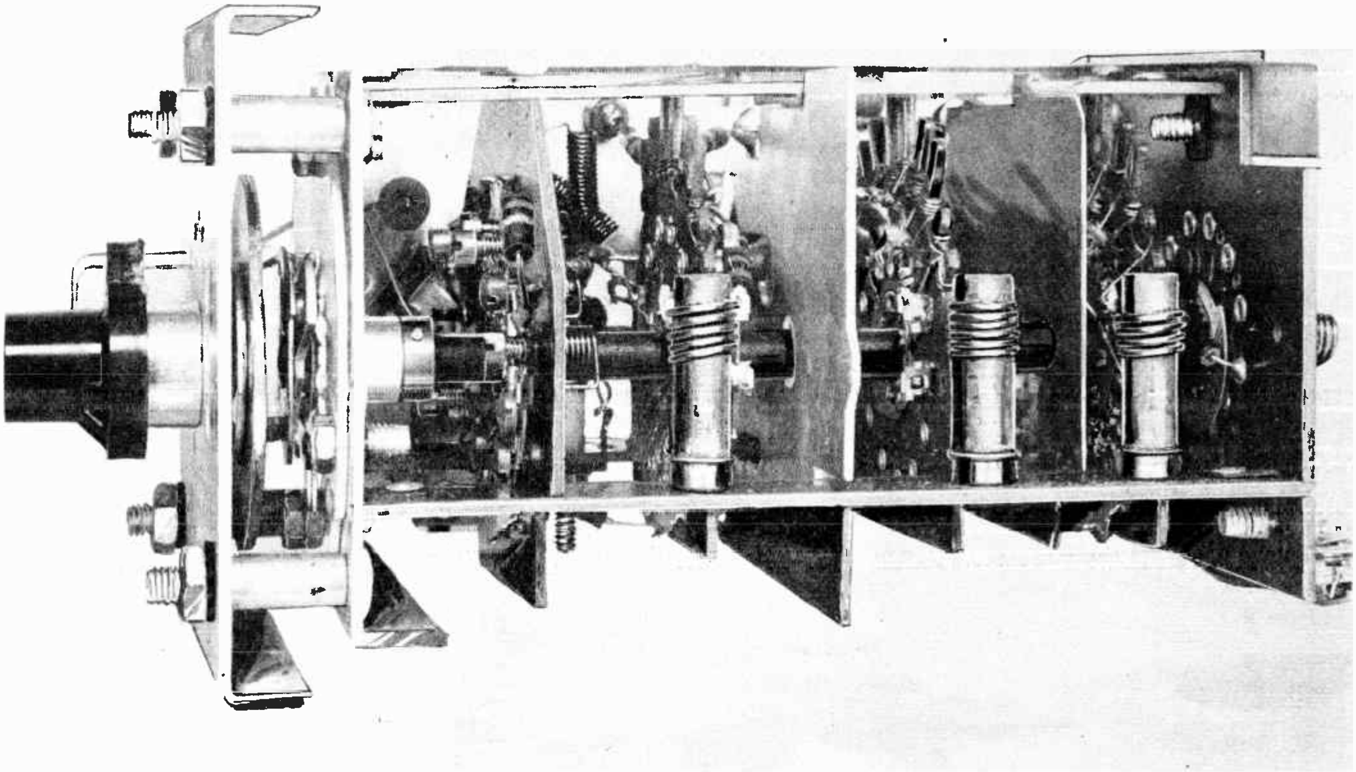

Fig. 1. A series-inductor or incremental tuner having trimmer capacitors and also adjustable inductors for alignment of all the principal resonant circuits.

Some characteristics to be watched for in r-f responses are illustrated by Fig. 2. Referring to diagram A, the video carrier is preferably on top of the response, not down on the outer slope of the curve, since that might mean too little amplification of vestigial side band frequencies. The sound carrier preferably is at a point no lower than 80 to 90 per cent of peak response.

The r-f response should be as narrow, and with skirts as steep, as will allow correct positioning of video and sound carrier markers. A narrow response has the advantage of increased selectivity, with reduction of noise and interference. Also, with relatively narrow band width it ordinarily is possible to have greater gain.

R-f responses usually have two peaks, as in diagram B. The two peaks should be of nearly equal height, or the lower one should be no less than 90 per cent of the higher peak. The deepest point of the valley between peaks should be no farther down than 80 to 90 per cent of the higher peak. The flatter the top, the more satisfactory is the response.

An r-f response may be single-peaked to obtain maximum possible gain for reception in fringe areas. In this case the video carrier should be at or close to the single peak, as at C.

Fig. 3 illustrates several r-f response curves such as might be obtained in practice. All maximum amplitudes have been brought up to the same value, although the broader responses ordinarily would have less gain than those which are relatively narrow. R-f responses normally have skirts whose lower parts extend into adjacent channels, but with

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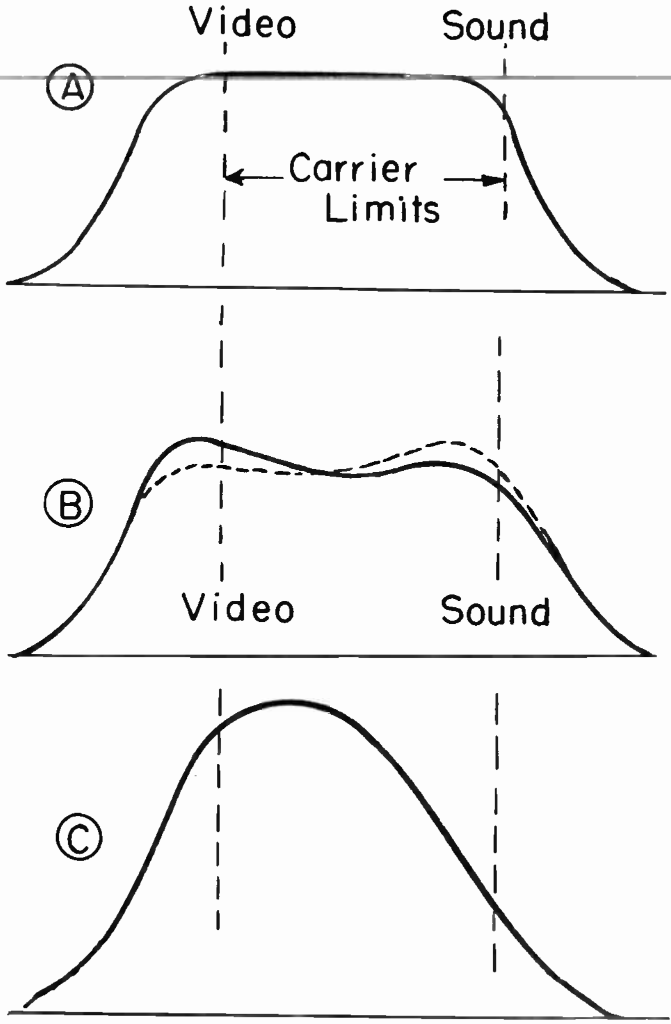

Fig. 2. Video and sound carriers on r-f frequency responses.

modern tuners the skirts will not go so far as the second channel on either side unless gain is very low and response correspondingly broad.

When channel selection is by means of inductors, band width normally increases in going from lower to higher channels. Along with greater band width there is a tendency toward less gain. However, individual channel inductors usually are designed to provide nearly equal band widths on all channels.

In some tuners of early design a single inductor or single inductor-capacitor combination is used for tuning either of two adjacent channels in the high band, usually channels 7 or 8, 9 or 10, and 11 or 12. Since only one channel in any of these pairs will be active in a given locality, the single tuning

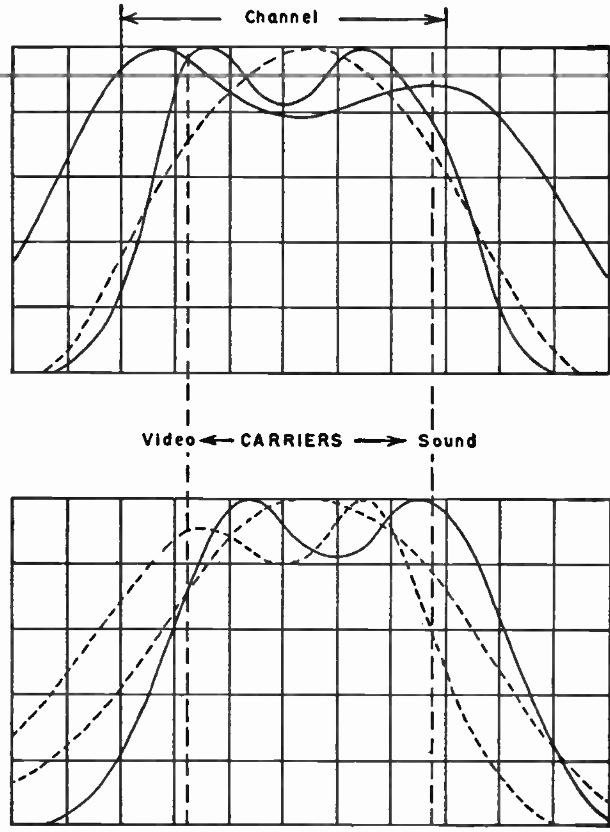

Fig. 3. R-f responses such as may be obtained in practice.

element may be aligned for the channel in which there is local reception. Sometimes adjustment of a fine tuning control is relied on to select either channel of a pair.

Because tuners of different makes and styles have different kinds of adjustments for their several resonant circuits there can be no standardized alignment procedure which will apply equally to all units. If you have, or can obtain, specific instructions for a given tuner, these instructions should be followed in preference to any other methods.

Some tuners have so many adjusters for circuits, bands, and channels that it is nearly impossible to make satisfactory alignment without specific instructions. Others have relatively few adjustments. Then alignment is fairly easy, although results may be only moderately satisfactory until you have had considerable experience.

As you work with all types of tuners it will become apparent that the effects of adjusting r-f grid, r-f plate, and mixer grid

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circuits are much the same on the response no matter how you carry out the alignment steps. We shall examine these effects, then note some methods for obtaining them on tuners in common use.

Assume first that our tuner has alignment adjustments for (a) the r-f grid or antenna circuit, (b) the r-f plate circuit, (c) the mixer grid circuit, and (d) the oscillator circuit. The r-f plate and mixer grid circuits (b and c) act together as some kind of coupling transformer. While working with r-f responses we are not concerned with oscillator alignment.

Alignment of the r-f grid or antenna circuit sometimes is performed as a separate operation. Sweep and marker generators are connected through a matching pad to the antenna terminals. The oscilloscope, with a detector probe on its vertical input, is connected to the r-f plate. The r-f plate circuit is temporarily provided with a non-resonant load, in much the same manner that the mixer plate is provided with such a load when the scope is connected to the mixer plate. While sweeping each channel, the r-f grid or antenna circuit is aligned for the highest response between video and sound carrier markers.

This response might be as shown by the full-line curve at 1 in Fig. 4. If the r-f grid circuit is aligned for a lower frequency the response will move bodily to position A, and if aligned for a higher frequency it will move to position B. Keep in mind that these are the effects of r-f grid adjustments.

Frequency response of whatever coupling is used between r-f plate and mixer grid would be somewhat as shown at 2 of Fig. 4. The two peaks are due to tuning one side of this coupling to a frequency lower than that to which the other side is tuned.

To the interstage coupling will be applied, through the r-f amplifier tube, the voltage amplitudes shown at 1. That is, the frequency response of the r-f grid circuit will be applied to the interstage coupling. If the r-f grid response is as shown by the full-line curve at 1, it will combine with the coupling response at 2 to produce at the grid of the mixer an r-f response such as shown at 3.

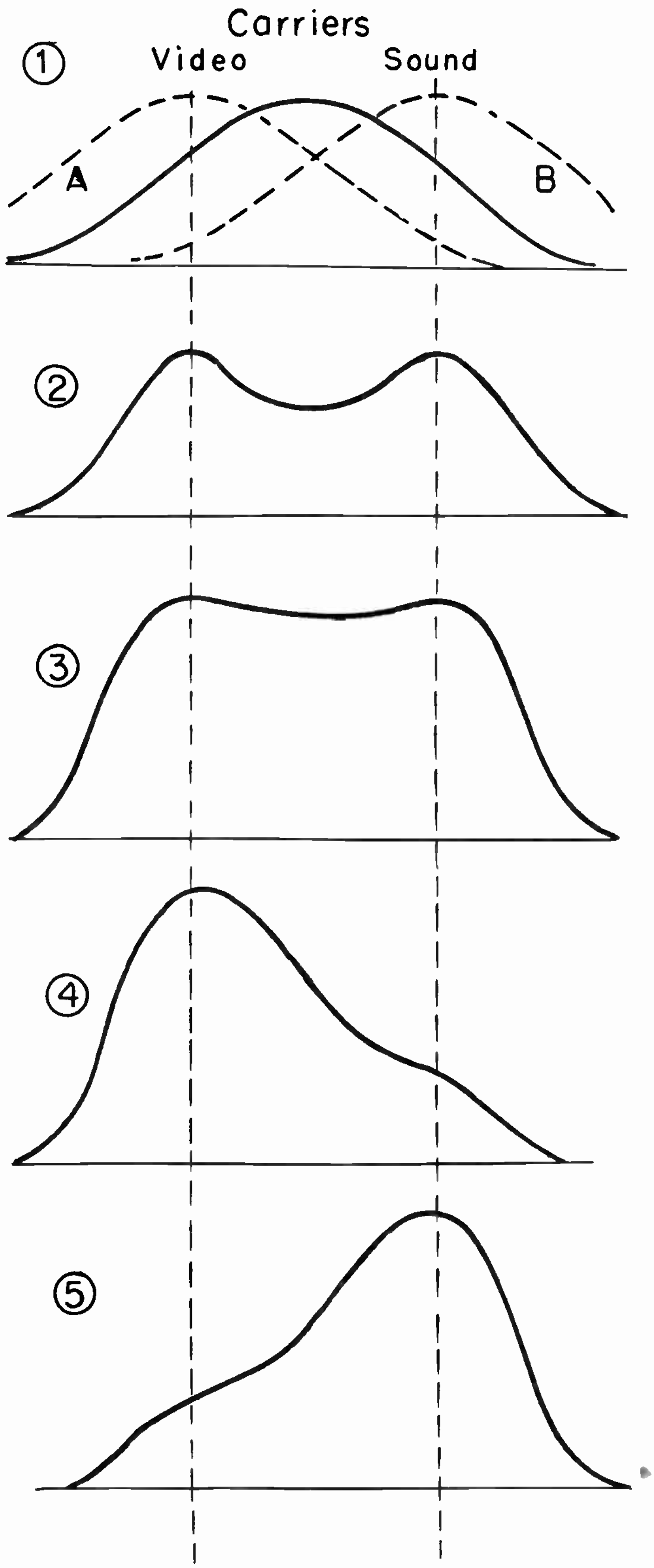

Fig. 4. How adjustment of the r-f grid or antenna circuit affects the response observed at the mixer grid.

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Supposing now that the r-f grid circuit is adjusted for a lower frequency, as at A of diagram 1, while the interstage coupling adjustments are unchanged. The result will be somewhat as shown at 4. The peak of the misaligned r-f grid response combines with the low-frequency peak of the interstage response to produce a high peak on the video side of the overall response. There is a decided downward tilt toward the sound side of the overall response.

Were the r-f grid circuit adjusted for higher frequency, as at B of diagram 1, the overall result would be somewhat as shown at 5. The peak of r-f grid response combines with the high-frequency peak of the interstage response. There is a decided upward tilt toward the sound side of the overall response.

Correct adjustment of the r-f grid circuit will correct a tilt in overall response and will result in nearly uniform gain, also maximum gain. But these things can be accomplished by r-f grid adjustment only when r-f plate and mixer grid circuits are correctly adjusted to produce an interstage response such as at 2 of Fig. 4.

Now let's look at what may be done with adjustments of mixer grid and r-f plate circuits, as shown by Fig. 5. We shall assume that adjustment of the mixer grid circuit affects chiefly the video carrier side of the response, while adjustment of the r-f grid circuit affects chiefly the sound carrier side.

At 1 of Fig. 5 the full-line curve represents what may be called the original response, before any adjustments are changed. If the mixer grid circuit is adjusted for lower frequency the video side of the response will move outward, at A. The peak on the video side will drop because it is getting farther from the sound peak, also is affected by less voltage from the r-f grid response coming through the r-f amplifier.

If the mixer grid circuit is adjusted for higher frequency the video side of the response will move inward and the video peak will become higher, as at B.

Diagram 2 shows how adjustment of the r-f plate circuit will affect the sound side of the response. Tuning this circuit to higher frequency moves the sound side out, and the sound peak drops, as at A. Tuning to lower frequency moves the sound side in, and the peak rises, as at B.

As shown by diagram 3, both sides of the response mightbbe moved outward (A), and

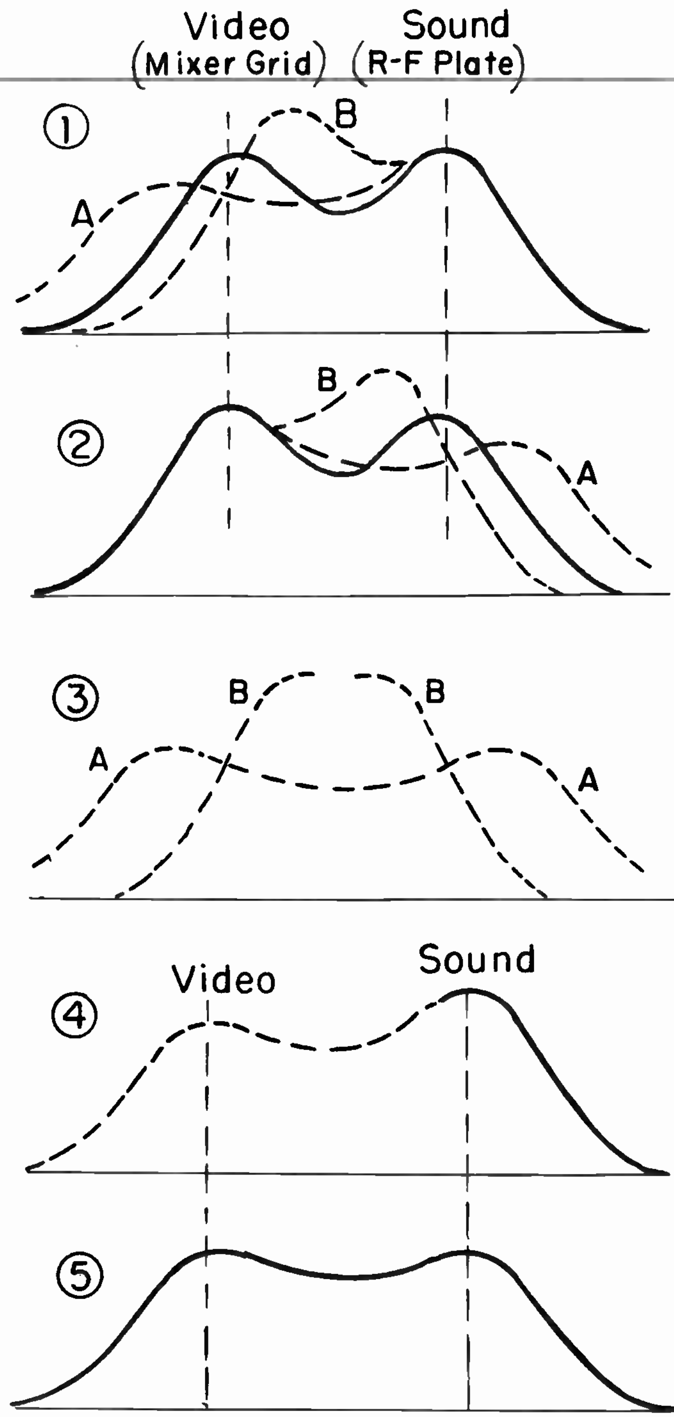

Fig. 5. How adjustments of r-f plate and mixer grid circuits affect the response.

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both peaks dropped, by tuning the mixer grid circuit to lower frequency and the r-f plate circuit to higher frequency. Both sides might be moved inward and both peaks raised (B) by tuning the mixer grid to higher frequency and the r-f plate to lower frequency.

It is apparent that adjustments of mixer grid and r-f plate circuits will bring response peaks to correct positions in relation to video and sound carrier markers. These adjustments also alter the band width of the response, but this is incidental to correct marker positioning.

Supposing that video and sound carrier markers appear at positions of diagram 4. To have the video marker at or near a response peak you will have adjusted the mixer grid to lower frequency. This causes a downward tilt toward the video side of the response. This tilt is corrected by readjustment of the r-f grid circuit to bring the center or the peak of r-f grid response midway between the two markers. When the r-f grid circuit is readjusted the overall response will become as in diagram 5.

An entire response may be shifted to lower or higher frequency range, without material change of curve shape, by altering all adjusters in the same way. That is, to move the response to lower frequencies, increase all alignment capacitances or inductances. To move the response to a higher frequency range, decrease all capacitances or inductances.

Every adjuster affects the entire response curve to some extent, although a given adjuster may affect one part of the curve more than other parts. Every time you make adjustments of mixer grid and r-f plate circuits for correct placing of markers, the r-f grid circuit must be readjusted to avoid tilt.

Make only very small changes of any one adjuster at one time. When a certain direction of adjustment, clockwise or counterclockwise, seems to be making a desired improvement, don't go too far with this one adjuster. Try other adjusters for an improvement of the same kind. Work back and forth between all the adjusters in arriving at a final desired response.

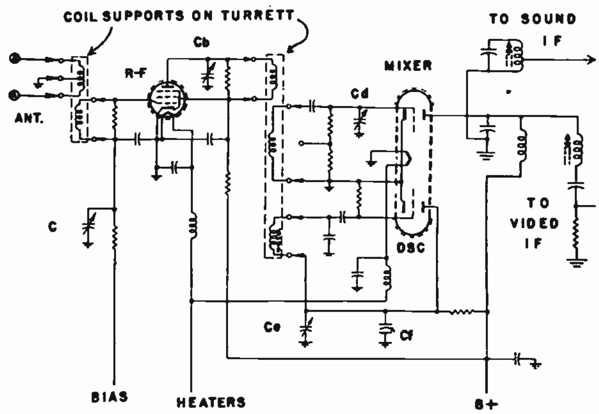

Fig. 6. A turret tuner with pentode r-f amplifier.

Fig. 6 is a circuit diagram for one style of tuner, a turret type, in which are the alignment adjustments whose effects have been explained. At C is a trimmer capacitor for the r-f grid or antenna circuit. The r-f plate trimmer capacitor is marked Cb and the trimmer capacitor for the mixer grid is marked Cd. Trimmer capacitor Ce is in parallel with the fine tuning capacitor Cf.

Fig. 7 is a circuit diagram for a turret type tuner in which the r-f amplifier is of the cascode style with a twin triode, instead of the pentode r-f amplifier of Fig. 6. Adjustments for r-f frequency response are the same, and have the same effects in the cascode tuner as in the pentode type. The r-f grid or antenna trimmer is Ca, the r-f plate trimmer is Cp, and the mixer grid trimmer is Cm. There is no trimmer capacitor in parallel with the fine tuning capacitor.

When aligning tuners of types such as shown by Figs. 6 and 7 it is advisable to begin with a high-band channel number 10, 11, or 12. Then observe the responses on all other channels. Alignment trimmers may be slightly readjusted for the best compromise of marker positions on all channels, or a channel in which there are weak signals may be favored at the expense of channels in which received signals are stronger. If the response for one or two channels is too far off for even a compromise alignment, the tune drum strips should be replaced with new ones.

In a number of tuners there are adjustable inductors in addition to trimmer capaci-

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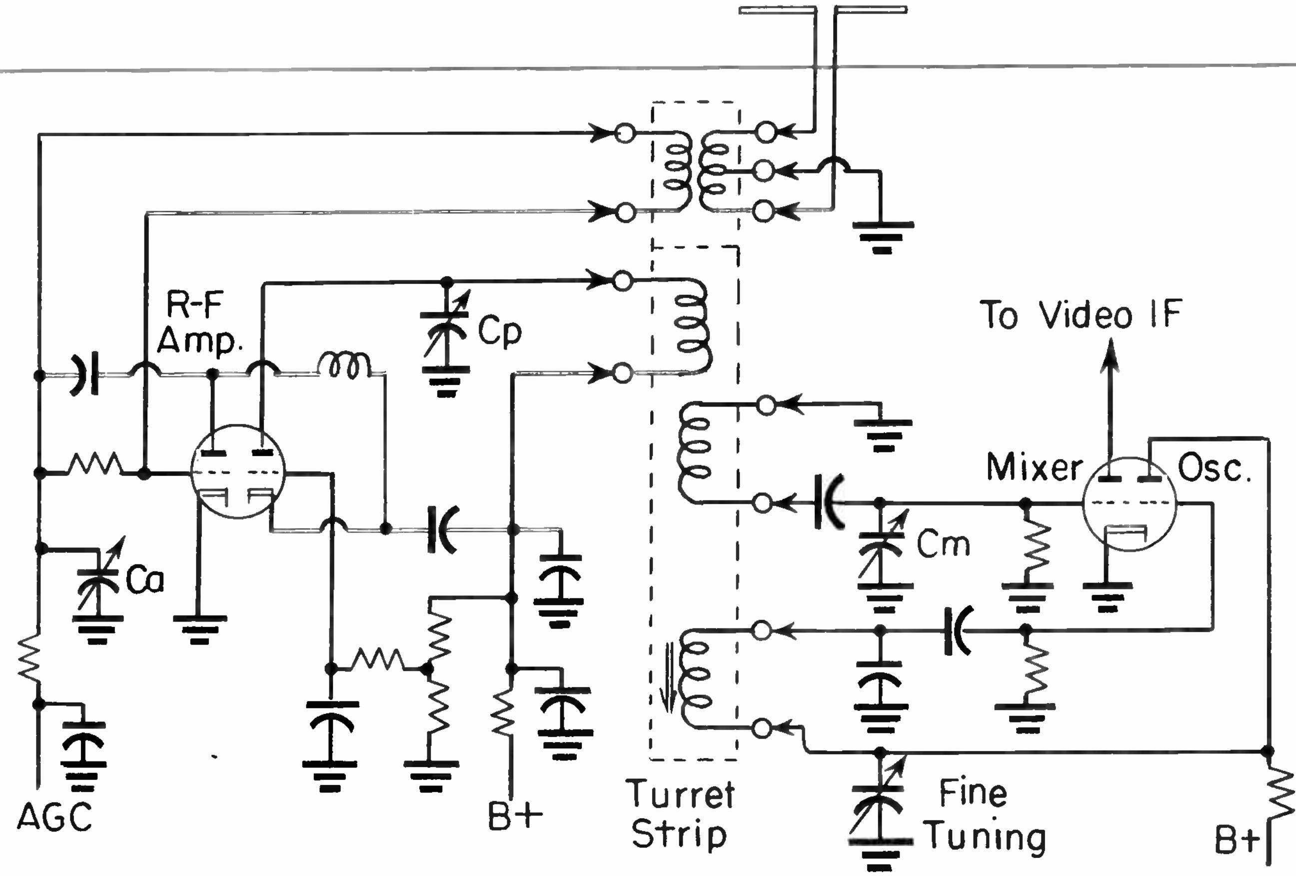

Fig. 7. A turret tuner with cascode r-f amplifier.

tors for alignment of r-f grid, r-f plate, and mixer grid circuits. An example is illustrated by Fig. 8. On the r-f grid is a trimmer capacitor Ca. In series between the r-f grid and channel selector coil L1 is adjustable inductor La.

On the r-f plate circuit is trimmer capacitor Cp. In series between the plate and channel selector coil L2 is adjustable inductor Lp. On the mixer grid circuit is trimmer capacitor Cm, and in series between this grid and channel selector coil L3 is adjustable inductor Lm.

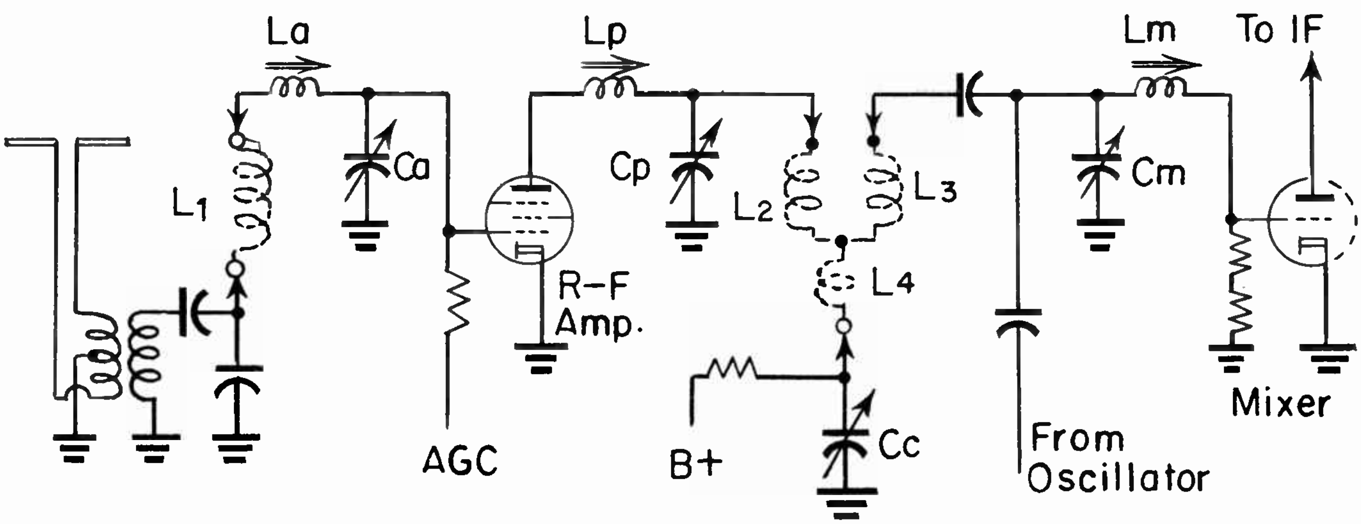

Fig. 8. Adjustable inductors in addition to trimmer capacitors for overall alignment.

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The circuit diagram of Fig. 8 applies to a turret tuner whose drum strips carry the channel selector coils. Between r-f amplifier and mixer the transformer with primary L2 and secondary L3 is of the bottom coupling type with coupling by means of reactances in L4 and adjustable capacitor Cc. Capacitor Cc provides variable coupling between r-f amplifier and mixer.

So far as the alignment inductors and trimmer capacitors are concerned, they might be used with any other kind of channel selector circuits. This is true also of the variable coupling feature between r-f plate and mixer grid. The r-f amplifier is shown as a pentode, but it might otherwise be a cascode amplifier.

Tuners of this general type may be designed with trimmer capacitors Ca, Cp, and Cm for low-band alignment, and with inductors La, Lp, and Lm for high-band alignment. In other cases the capacitors are used for high-band alignment, and the inductors for low-band alignment. For each band you must use the kind of adjusters, capacitors or inductors, for which the tuner is designed. If trimmer capacitors are intended for low-band alignment, the inductors will have little effect in this band. If low-band alignment is to be with inductors, the trimmer capacitors will have relatively little effect in this band.

The effects of adjusting trimmer capaciitors will be the same as were the adjustable inductors not present, and will be the same as described earlier in this lesson. The effect of an adjustable inductor will be practically the same as that of a trimmer capaictor on the same circuit. That is, an r-f grid inductor will tilt the response by raising either side while lowering the other side of the curve. Inductors on r-f plate and mixer grid are used for placing video and sound carrier markers at correct positions. One of these two inductors will have its chief effect on one side of the response, while the other inductor will chiefly affect the other side.

COUPLING ADJUSTMENTS. The purpose of any variable coupling between r-f plate and mixer grid is to vary the band width of the response. The frequency band of the response becomes wider with closer coupling, narrower with looser coupling. (Where there is bottom capacitive coupling, as in Fig. 8, coupling is made closer and band width greater by increased capacitive reactance, and to obtain more reactance you have to reduce the capacitance. Therefore, when bottom coupling capacitance is decreased, there is more reactance, closer coupling, and a wider frequency response. Increasing the capacitance has opposite effects.)

(Were bottom coupling to be with variable inductance instead of capacitance the rule about reactance still would hold good. To increase inductive reactance, for closer coupling and more band width, you have to increase the inductance. Decreasing the coupling inductance will narrow the band width of the response.)

Were inductors for r-f plate, mixer grid, and oscillator for each channel are on the same cylindrical form there is inductive coupling between the circuits. To change the coupling between r-f plate and mixer grid it usually is necessary to shift the r-f plate coil one way or the other with reference to the mixer grid coil.

Effects of changing an inductive coupling are illustrated by Fig. 9. At 1 we have what may be considered a normal response with normal coupling. At 2 the r-f plate coil has been moved closer to the mixer grid coil, to increase the coupling and widen the band. At 3 the r-f plate coil has been moved farther away, to decrease the coupling and narrow the band.

The response at 1 has peaks of equal height, because the r-f grid or antenna circuit has been adjusted for maximum amplitude midway between video and sound carriers, as explained earlier. At 2 we have a wider response, but also a decided tilt. There is a tilt because the r-f grid or antenna circuit has not been readjusted to suit the new band pass. Note also that the entire response has moved to lower frequencies. This is because closer coupling has increased mutual inductance, and more inductance always lowers resonant frequencies. At 3 there is not only a narrow band pass, but the response has shifted to higher frequencies.

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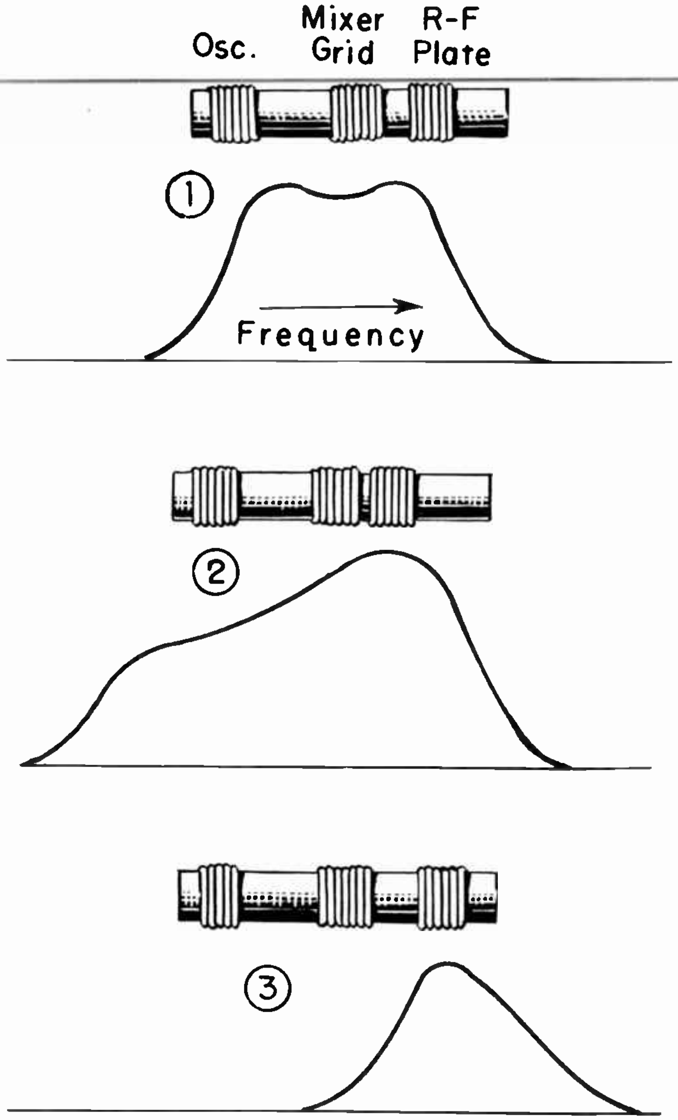

Fig. 9. Changes of inductive coupling between mixer grid and r-f plate, and how the frequency response is affected.

This shift is due to less mutual inductance with looser coupling.

Capacitive couplings tilt response curves when coupling is varied, because changes of total capacitance in the tuned circuits alter the frequencies of resonance and cause responses to shift to lower or higher ranges of frequency. To correct the tilt it is necessary to readjust the r-f grid or antenna circuit. Usually the first and most noticeable effect of varying a coupling adjustment is tilting of the response. Only after the tilt is corrected will the changed band width be evident.

If a tuner has no adjustment of either a capacitor or inductor for coupling and band width, the band covered by the response may be varied by adjustments of r-f plate and mixer grid circuits. The band is widened by adjusting these two circuits for frequencies farther apart, and is narrowed by adjusting them more nearly to the same frequency.

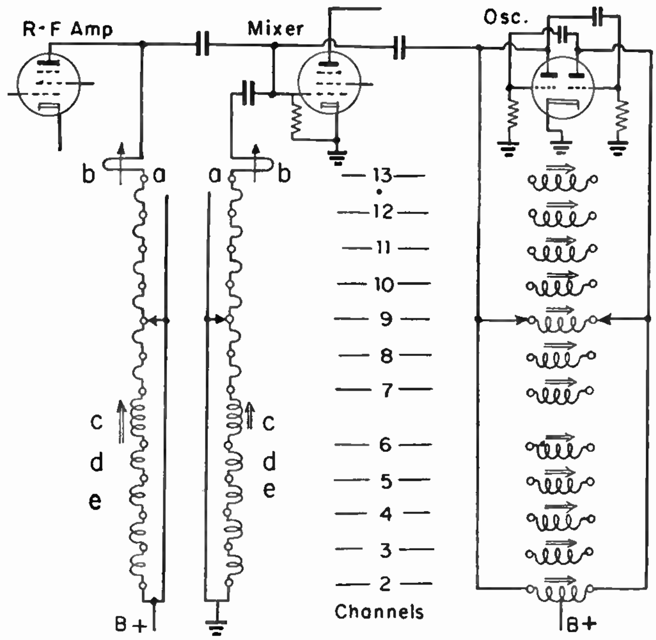

Fig. 10. Points of alignment adjustment on series inductors of an incremental tuner.

SERIES-INDUCTOR OR INCREMENTAL TUNERS. Fig. 10 illustrates in an elementary way how an r-f plate circuit and mixer grid circuit may be tuned with series or incremental inductors. With this method of tuning it is essential to commence alignment on the highest channel and work progressively to the lowest channel. When the selector is set for channel 13 the switch points are at a-a, and the only portions of the inductances not shorted out are b-b. These unshorted portions are aligned for band width and correct placing of video and sound carrier markers. It may be assumed that the small incremental loops for remaining high-band channels will make suitable increases of inductance as brought into the active circuit by moving the channel selector switch.

With the selector switch set for channel 6 it is in order to adjust inductors c-c, which affect all channels in the low band, but none in the high band. Next the response is observed on each lower channel. With the

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selector set for channel 5 the response on this channel may be corrected by adjustment of inductors c-c, which now are in the active circuits. The response on channel 4 may be corrected by adjustment of inductors e-e, and so on for remaining low band channels.

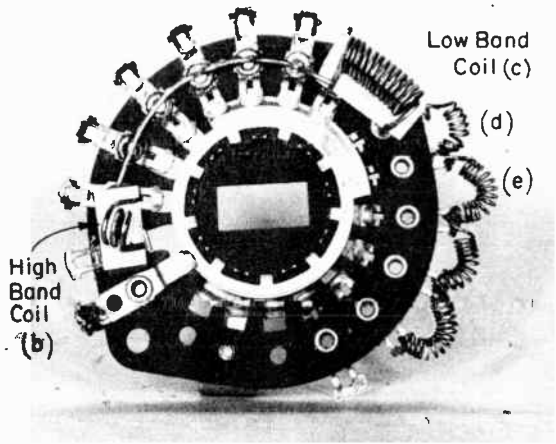

Fig. 11. All adjustable series inductors may be aligned by spreading or squeezing turns of the various coils.

Adjustment of both high-band and low-band coils may be by spreading or squeezing turns, as with the switch wafer construction of Fig. 11. The coils are lettered similarly to those of Fig. 10. With other constructions the low-band inductors, between switch points for channels 7 and 6, may have movable cores. Such adjustments may be seen at the top of Fig. 12. Turns of other low-band coils have been spread to alter their inductances.

The tuner of Fig. 10 has separate inductors for each channel on the oscillator circuit. Each inductor is provided with a movable core. Other tuners have series or incremental inductors for the oscillator circuit. Each channel section of a series oscillator inductor usually is provided with its own adjustment, often a brass screw inside a wound coil or else a brass screw near the outside of a loop or single turn. Individual oscillator inductors may be aligned in any order. Series oscillator inductors must be aligned progressively from highest to lowest channels.

Fig. 13 is a picture of an incremental tuner having only three series inductors on

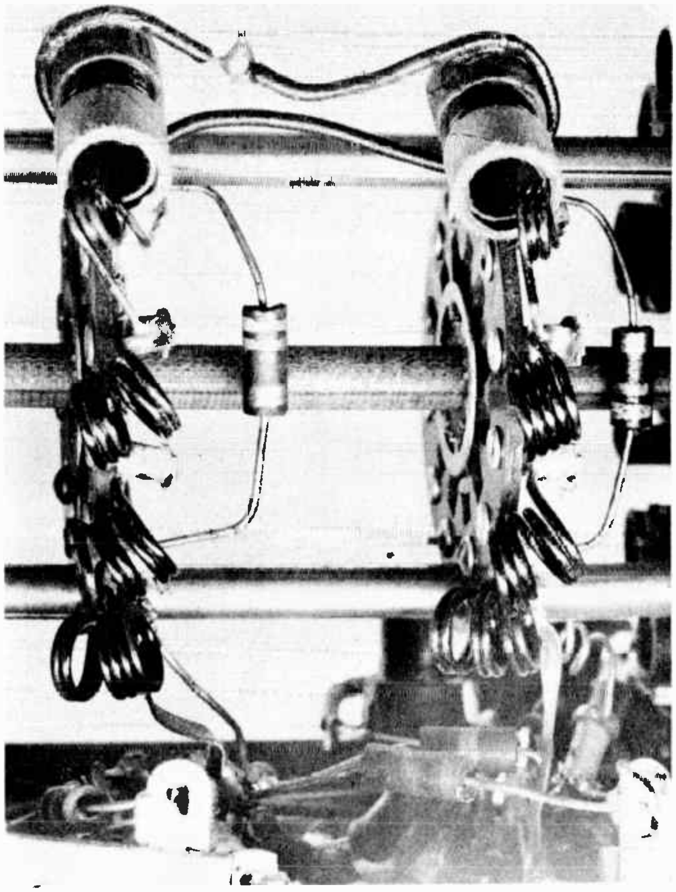

Fig. 12. Overall alignment for the low band is by means of movable-core inductors at the tops of these switch wafers.

three switch wafers. Inductor sections on the front wafer are for the r-f grid circuit, those on the middle wafer for the r-f plate circuit, and those on tne rear wafer for the oscillator circuit. All the inductor sections are adjusted by spreading or squeezing turns, or else by moving the smaller loops. In series with the r-f plate inductor string is a movable core inductor whose adjustment screw is accessible from the top of the tuner frame. Signal transfer from r-f plate to mixer grid is through a fixed capacitor, in the same manner as from any other tuned impedance coupling to a following grid. There is an alignment trimmer capacitor on the mixer grid circuit.

Alignment of r-f grid inductors on the tuner of Fig. 13 affects chiefly the video carrier side of the response, while alignment of r-f plate inductors affects chiefly the sound carrier side. Coil turns are spread or

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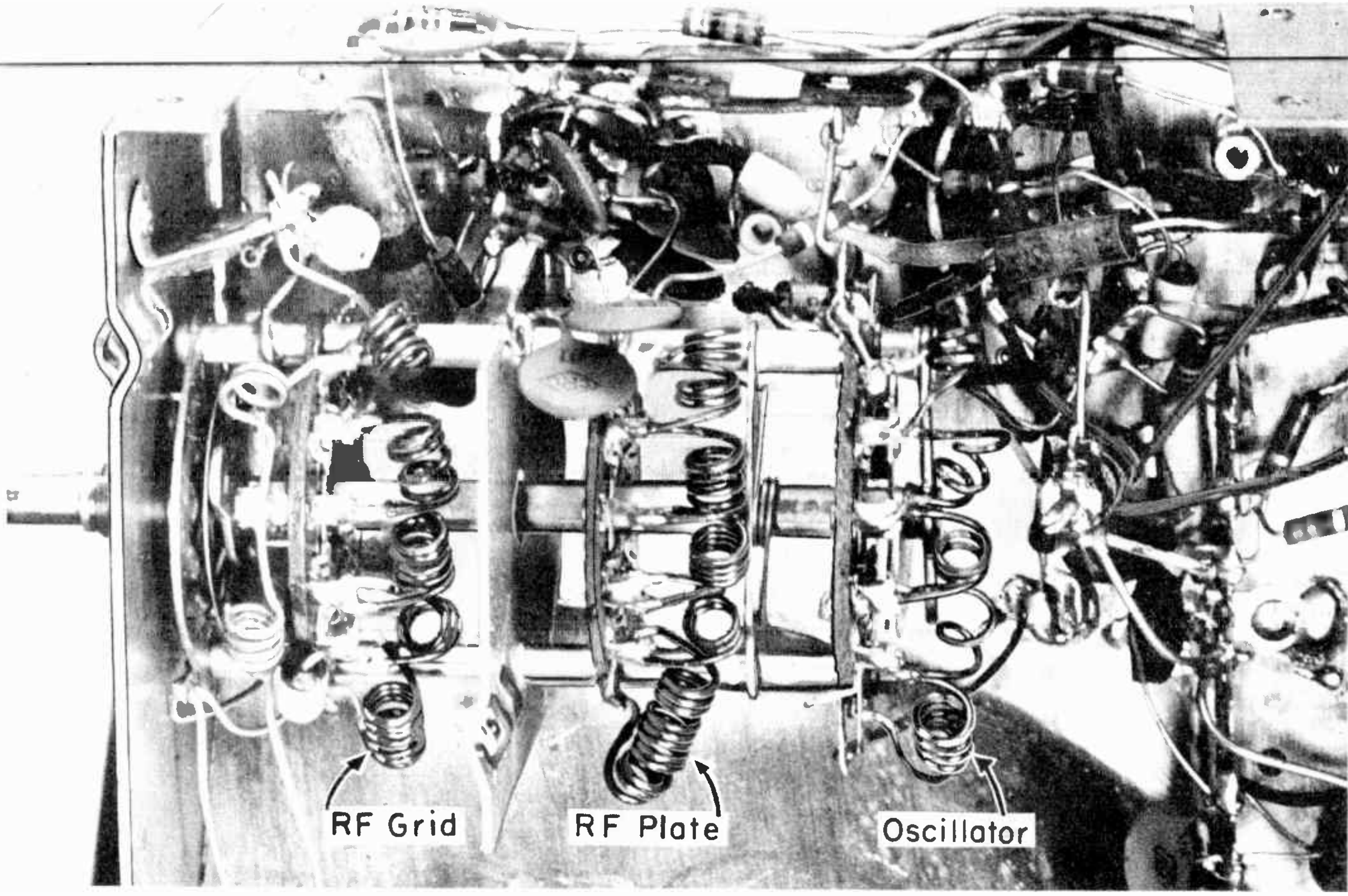

Fig. 13. An incremental tuner with series inductors for r-f grid, r-f plate, and oscillator circuits, not for the mixer grid circuit.

squeezed for low-band alignment. The mixer grid trimmer capacitor is used for positioning the carrier markers while tuned to channel 7, the bottom of the high band. The movable-core inductor in series with the r-f plate is used for positioning carrier markers while tuned to channel 13, the top of the high band.

In many of the older incremental tuners there are tapped series inductors for only the r-f plate and mixer grid, usually with separate channel coils for the oscillator. Such a design is shown by Fig. 14. R-f plate to mixer coupling is through a top capacitor. Coupling and band width are maintained of satisfactory values for the various channels by additional coupling capacitors at various points between the inductor strings.

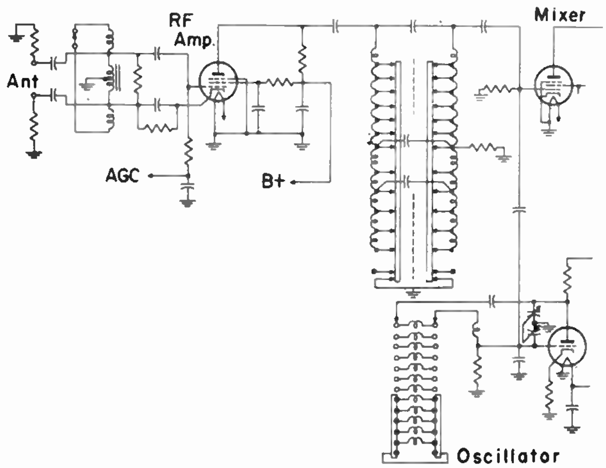

Fig. 14. This incremental tuner has series inductors for r-f plate and mixer grid, but not for the r-f grid or antenna circuit.

Fig. 15 shows circuits for a series-inductor tuner in which the r-f amplifier is a cascode type and the mixer-oscillator tube is a pentode-triode. Lettered sections of the band selector switch tune the following circuits.

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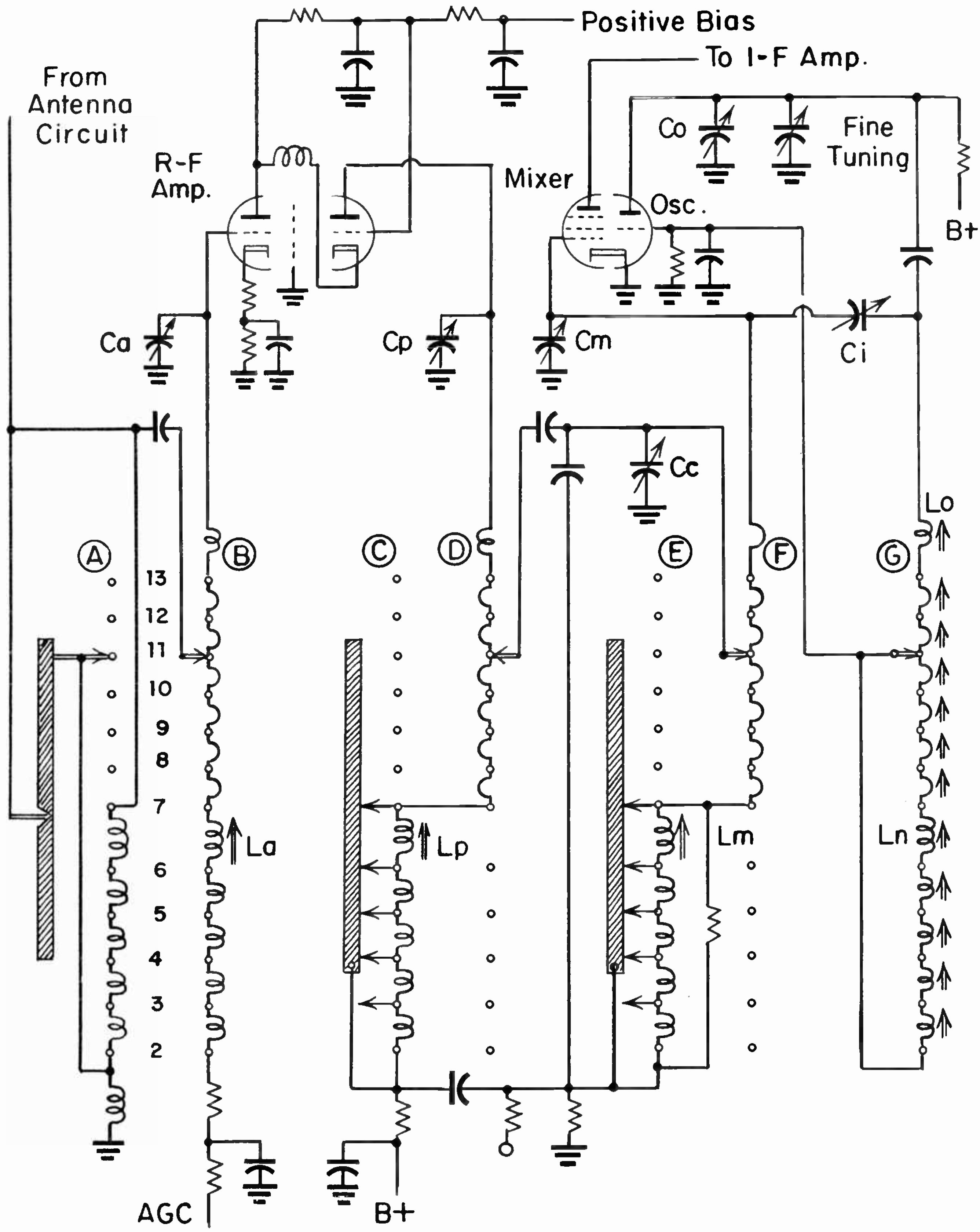

Fig. 15. An incremental tuner having trimmer capacitors and adjustable inductors for all circuits, also adjustable r-f to mixer coupling and adjustable oscillator injection.

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A. Antenna
B. R-f grid.
C. R-f plate, low band.
D. R-f plate, high band.
E. Mixer grid, low band.
F. Mixer grid, high band.
G. Oscillator.

Switch rotor tongues and segments are shown in positions for reception of channel 11. Tongues and segments move up on the diagram for higher channels, down for lower channels. Shaded rotor segments short sections of low-band inductors during high-band reception. Each shorting segment moves with the corresponding tongue contact on the opposite side of the same switch wafer. Pairs of segments on opposite sides of single wafers are A-B, C-D, and E-F.

Trimmer capacitors for r-f alignment are at Ca for the r-f grid, at Cp for the r-f plate, and at Cm for the mixer grid. At Co is a trimmer in parallel with the fine tuning capacitor. All the r-f trimmer capacitors, also oscillator inductor Lo, are used for high-band alignment. Low-band alignment is made with adjustable inductor La for the r-f grid, with Lp for the r-f plate, with Lm for the mixer grid, and with Ln for the oscillator. There are also individual oscillator inductor adjusters for each channel. Since oscillator inductor sections are in series, these adjusters must be aligned in order from highest to lowest channel after preliminary settings of inductors Ln and Lo.

At Cc is an adjustable capacitor for varying the coupling between r-f plate and mixer grid. This is a bottom coupling capacitor because it is between ground and the lower ends of whatever inductor sections are active with the switch segments in any given position.

At Ci is an adjustable capacitor for regulating injection voltage from oscillator to mixer grid. Service data for receivers having adjustable oscillator injection will specify the desired or required voltage. Since oscillator injection voltage varies the amplitude of r-f voltages at the mixer grid it will vary the mixer grid bias. Mixer grid bias may be measured with a d-c VTVM connected between ground and the mixer grid or a test point tap on the grid resistor. Bias voltage thus measured will vary on different channels, but with proper operation it usually will be somewhere between 2.0 and 5.0 negative d-c volts in tuners of modern types.

VARIABLE CAPACITANCE TUNERS. Fig. 16 shows circuits for a variable capacitance tuner which illustrates various features found in many units of this class. The variable capacitors, all ganged on a common tuning shaft, are marked A for the r-f grid or antenna circuit, P for the r-f plate circuit, M for the mixer grid circuit, and Oa and Ob for the Colpitts oscillator circuit. The two oscillator tuning units are the equivalent of a split stator capacitor with grounded rotor.

Tuning is continuous in the low band and in the high band, with band selection by switches numbered on the diagram. These switches, all operated by a common shaft, are shown in full-line positions for the low band and in broken-line positions for the high band. Switch functions are as follows:

1. Connects entire antenna transformer secondary for low band, and only part of the secondary for high-band tuning.

2. In high-band position leaves capacitor C2 in series with tuning capacitor A for reduced capacitance, while shorting resistor R2 which is in series with r-f grid inductor La. In low-band position shorts capacitor C2 and leaves R2 in series with La.

3. and 4. In high-band positions these switches connect upper inductor Lp to the r-f plate and upper inductor Lm to the mixer grid, while leaving capacitors C3 and C4 in series with tuning capacitors P and M. In low-band positions the lower inductors Lp and Lm are connected to r-f plate and mixer grid, while capacitors C3 and C4 are shorted.

5. For low-band tuning shorts series capacitor C5 which is in series with tuning capacitor Oa.

6. Shorts part of oscillator inductor Lo for high-band tuning.

7. Connects an oscillator injection capacitor Ci for high-band tuning, thus increas-

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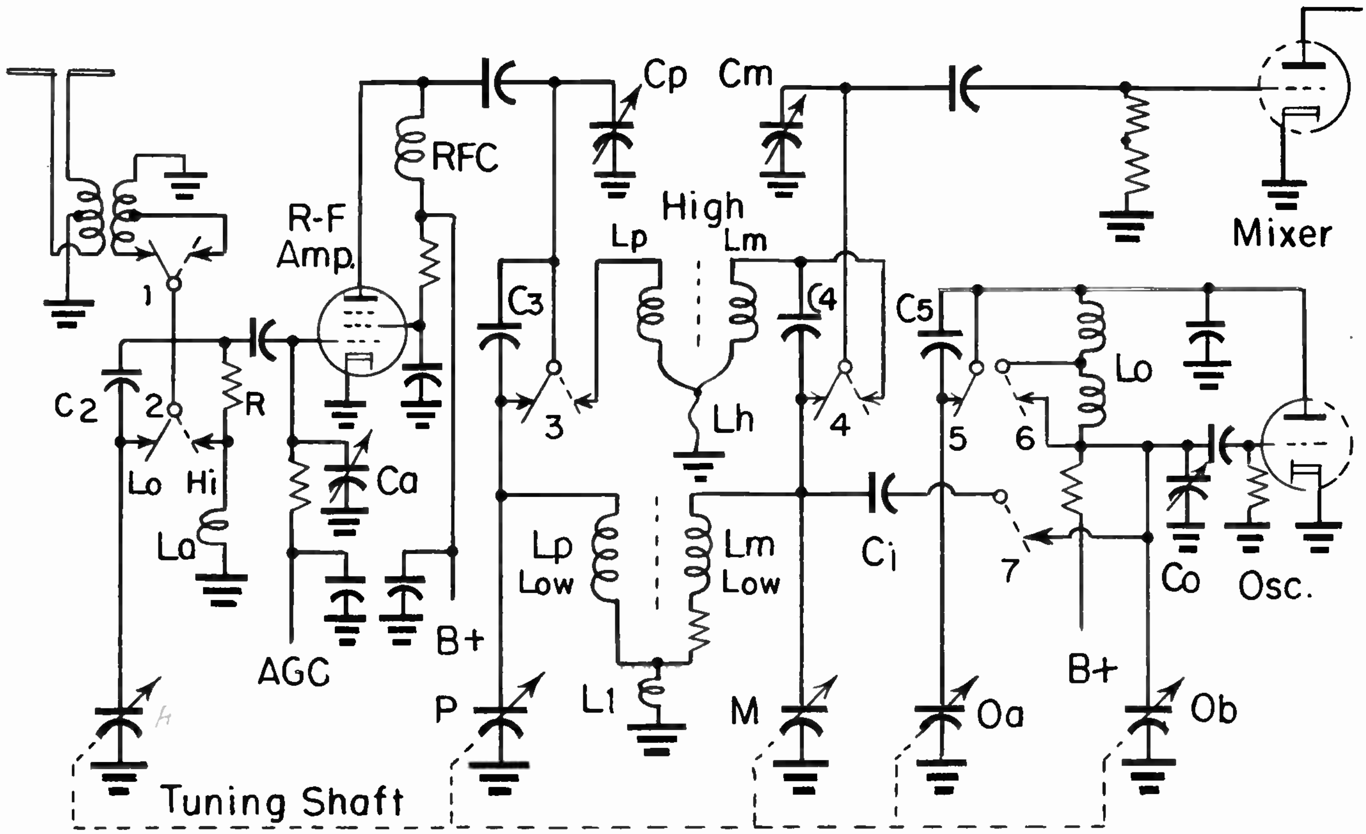

Fig. 16. Alignment adjustments on a variable capacitor tuner providing continuous tuning in each band.

ing the amplitude of high-band frequency responses.

There are alignment trimmer capacitors similar to those of other tuners; Ca for r-f grid, Cp for r-f plate, Cm for mixer grid, and Co for oscillator. Since there is continuous tuning in each band no fine tuning capacitor is needed. However, trimmer Co is in parallel with oscillator variable tuning capacitor Ob.

Interstage inductors Lp and Lm are not inductively coupled, in fact these two inductors for each band are shielded from each other. There is bottom inductive coupling at Lh for the two high-band inductors and at L1 for the two low-band inductors. Interstage coupling is made closer, and band width greater, by increasing the inductance and inductive reactance of the bottom coupling inductors. Decreasing these inductances, and their reactances, narrows the response band.

Principles of r-f alignment are the same as for other tuners having adjustably resonated circuits for r-f grid, r-f plate, and mixer grid. The r-f plate and mixer grid circuits are adjusted to place video and sound carrier markers at proper points on responses, also to move response curves bodily to lower or higher frequencies. The r-f grid or antenna circuit is adjusted to overcome any tilt of the responses, by centering the range of r-f grid voltage between the carrier markers.

In the particular tuner illustrated by Fig. 16 inductances of high-band coils Lp and Lm are altered for response on channel 7 by pushing these coils farther on or off brass studs. Pushing the coils farther onto the studs decreases inductance, farther off increases inductance. Low-band coils Lp and Lm, also r-f grid inductor La, are adjusted for channel 2 by spreading or squeezing turns. Trimmer capacitors are adjusted for responses on the highest channel in either band, to obtain the best compromise between responses on channels 6 and 13.

Plates of the variable tuning capacitors should be fully meshed for tuning to channels

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2 and 7, and completely or nearly out of mesh for channels 6 and 13. Do not bend the variable capacitor plates to obtain a desired response nor to favor any channel, since this is sure to throw other channels in one or both bands out of alignment. Use care not to accidentally bend or displace the capacitor plates.

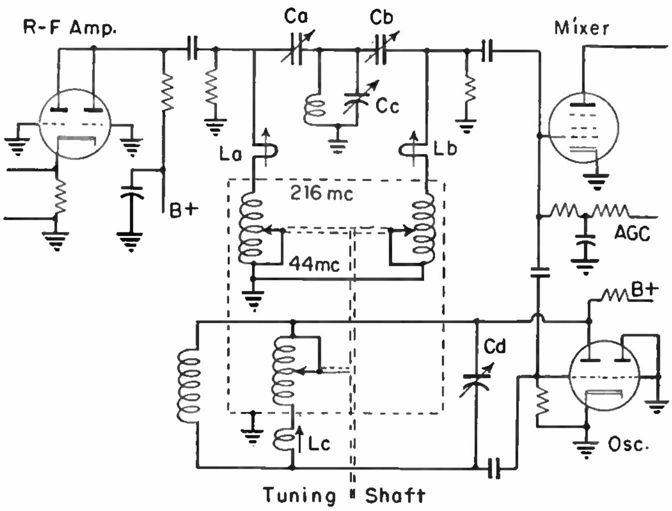

Fig. 17. Alignment adjustments for a three-circuit spiral-inductor tuner.

SPIRAL INDUCTOR TUNERS. Fig. 17 shows alignment adjustments for a tuner in which the broken-line rectangle encloses three continuously variable inductors of the spiral type, on which brushes are rotated by the channel selector shaft. Low-band alignment, for band width and placing of carrier markers, is by means of trimmer type top coupling capacitors Ca, Cb, and Cc, and for oscillator frequency by Cd.

High band alignment for band width and marker positions is by means of inductor La on the r-f plate and Lb on the mixer grid. High-band oscillator alignment is by means of inductor Lc. These "end inductors" are loops or one or more coil turns located outside the spiral inductor housing. Adjustment is by spreading or squeezing coil turns or by moving a loop closer to or farther from adjacent metal.

If the tuner is of the four-circuit type, with one element in the r-f grid or antenna circuit, the fourth element is adjusted to correct any tilt of response curves. The three-circuit spiral-inductor unit sometimes is used with one element on the r-f grid, a second on the r-f plate, and the third on the oscillator circuit, with alignment trimmer capacitors as well as the end inductors on each element. The r-f plate is coupled to the mixer grid through a fixed capacitor. End inductors are used for high-band alignment, and trimmer capacitors for low-band alignment.

TRAPS FOR TUNERS. Many receivers provide reduction of interference from short-wave a-m transmitters and from f-m broadcast transmitters by means of wave traps connected between antenna and r-f grid circuit or at other points in tuners. These traps may be built into a tuner, or may be separate units mounted on the outside of the tuner. Some traps are adjustable for frequency, usually by movable cores in trap inductors, while others are constructed with fixed inductors and fixed capacitors of suitable values, and are not adjustable.

A-m signals from amateur transmitters and other radioservices causing interference may be at frequencies close to or within the band or intermediate frequencies used in the TV receiver. Traps for attenuating such interference are called i-f traps, and must be tuned within or close to the i-f range of the receiver. Traps for attenuating f-m broadcast interference are called f-m traps.

One style of external trap is constructed as in Fig. 18. There are two high-Q inductors having movable cores, and two fixed ceramic capacitors. A few traps are made with fixed inductors and adjustable ceramic capacitors. The style of trap pictured is most often employed as a series resonant type with connections shown at 1 of Fig. 19. The two trap inductors are adjusted for resonance at the interference frequency, whereupon the trap circuits provide minimum impedance and nearly a short circuit from each antenna line to ground at this frequency.

Two parallel resonant traps may be used as in diagram 2, one trap in series with each side of the antenna transmission line. Parallel resonant traps have maximum impedance at frequencies to which the traps are tuned, therefore attenuate signals at the tuned frequencies.

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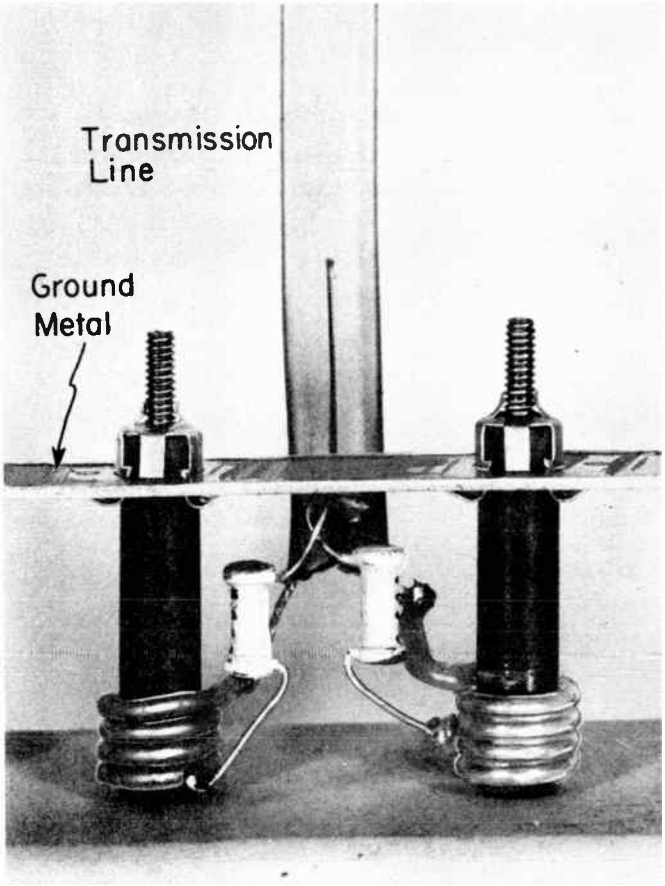

Fig. 18. A trap for connection between antenna transmission line and r-f grid circuit in a tuner.

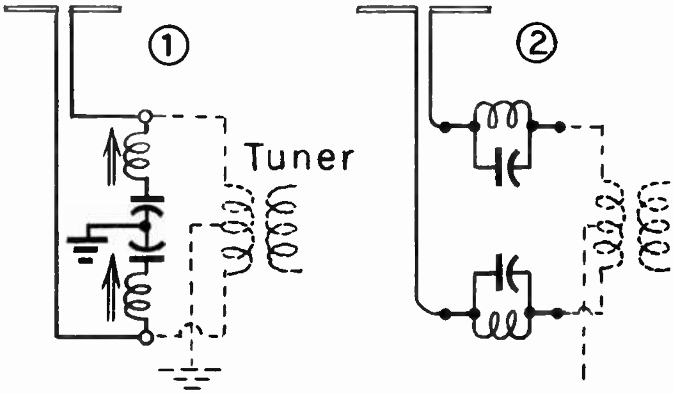

Fig. 19. Connections of series resonant and of parallel resonant antenna traps.

Two traps in the two sides of the antenna circuit may be tuned to the same interference frequency. In other cases, one trap is tuned to a frequency somewhat higher than the video intermediate (for i-f traps) and the other to a frequency somewhat lower than the sound intermediate of the receiver. Then, if the traps do not resonate too sharply, there is attenuation of all frequencies in the i-f range of the receiver. In some tuners there is only one parallel resonant trap, in series with one antenna lead or terminal.

A series resonant trap may be on the cathode of an r-f amplifier, as at 1 of Fig. 20 for a cascode amplifier. Because of its small impedance at the frequency to which tuned, such a trap provides what amounts to a short circuit to ground at the interference frequency for which the trap is tuned. In some receivers employing a grounded grid r-f amplifier, with signal input to the cathode, a series resonant trap is connected between this cathode and ground.

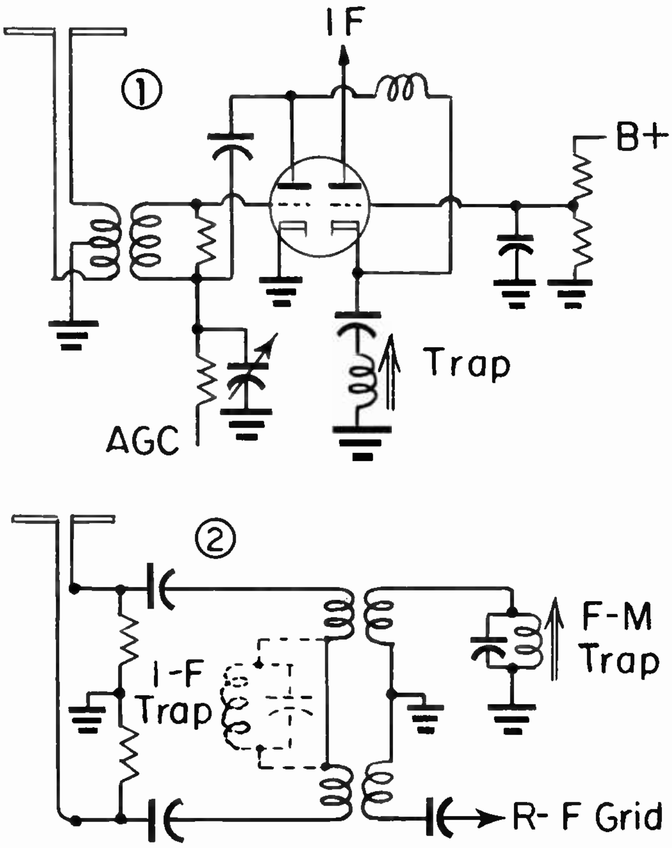

Fig. 20. I-f and f-m trap connections as found in some tuners.

Full-line connections at 2 of Fig. 20 show one method of connecting a parallel resonant f-m trap to an antenna circuit. Energy which maintains circulating currents in this trap is taken from the antenna circuit, and attenuates signal voltages at the frequency for which the trap is tuned. An additional i-f trap may be incorporated as shown by broken lines, taking the place of the full-line connection between inductors above and below the i-f trap.

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TRAP ALIGNMENT. Where traps are of rather simple designs, as in Figs. 19 and 20, it may be possible to make fairly satisfactory adjustment while receiving a transmitted program, without using instruments. The channel selector, fine tuning, and contrast controls are set to make the interference evident in pictures or sound. Then the trap is adjusted for minimum interference effect.

When interference frequencies are known or can be determined, a better job can be done with a modulated r-f signal generator and oscilloscope. If a trap is intended to reduce i-f interference, it will be tuned to the receiver video or sound intermediate or to something close to these frequencies.

As an example, a-m signals in the radio amateur band between 21.00 and 21.45 mc may interfere with sound in a TV receiver having sound intermediate of 21.25 mc or any other sound intermediate within the interference range. An i-f trap tuned in this range should greatly attenuate or completely prevent the interference. Similarly, TV sets with video intermediates such as 45.75 mc could suffer interference from police, amateur, and point-to-point a-m transmissions in the 45-mc band. Then an i-f trap or traps should be tuned in this range of frequencies.

An f-m trap would be tuned somewhere within the f-m broadcast band of 88 to 108 mc, at whatever frequency would best attenuate interfering f-m signals. Most f-m broadcast interference is with sound on channel 6, since the bottom of the f-m band, 88 mc, is also the top frequency and close to the sound carrier of channel 6.

Procedure for trap alignment with generator and oscilloscope is as follows:

1. Tune in the picture and sound program on a channel in which interference is evident. Leave the channel selector on this channel for remaining steps.

2. Adjust the contrast control, and a fine tuning control if present, to positions giving strongest picture and sound without distortion. Leave contrast and fine tuning in these positions.

3. Use an r-f signal generator operating with audio or tone modulation, and capable of tuning to the interference frequency by using fundamentals or harmonics. Connect the high-side generator lead to either antenna terminal through no more than 5 mmf, and preferably as little as 1 mmf if this allows scope traces of readable height in following steps. This small coupling capacitance is necessary especially when the generator cable goes directly or nearly directly to a trap, to avoid adding excessive cable capacitance and affecting trap resonance. Where a trap follows a tube in the tuner, the small coupling capacitance is not so important. Connect the low-side generator cable to tuner ground metal.

4. Connect the oscilloscope across the video detector load.

5. Override agc voltage with about $1\frac{1}{2}$ d-c volts. It would be desirable to remove agc completely from the tuner, by grounding the r-f amplifier grid return, but bias should not be removed from the i-f amplifier, merely overriden.

6. Tune the signal generator to the interference frequency and adjust its r-f output to a high value.

7. Adjust the internal sweep of the scope to bring a trace of signal generator tone modulation onto the screen. Adjust the vertical gain to make this trace nearly as high as the screen, or as high as possible with vertical gain at maximum. Now the scope is being used as an output voltmeter, with strength of interference at the video detector proportional to trace height.

8. Adjust the trap or traps for minimum height of trace on the scope screen. As this adjustment proceeds, increase r-f output of the signal generator, also vertical gain of the scope if not already at maximum, so that changes of trace height are clearly apparent.

SENSITIVITY OF RECEIVERS. You will find it instructive to make the following experiment. Connect a d-c VTVM across the video detector load of a receiver. Override the agc with about $1\frac{1}{2}$ d-c volts. Place the set in operation, and tune in various programs

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or channels. The stronger the received signal the greater will be the d-c voltage at the video detector load.

Sensitivity of a receiver is specified as strength of signal, in r-f microvolts, required at the antenna terminals for production of one d-c volt across the video detector load. The less the required input microvolts the greater is the receiver sensitivity. One volt across the video detector output is the usual standard output, because with this much voltage or more there should be satisfactory reproduction of pictures.

There are no generally recognized standards or requirements for receiver sensitivity, it varies between different models of receivers. Sensitivity of modern sets of good quality may be something like 25 to 50 microvolts in the low band, and usually will run around 50 to 100 microvolts in the high band. Older sets have less sensitivity, they require more r-f microvolts input to produce one volt at the video detector load.

Measurement of sensitivity requires an unmodulated r-f signal generator whose output is calibrated in microvolts. The generator need not have more than moderate accuracy so far as signal frequencies are concerned. The procedure follows:

1. Connect the r-f signal generator through a matching pad to the receiver antenna terminals.

2. Connect a d-c VTVM across the video detector load. A d-c moving coil voltmeter having sensitivity no less than 20,000 ohms per volt may be used instead of the VTVM.

3. Override the agc with about $1\frac{1}{2}$ volts. If convenient, it is preferable to remove all agc voltage from the r-f amplifier while leaving the $1\frac{1}{2}$ volt override on the i-f amplifier.

4. Set the channel selector to each channel in which sensitivity is to be measured. If the VTVM readings waver during following steps a transmitted signal, in addition to the generator signal, is entering the receiver. Measurements are most reliable on channels in which there is no local transmission.

5. Adjust contrast and fine tuning controls as for normal reception, or adjust the contrast control for the maximum that does not cause distortion of pictures.

6. Tune the signal generator to the center frequency of each channel in which sensitivity is to be measured. That is, for channel 5, extending from 76 to 82 mc, tune the signal generator to 79 mc. If the generator is tuned to the video carrier of a channel, apparent sensitivity will vary with adjustment of a fine tuning control or movement of a continuous-tuning selector.

7. Adjust the output of the signal generator to produce one d-c volt at the video detector. The number of microvolts output is a measure of receiver sensitivity on the channel for which the set then is tuned.

Sensitivity of an i-f amplifier section may be measured with the same signal generator connected through a blocking capacitor, not a matching pad, to the mixer grid or mixer grid resistor, or coupled to the mixer through an ungrounded shield or band around the tube envelope. The VTVM or d-c voltmeter is connected to the video detector load.

INCREASING THE SENSITIVITY. Some of the more common causes for lack of sensitivity are as follows:

A-c power line voltage is lower than its rated value.

The low-voltage power rectifier or rectifiers, either tube or selenium type, are weak and should be replaced. This fault lowers all plate and screen voltages.

There are weak tubes in the tuner, i-f amplifier, video detector, or video amplifier sections. Try replacing the tubes, one at a time.

I-f amplifier alignment is such as produces an excessively broad response, with too little amplitude, or the video i-f marker may be too far down on the response.

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The tuner is aligned for a response excessively broad, and of too little gain.

Agc voltage is too negative, especially on the r-f amplifier in the tuner.

Plate and screen voltages are too low on i-f amplifiers, video amplifiers, and possibly on the r-f amplifier. If voltages are raised, check resulting biases.

Video amplifier bias is too negative. This may indicate a fault in the contrast control circuit.

If a set is used in a fringe area where all received signals are weak it is possible to make certain changes in the tuner to increase the sensitivity. Although the changes to be mentioned will improve reception of weak signals, they are likely to impair the performance on signals of normal strength.

1. Operate the r-f amplifier without agc. Disconnect its grid return resistor from the agc line or bus and connect the grid return to ground or B-minus at which the r-f cathode is connected. In a manufacturer's tube manual check the characteristics of the r-f amplifier tube, then measure actual plate or plate and screen voltages to make sure that they do not exceed the maximums for operation with zero grid bias.

2. If the r-f amplifier is a pentode, increase its screen voltage, and also the plate voltage when plate and screen are on the same supply line. Plate and screen voltages may be increased by connecting the B-plus line of the tuner to a higher voltage somewhere in the B-supply circuits. The voltages may be increased also by using less dropping or decoupling resistance, but this requires care that decoupling is not so reduced as to allow feedbacks. Measure the changed plate and screen voltages, also the negative grid voltage or agc voltage with reference to the tube cathode, and make sure that the higher voltages are within maximum limits for the tube used.

3. For an r-f amplifier pentode substitute a type having greater transconductance. It will be necessary to check differences between base pin connections, and how the tuner circuits are connected to socket lugs. A 6AG5 might be replaced by a 6BC5 with no changes of socket connections or element voltages, but a 6CB6 has different element connections to pins 2 and 7, and might require changes of socket wiring.

4. Align the tuner to provide a frequency response of greater amplitude and somewhat narrower pass band. This may be done by readjustment in r-f plate and mixer grid circuits, by an interstage coupling adjustment, or both ways.

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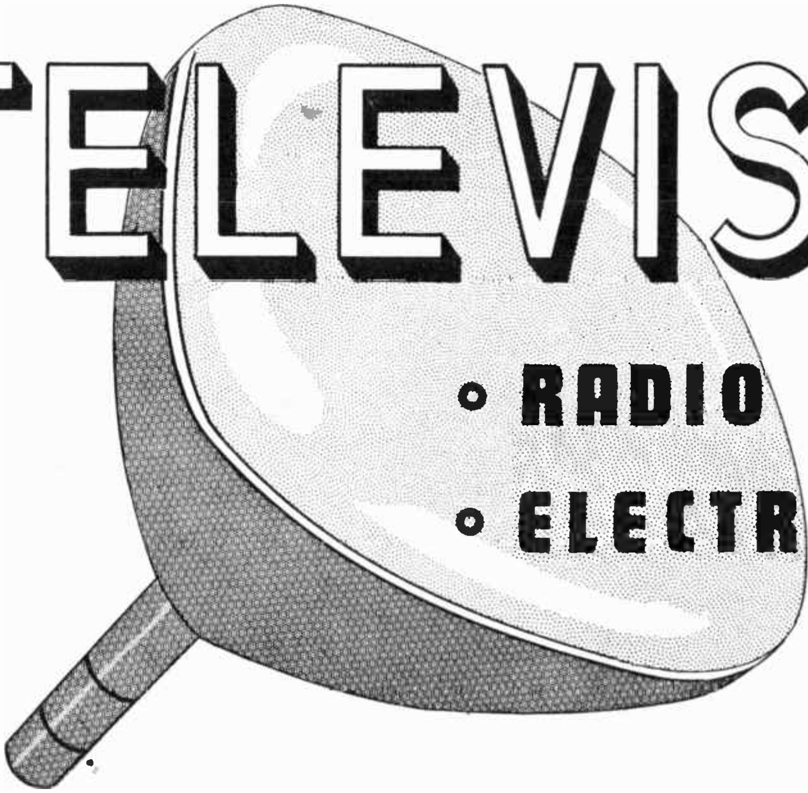

TELEVISION

• RADIO

• ELECTRONICS

LESSON 83—PICTURE AND PATTERN ANALYSIS—PART 1

Coyne School

practical home training

Chicago, Illinois

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Lesson 83

PICTURE AND PATTERN ANALYSIS—PART 1

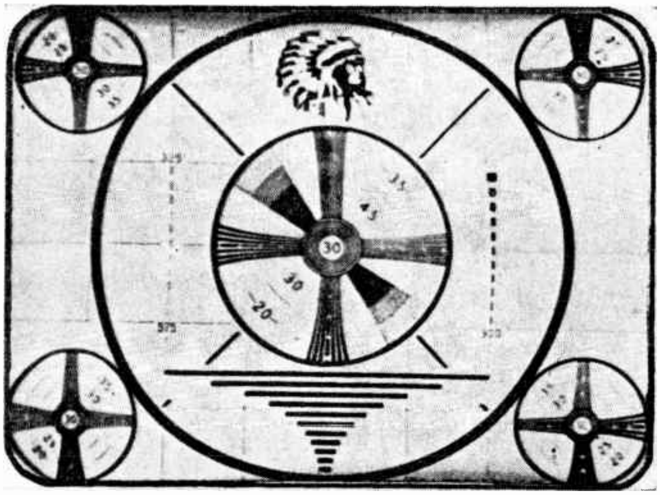

Fig. 1-A

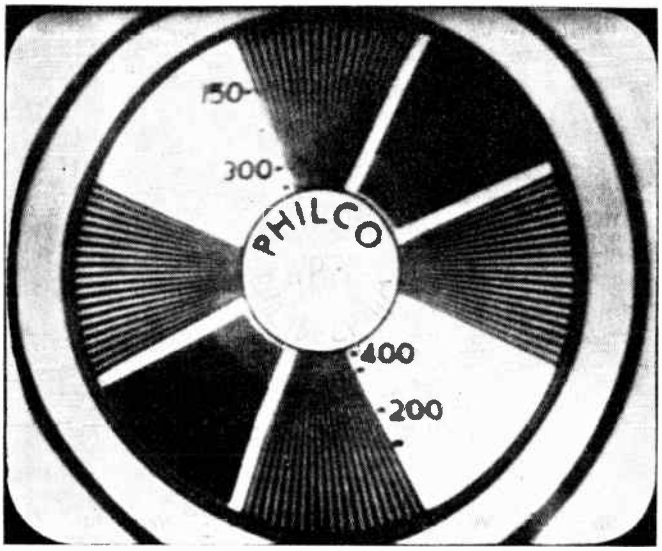

Fig. 1-B

Fig. 1. Transmitted test patterns have lines, circles, and shadings which make picture faults easily recognizable.

When talking about troubles which may exist in circuits and parts of receivers we often have looked at the results as they appear in pictures and patterns on the screen. Then we know all about the trouble to begin with, and observed the symptoms. In actual practice you won't always know what troubles are present, and will see only their symptoms on the picture tube. In this and following lessons we shall look at faulty pictures, patterns, and other effects that show up on picture tubes, and learn what troubles to look for in each case.

It is easiest to identify trouble symptoms appearing on a picture tube when you are able to tune in a transmitted test pattern, such as that of Fig. 1 or something generally similar. Most of our photographs in these trouble shooting lessons are of test patterns, because patterns most clearly illustrate the faults. Nowadays these patterns are transmitted only during a few periods when there are no regular programs. However, you can easily identify the same faults on program pictures, especially during "commercials" which usually show wording and many stationary objects.

When some causes for a certain defect on the screen are more common that others, or easier to look for, these troubles are listed first. Often there will be two or more faults at the same time. Try first to correct the worst fault; the others then are likely to disappear. Another way is to read the lists of causes for each existing fault. If some causes appear in two or more lists, those causes are likely to be present and you should work on them first.

Not all of the listed troubles can exist in all kinds of receivers. If you know that parts or circuits mentioned are not used, ignore these portions of the lists.

It is assumed that you have made ordinary service adjustments before looking for trouble. As one example, when pictures are out of sync horizontally, the lists won't tell you to adjust the horizontal hold control - you know that this should be done. Troubles listed are only those which remain after ordinary service and operating adjustments have been made.

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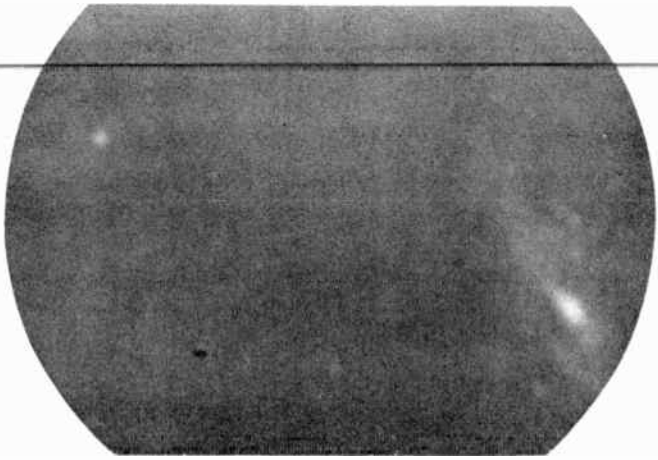

Fig. 2. No pictures and no raster, a dark screen.

SCREEN DARK. NO SOUND. NO PICTURE OR RASTER. Fig. 2.

Since all sections of the receiver are affected, the trouble must be something that affects all sections. Troubles that affect all sections include (a) no heater voltage (b) B-voltage zero or very low.

No Heater Voltage.

When glass tubes remain dark and metal tubes cold look for the following:

Poor contacts at wall plug on power cord or at safety interlock on chassis.

Power cord defective under insulation.

Blown fuse in primary circuit of power transformer.

Defective on-off switch in receiver.

Poor connections in leads from power transformer heater windings.

Power transformer defective.

Series heaters. An open heater in one tube puts out all tubes on the same string. TV receivers usually have more than one heater string, so all tubes may not go out at the same time.

B-voltage Zero Or Very Low

Use d-c voltmeter, on high range, to check voltages at plate and screen socket contacts at several places in the set.

Power rectifier defective. Try replacing a tube rectifier. Make voltmeter tests before replacing a selenium rectifier.

When speaker field is power filter choke, check all connections to field coil, including any plug connector.

If focus coil carries B-current, check all connections in the coil circuit.

Voltage Tests for B-voltage.

Measure d-c voltages along path of B-current from power rectifier cathode through filter and from filter output to plate and screen circuits.

Voltage abnormally high. Indicates open circuit or excessively high resistance. Voltage will be zero or low when point of trouble has been passed.

Voltage abnormally low, but not zero. Indicates heavy overload due to short or ground. Look for resistors overheated by current through a shorted capacitor, then locate and replace the capacitor. May be necessary to temporarily disconnect B-voltage lines, working away from the d-c power supply, until opening a line allows B-voltage to rise at the power supply. The short or ground is beyond the point then opened.

SCREEN DARK. SOUND O.K. NO PICTURES OR RASTER

Since there is no raster, the trouble must affect (a) sweep and deflection circuits from oscillators to yoke on picture tube (b) high voltage or other voltages on the picture tube (c) or the picture tube is defective.

Control Settings.

Combination TV-Phono-Radio switch not at TV position.

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Brightness control turned too low.

Picture Tube Heater Not Lighted.

Socket not secure on picture tube base. If heater lights only while holding or moving the socket, examine socket contacts and lead connections. If socket OK, try resoldering the tips of heater pins on picture tube base.

Remove socket from picture tube. Check for open heater by using ohmmeter on heater pins of tube.

If both heater and socket OK, use a-c voltmeter to check heater voltage at socket contacts.

Picture Tube Heater Lighted.

Lead for high-voltage anode loose at tube connector.

Ion trap magnet misadjusted, turned front for back, upside down.

Tube removed and not replaced after servicing. Horizontal oscillator, output amplifier, or damper.

B-voltage low or absent. Measure on lines supplying horizontal oscillator, output amplifier, or sweep and deflection circuits.

Brightness control circuit. Observe d-c voltage between picture tube grid and cathode as brightness control operated. Should vary, and drop to 50 volts or less at maximum brightness setting. Otherwise check entire control circuit.

First anode or second grid of picture tube, pin 10. Voltage low or zero.

Picture Tube Second Anode Voltage Low Or Zero.

Check the following tubes for weakness, wrong voltages at socket terminals, and poor connections at sockets: Horizontal oscillator. Horizontal output amplifier. High-voltage rectifier. Damper.

Fuse blown in line to horizontal output transformer. Determine the cause. Defective horizontal output amplifier. Shorts or grounds on any leads connected to horizontal output transformer. Defective transformer.

High-voltage filter capacitor leaky, shorted.

High-voltage filter resistor open, disconnected.

Defective width control inductor or transformer. Temporarily disconnect one end of this inductor.

Damper low-side circuit. Capacitor shorted, leaky. Leads grounded.

Deflecting yoke. Leads grounded or shorted. Internal shorts, opens. Not a good impedance match for output transformer.

Horizontal output transformer. Windings open, shorted, grounded.

Sawtooth signal weak or absent at grid of horizontal output amplifier. Observe with oscilloscope. Check horizontal oscillator and all parts between oscillator and grid of amplifier, including drive control and its adjustment.

R-f type high-voltage power supply. Tubes weak. Voltage adjustment incorrect. Low B-voltage to oscillator. Capacitors leaky, shorted.

Picture tube defects.

Emission may be failing; try increasing heater voltage with a voltage booster. Cathode open; if operation is intermittent try resoldering at tip of base pin for cathode, pin 11. Internal shorts between elements.

RASTER ONLY. NO PICTURE. NO SOUND. Fig. 3

Because there is a raster, the trouble cannot be affecting sweep oscillator or deflection systems. Since the trouble affects both pictures and sound, it must be in sections carrying signals for both pictures and sound. These sections extend from the tuner to the sound takeoff.

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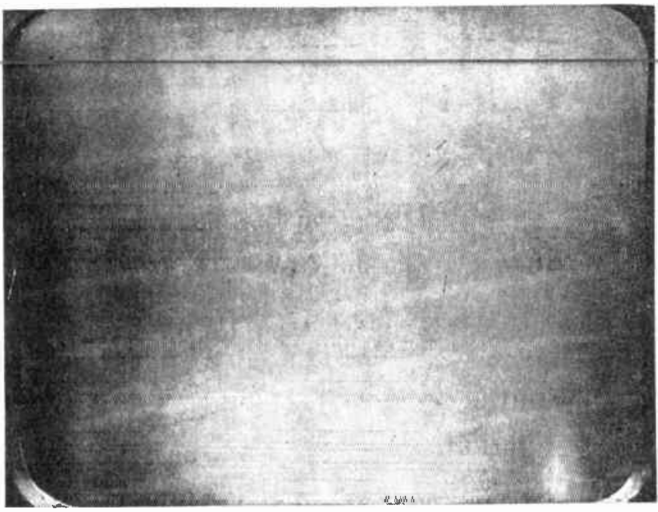

Fig. 3. A raster, but no pictures.

Tuner Trouble.

Any tubes weak. Cathode-heater leakage in r-f oscillator.

Oscillator badly misaligned.

Transmission line or antenna disconnected, shorted, grounded.

Band switch or channel selector switch contacts dirty, loose, bent, broken.

Other Troubles.

I-f amplifier, video detector, video amplifier, from tuner to sound takeoff. Weak tubes. Extreme misalignment. Faults in any circuit elements or connections.

Most effective check method is with detector probe on a sensitive oscilloscope, following the video signal waveform from the tuner to the point at which it becomes weak or disappears. A fairly good check may be made by examining frequency responses from tuner to sound takeoff, noting where the response becomes weak, or badly off frequency.

RASTER ONLY. NO PICTURE. SOUND O.K.

Because there is sound reproduction it is probable, but not certain, that trouble is not in sections carrying sound signals. These sections extend from the antenna to sound takeoff, and through the sound and audio sections. This leaves for first examination the parts from the video detector or sound takeoff through the video amplifier to the picture tube grid cathode circuit. Do not forget to check d-c restorer circuits, also the contrast control.

Tubes weak, or tube element voltages incorrect.

Capacitors open, leaky, shorted. Especially the coupling capacitors.

Resistors open, poor contacts. Especially the plate load resistors.

Peaker inductors open.

The agc system may be maintaining i-f amplifier grid voltages too negative. Check agc rectifiers, amplifiers, and their circuit elements.

Raster only a faint, distributed glow. Check ion trap magnet adjustment.

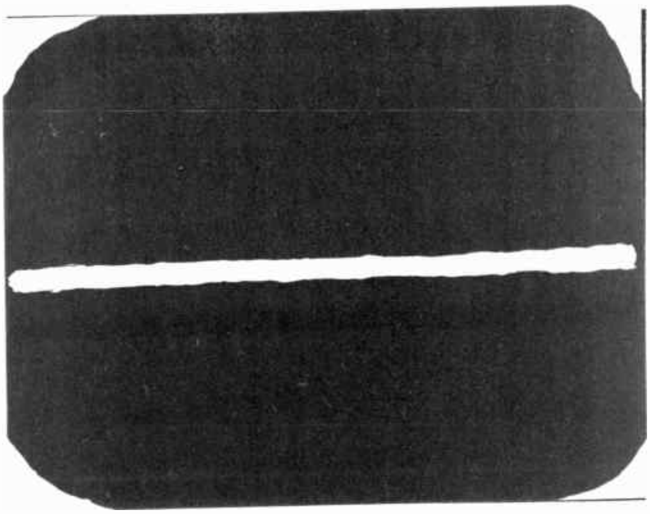

Fig. 4. A single line may be horizontal, like this one, or may be vertical.

LINE ONLY. NO RASTER. NO PICTURE.

Horizontal Line. Fig. 4 .

The vertical oscillator or sweep sections

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are in trouble, while the horizontal oscillator and sweep sections are operating. Reduce brightness to leave the line only barely visible during tests. Check vertical oscillator and sweep sections.

Tubes weak, or tube element voltages incorrect.

Coupling capacitors, and possibly other capacitors, open, leaky, shorted.

Resistors open, poor connections.

Feedback transformer on blocking oscillator. Poor connections, defective.

Vertical output transformer. Poor connections, grounded, internally open or shorted.

Vertical deflecting coils in yoke. Poor connections at leads, in plug connector. Coils open, shorted, grounded.

Horizontal line wavy, not straight, indicates internal trouble in vertical coils.

Vertical Line.

A line similar to that of Fig. 4, but vertical instead of horizontal. The horizontal sweep section is in trouble, while the vertical oscillator and sweep sections are operating. Because there is an electron beam in the picture tube, there is no trouble in the high-voltage power supply circuits or parts on a flyback output transformer. Turn off power, or reduce brightness to leave only faint line.

With flyback high-voltage power supply system.

Check horizontal deflecting coils in yoke, and their connections. Poor contacts or joints in leads or plug connector. Coils open, shorted, grounded.

With r-f high-voltage power supply system.

There is no trouble in the power supply itself, but trouble may be anywhere in the horizontal oscillator, sweep, or deflection circuits or parts, including the damper. Check for weak tubes, poor connections, wrong voltages, defects in feedback or output transformers, capacitors open, leaky, or shorted, resistors open.

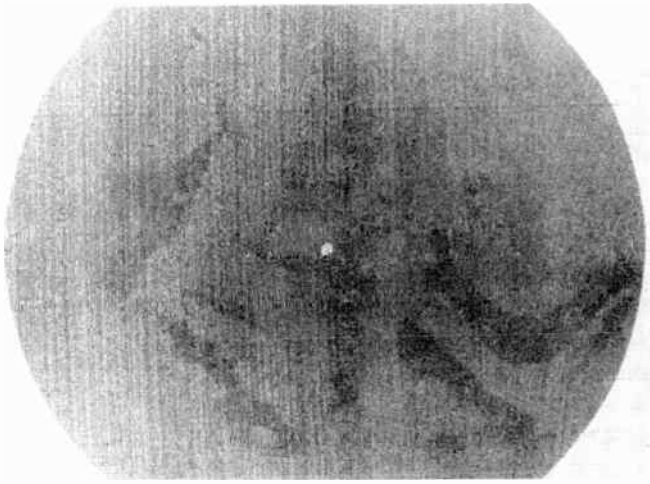

Fig. 5. A brilliant spot indicates no deflection of the beam.

SPOT ONLY. NO RASTER.
NO PICTURE. Fig. 5.

A bright spot can damage the picture tube screen in a few moments. If brightness control reduction does not make spot very faint, remove socket from picture tube or turn off power while looking for trouble.

Indicates that neither the vertical nor horizontal sweeps are operating, but that there is high voltage to the picture tube anode. With most flyback high-voltage power systems, failure in the horizontal sweep section would prevent production of high voltage and a spot. Then trouble could be only something affecting both pairs of yoke coils at same time, such as poor connections in a plug connector.

With r-f high-voltage power supply a spot results from trouble which affects both vertical and horizontal oscillator, sweep, or deflecting sections at same time. The fault probably would be in a B-voltage supply for both sections.

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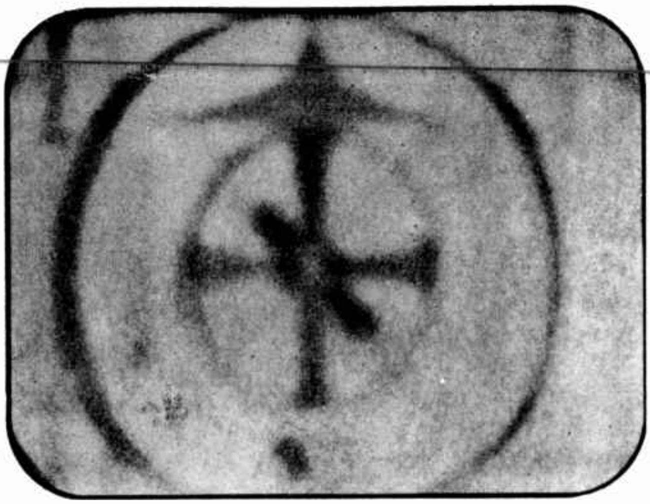

Fig. 6. Focus poor, horizontal trace lines not separated.

FOCUS POOR. Fig. 6

Apparent poor focusing may result from other troubles. Examine a raster. If horizontal trace lines are distinct, or can be made so by adjustment of a focus control, pictures which appear poorly focused are made so by other troubles. Then refer to: Definition poor. Smears. Multiple images. Ghosts. If focus cannot be made good on a raster, work through the following trouble lists.

Focus Coil Or PM Focuser.

Too far back toward base of picture tube.

Not centered around tube neck, not concentric.

Reversed, turned front for back, or leads reversed to a focus coil.

PM focuser has weak magnets.

Wrong type for picture tube, or for anode voltage used on picture tube.

Ion Trap Magnet

Misadjusted, too far forward or back, top where bottom should be.

Wrong type for picture tube.

Long continued misadjustment may have so damaged the electron gun that good focus impossible thereafter.

Voltages, Currents, Connections.

Coil connections or leads loose, bad joints, plug connector loose or defective.

Coil current has excessive ripple. Check power supply filtering

Coil current too small, too great, not enough range of control. Focus not fairly uniform from left to right, but improves with control all the way in one direction. Check all resistors and all d-c voltages in lines connected to focus control.

A-c power line voltage low or fluctuating.

B-voltage too low. Check lines from power supply to focus coil and control.

Focus coil internally shorted, grounded, or open.

Electrostatic focus picture tube. B-voltage low or zero on focusing anode; check leads to this anode, and focusing control if one is used.

Picture Tube An Associated Parts.

Voltage too low at second anode or ultor. Check for faults listed in this lesson under main heading "Screen Dark, Sound OK, No Pictures Or Raster", sub-heading "Picture Tube Second Anode Voltage Low or Zero".

Yoke too far back from flare of picture tube.

Voltage low at picture tube second grid or first anode, pin 10.

Cathode-heater leakage in picture tube.

Speaker field coil or other source of varying magnetic field near picture tube.

Parts magnetized. Any brackets or supports for picture tube and its accessories.

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Metal housing of focus coil. Metal cone of picture tube. Magnetization may be located by moving a small pocket compass around near suspected parts. The parts may be demagnetized in shops having suitable equipment.

Picture tube gassy. This may have resulted from long continued misadjustment of ion trap magnet.

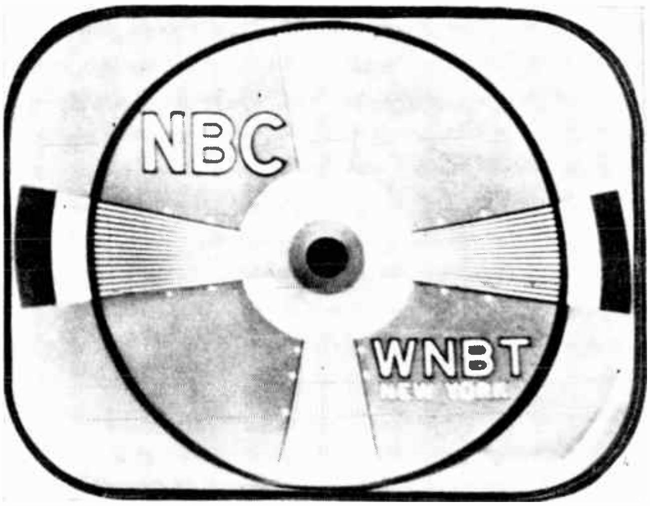

Fig. 7. Poor definition or resolution.

DEFINITION POOR. Fig. 7.

Poor definition means that narrow, sharp vertical and sloping lines are slightly blurred and not distinct. Lines of vertical wedges in test patterns are indistinct and run together before reaching the center, or reasonably close to the center. This fault usually results from lack of sufficient gain at the higher video frequencies. On a frequency response curve the amplitude will be too low toward the sound i-f marker, or the frequency band will be too narrow.

Apparent lack of definition may be due to troubles treated under any of the following lists: Focus Poor. Smears. Multiple Images. Ghosts.

Received picture signals sometimes lack sharp definition. This is likely to be true with motion picture reproductions and with some network programs coming over wire lines. Make observations on test patterns or live programs from local stations.

Excessively strong received signals, or the contrast control set too high, may cause poor definition.

Circuits From Video Detector To Picture Tube Signal Input.

Tubes weak, or tube element voltages wrong.

Poor connections at terminals or soldered joints in these circuits.

D-c restorer system. Tube weak. Circuit resistors open, shorted. Capacitors leaky, shorted.

Peaking inductors open circuited. If connecting a shorting wire across a peaker makes no difference in definition, the peaker may be shorted. If pictures improve, even though still of poor quality, the peaker may be open.

Coupling capacitors leaky. Will affect grid biases.

Decoupling capacitors open, leaky, shorted.

Video detector load resistor too great.

I-f Amplifier And Tuner Sections.

Fine tuning or continuous tuning misadjusted.

R-f oscillator misaligned, overall or on channels showing poor definition.

I-f amplifier alignment wrong, bandwidth too narrow.

R-f alignment wrong, causes i-f response to be too narrow.

Tubes weak, or tube element voltages wrong.

Coupling capacitors leaky, or possibly open.

Transmission line impedance does not match receiver or antenna. An unlikely cause for trouble.

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Fig. 8. Snow means too much noise in proportion to signal.

SNOW. Fig. 8.

Snow in pictures results from noise voltages which are high in relation to video signal voltages. Causes may be (a) weak signals, as in a fringe area (b) excessive pickup of external noise (c) excessive internal noise (d) lack of gain.

Weak Signals.

Antenna nor oriented or rotated to best position, or not high enough.

Antenna of type having too little gain for locality in which used.

Antenna or transmission line connections open, loose, corroded, shorted.

Noise.

Causes and remedies for excessive noise are explained in the lesson on "Noise In Television Receivers".

Make this test. Disconnect the antenna or transmission line from receiver or tuner, and short together the antenna terminals. Measure d-c voltage across the video detector load resistor while the receiver is tuned to an inactive channel. Should the meter read more than about 0.5 to 0.6 volt, there is probably excessive internal noise. Lower voltage usually indicates that snow in pictures is due to weak signals, external noise pickup, or lack of gain.

Gain Lacking.

Line voltage low, or B-voltage low from d-c power supply.

Weak tubes or tubes operating with low voltage on plates and screens. Check, in order, video detector, r-f oscillator, r-f amplifier, i-f amplifiers, video amplifiers, mixer.

I-f amplifier alignment. Video i-f marker too low on response. Response has insufficient height or amplitude, or is too broad to allow satisfactory gain.

Tuner alignment causing the same effects on i-f response.

Agc voltage remaining too negative on weak signals, especially at the r-f amplifier of the tuner.

Video amplifier tube biases too negative. Usually a fault of the contrast control or control circuits.

Video amplifier plate load resistor too small.

Video detector load resistor too small.

Band broadening resistors across tuned inductors too small, shorted. Examine resistors wherever used across inductors in tuner circuits, also in the i-f amplifier section.

STREAKS, SPECKLES. Fig. 9.

Short, dark streaks appearing irregularly on the picture, and of generally horizontal shape, are due to severe noise voltages picked up from external sources or produced within the receiver.

Causes and remedies for external and internal noise are explained in the lesson on "Noise In Television Pictures". Among the more common causes for internally caused streaking are:

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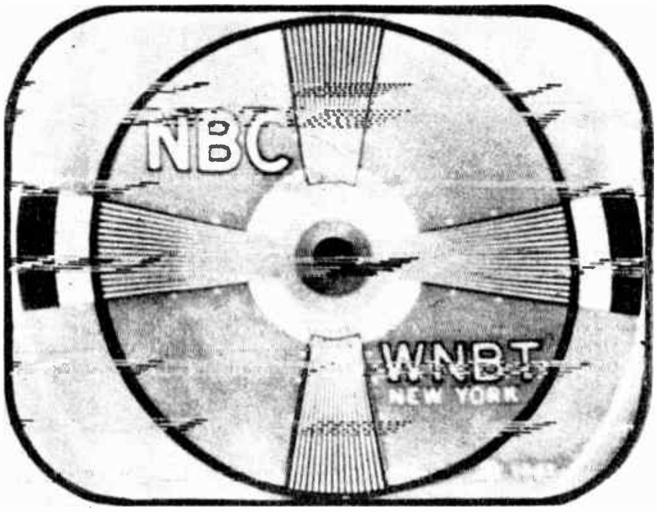

Fig. 9. Horizontal streaks and speckles indicate noise.

Fig. 11. Bad smearing, with long trailers.

Corona or arcing anywhere in the high-voltage power supply system.

Amplifier tubes, in any section, having slight internal shorts which occur with vibration.

Poor connections in the lead to the picture tube second grid or first anode, pin 10.

SMEARS OR TRAILERS. Figs. 10 and 11.

Fig. 10 illustrates smearing of the kind usually found when this fault is present. Fig. 11 shows an extremely bad case of smearing.

Fig. 10. Moderate smearing.

Smears consist of bright areas immediately at the right of dark masses or broad lines, or of dark areas immediately at the right of light masses and lines in pictures. Dark smears which follow dark objects sometimes extend to the right all the way through or far into objects of opposite tone in pictures. That is, a dark smear may extend into or through light objects. Sometimes a bright smear extends into or through darker areas in pictures. Slight smearing, not enough to cause serious loss of picture quality, is present in many receivers. In fact, slight smearing may seem to improve picture definition and contrast by accentuating the separations between lines and objects of different shadings.

Smearing usually is due to excessive gain or response at low video frequencies, or to phase shift, with which low and high frequencies do not pass through the video amplifier during equal times. Smearing most often is due to troubles in the video amplifier section, or in the video detector circuits.

Smearing is easily confused with the effect called multiple images or with the effect called ghosts. Smears immediately follow strong bright or dark masses or lines, and most often show only a single change of shading, bright to dark or dark to bright. Multiple images have several closely spaced changes between light and dark, and these changes commence immediately at the right of pic-

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ture lines. Ghosts most often are distinctly separated from picture elements, and repeat the original picture elements. That is, dark picture lines will be repeated in ghost lines almost as dark, while bright picture lines will be repeated by fairly bright ghost lines. Common causes for smearing are as follows:

Controls.

Contrast control turned too high, overloads the video amplifier.

Try other stations or channels. There may be smearing on some motion picture reproductions or on pictures carried by wire lines, and no smearing on live programs.

Video Amplifier.

Tube weak, allows overloading.

Plate or screen voltages too low.

Plate or screen voltages too high for the grid bias voltage.

Grid bias not sufficiently negative.

Cathode bias bypass capacitor open, disconnected.

Coupling capacitor leaky.

Plate load resistance too great.

Decoupling capacitor or resistor of wrong value when these elements are depended on for low-frequency compensation.

Video Detector.

Tube or crystal weak.

Load resistance too great.

MULTIPLE IMAGES. Fig. 12

Multiple images are caused by oscillations at high video frequencies in the video amplifier or video detector sections. The oscillations are started by sudden or sharp changes of picture tones, dark to bright, or vice versa. Energy losses in the affected circuits cause each oscillating cycle to be weaker than the one preceding; consequently the effects become rapidly weaker and die away on the right-hand side of the picture line or mass at which they start.

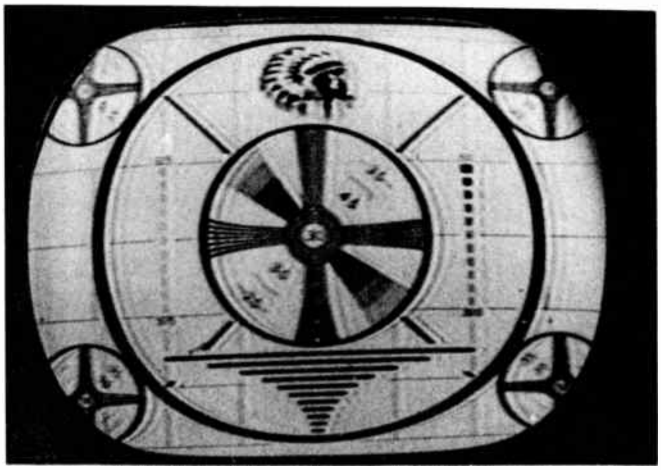

Fig. 12. Multiple images due to oscillation in the receiver.

Multiple images in pictures consist of a number of closely spaced alternate light and dark lines immediately at the right of sharp changes in shading, and becoming less and less distinct toward the right. Spacings are equal between successive lines of the multiple image. Multiple images are most noticeable when the contrast control is turned high for reception of any channel, therefore tend to be most noticeable when receiving weak signals which require a high setting of this control.

The stronger the response of the video amplifier and detector systems at high video frequencies the greater is the likelihood of multiple images, since this effect results from high-frequency oscillations. If high-frequency response is poor, multiple images seldom appear.

Multiple images may be confused with smears or with ghosts. Refer to explanations under these other headings if you are in doubt.

Video Amplifier And Detector Sections.

Peaker shunt resistances too great, or shunt resistors open. Look first for this kind of trouble in peakers that are in series between detector and amplifier grid, in series between amplifier plates and grids, and in series between amplifier and picture tube.

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Peakers in series with load resistors seldom cause trouble, because they are damped by the load resistances.

Peaker inductance too great, allowing resonant peaks within the pass band of the video amplifier system.

Leads wrongly dressed in video amplifier, detector, and picture tube input, to allow feedbacks causing resonant peaks. Check all plate and grid leads.

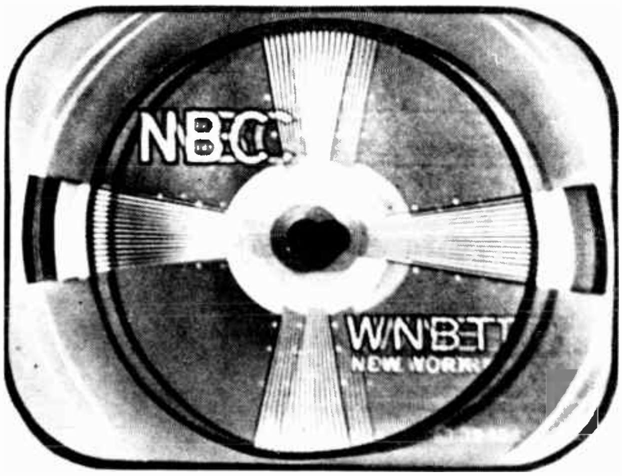

Fig. 13. Ghosts due to reflection of transmitted signals.

GHOSTS. Fig. 13.

Ghosts are caused by the same transmitted signal reaching the receiver at two different instants of time, one a small fraction of a second before the other. What is called the direct signal comes in a direct line through space from transmitter to receiver antenna. The other received signal passes from the transmitter first to some object from which it reflected, much as light is reflected from a mirror surface. The reflected signal goes to the receiver antenna, and because it has traveled a longer distance, the reflected signal arrives an instant later than the direct signal. The reflected signal usually is weaker than the direct signal.

A ghost image in pictures is a fairly complete duplicate of vertical and sloping lines of the principal image or picture. Usually the ghost image is distinctly separate from the direct image, although the ghost sometimes is so close as to merely blur the principal image and cause the effect of very poor definition. Since the ghost signal arrives later than the direct signal, the ghost image appears at the right of the direct image.

Ghosts seldom are the same on all channels, because reflections from different transmitters travel different distances in their reflection paths. This is one method of distinguishing ghosts from multiple images and smears, since thses latter two troubles are likely to be much the same in effect on all channels.

In practically all cases, ghosts result from faults at the receiving antenna, not within the receiver. There is one rather unusual exception, when the transmission line from antenna to receiver is very long. Then, with a receiver lacking shielding, one signal may be picked up in leads or parts of the tuner, while a delayed signal arrives by way of the long transmission line. Remedies for ghosts of usual kinds are as follows:

Antenna.

Orient or rotate the antenna on its mast to a position which reduces strength of reflected signals more than strength of direct signals.

Raise the antenna higher. In a few cases ghosts may be less troublesome with the antenna lower.

Move the antenna to a different location. A few feet one way or another may make a decided improvement.

Use an antenna having better directional properties, one which greatly reduces strength of signals coming from all but one general direction.

Indoor and built-in antennas are likely to pick up reflected signals which cause ghosts very close to principal images. Change to a good outdoor antenna.

If reflected signals are coming to the receiver from a direction opposite to that in which the transmitter is located, and if the

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antenna does not have a reflector, add a reflector or install a new antenna so equipped.

If reflected signals are coming to the same side of the receiving antenna as direct signals, but from a different angle, and if the antenna has no director element in front of it, the addition of a director may help.

An unusual cause for ghosts is back and forth reflections of signal energy in the transmission line between antenna and receiver. This may happen where the line impedance is not a good match for antenna impedance and input impedance of the receiver. It is more likely to happen with fairly short transmission lines than with long ones.

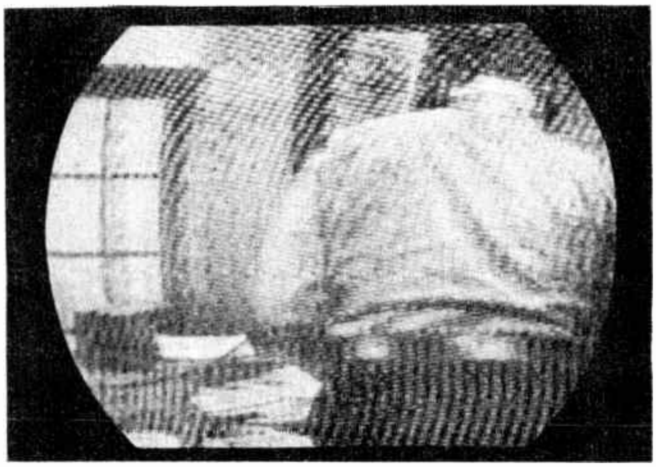

Fig. 14. High-frequency voltages beating with signals.

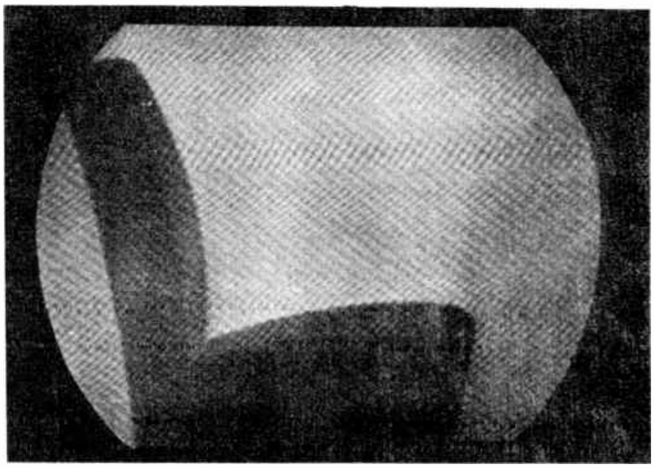

Fig. 15. Crosshatch effect caused by beating.

LINES, SLANTING AND SHIFTING.
Figs. 14 and 15

Rather narrow lines which add themselves to pictures sometimes slant one way, again the opposite way, or may become temporarily vertical, while shifting their positions almost continually. As a rule these lines are much fainter and less distinct than shown by the photographs, in which the effects are emphasized to make them clearly apparent.

These lines are caused by voltages at high video frequencies reaching the grid or cathode input of the picture tube. The frequencies often result from received interference signals which beat with received program signals, or they may be inter-carrier beats resulting from combination of video and sound intermediate frequencies in the receiver.

Two beat effects occuring at the same time may produce two sets of lines sloping in different directions, and crossing each other at fairly uniform spacings. The effect, called a crosshatch, is shown by Fig. 15.

Intercarrier Beats.

The 4.5-mv trap may be misaligned, or none may be used.

Sound takeoff misaligned. A tuned takeoff acts as a trap to prevent 4.5-mc beats from passing beyond the takeoff to the picture tube.

Dressing of leads may cause trouble. The picture tube signal input lead, grid or cathode, may be too close to the chassis or to parts carrying other signals. Where the sound system is a dual or split type, leads in the sound i-f and video i-f sections may be too close together while far from chassis metal.

External Interference.

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Amplitude-modulated radio signals of any kind. These signal frequencies may be in or close to the i-f range of the receiver, they may be harmonics of lower transmitted frequencies, or they may be at frequencies higher than carrier frequencies of the TV channel tuned in. The interference lines shift and change direction while the interfering signal is modulated.

Radiation from nearby television receivers.

Signals from a lower adjacent television channel. This sometimes is the trouble when the receiver has no adjacent sound trap, or when such a trap is misaligned.

Remedies For External Interference.

Careful adjustment of fine tuning or continuous tuning control.

Antenna oriented or rotated to reduce the interference. An antenna having more pronounced directional properties may be used.

A shielded transmission line between antenna and receiver may reduce interference from nearby sources.

R-f High-voltage Power Supply.

The operating frequency of an r-f power supply may cause beat effects when following troubles are present.

Loose, dirty, or corroded connections in the power supply.

Shield not grounded to chassis. In some designs the ground connection is only through a capacitor and resistor, with the shield otherwise insulated from the main chassis.

High-voltage filter capactior open, disconnected.

Faulty filtering or decoupling elements on B-plus leads to the high-voltage power supply.

Power supply oscillator plate and grid leads not dressed close to the chassis or shield.

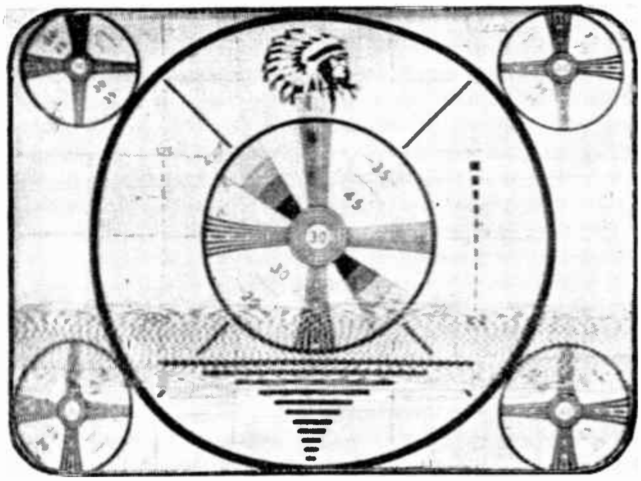

Fig. 16. Fairly strong herringbone or "diathermy" effect.

Fig. 17. Weak herringbone just below center of pattern.

HERRINGBONE EFFECT. Figs. 16 and 17.

A herringbone effect appears as criss-crossed diagonal or curved lines that interweave to form a horizontal band occupying only part of the total picture height. Nearly always the cause is interference from some kind of electrical apparatus which operates at or produces radio frequencies of several hundred kilocycles. The effects on received pictures will appear only while the apparatus is turned on, and will disappear when it is turned off. Apparatus which commonly causes this kind of picture interference includes the following:

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Medical diathermy devices of old style, which now are forbidden or discouraged in most places.

X-ray apparatus which is not properly shielded and otherwise prevented from radiating.

Heating devices which operate at radio frequencies.

Ultra-violet lamps.

Fluorescent lamps having accessories of poor quality.

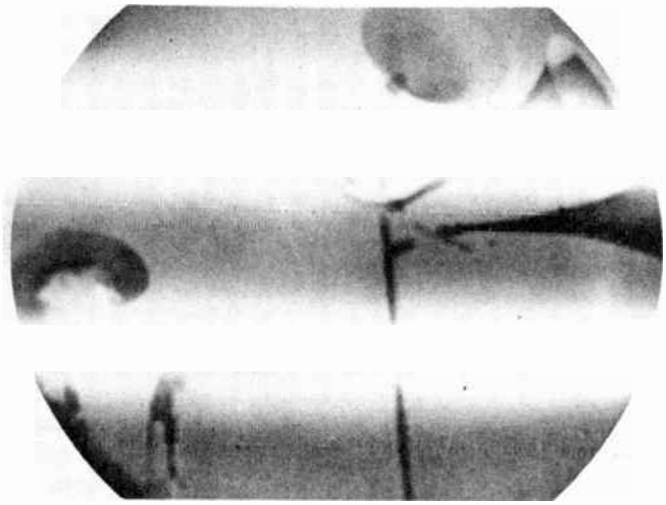

Fig. 18. Flashes may completely obliterate parts of pictures.

FLASHES. Fig. 18.

Bright flashes on pictures result from intermittent and strong electromagnetic fields reaching the antenna from external sources, or from disturbances within the receiver which momentarily interrupt signal voltages.

Sparking or arcing anywhere in the high-voltage power supply system.

Loose, corroded, or otherwise intermittent connections in B-plug lines to tuner, i-f amplifier, or video amplifier sections. Check all the way to the power supply.

Intermittent internal shorts between elements of any amplifier, detector, or agc tube. Try lightly tapping each tube to note whether flashing is caused or is made worse by one of them.

If flashing occurs only with antenna and transmission line connected to the receiver, the cause is some external source of spark type interference. These sources are of the kinds which cause noise, but to cause flashing they are very strong or are close to the receiver.

FLICKER

Flickering means variations of brightness occuring more or less continually and usually at a fairly uniform rate. The picture, as a whole, remains in its correct position without jumping sideways or vertically, but varies in brightness.

<u>AGC Circuit.</u>

Control tube defective.

Loose or dirty connections anywhere in the agc circuit, including the bus to grid returns. Check all bypass capacitors.

Time constant too short. Check for resistors shorted or of too little resistance. Capacitors too small, leaky.

<u>D-c Restorer Circuit.</u>

Tube defective.

Time constant too short. Check for resistors shorted, or of too small value. Capacitors leaky, or of too small value.

<u>Picture Tube.</u>

Internal intermittent shorts, heater to cathode, grid to cathode.

PAIRING OR FAULTY INTERLACING.
Figs. 19 and 20.

Horizontal trace lines for one picture field should commence at the upper left in the picture area, and for the following field at the upper center. Then all trace lines in

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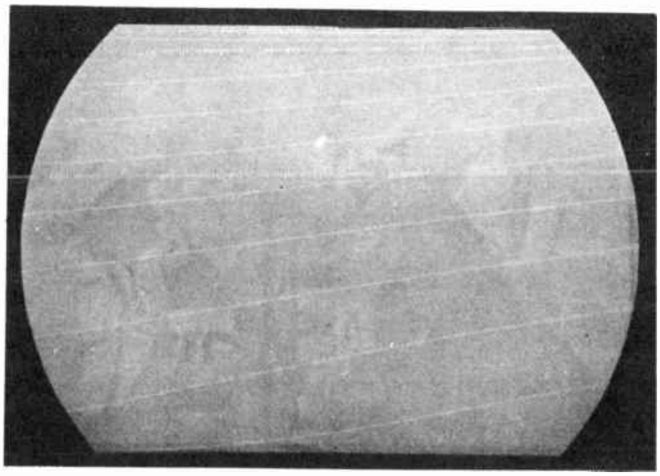

Fig. 19. Retrace lines uniformly separated or with separations varying at uniform rate indicate satisfactory interlacing.

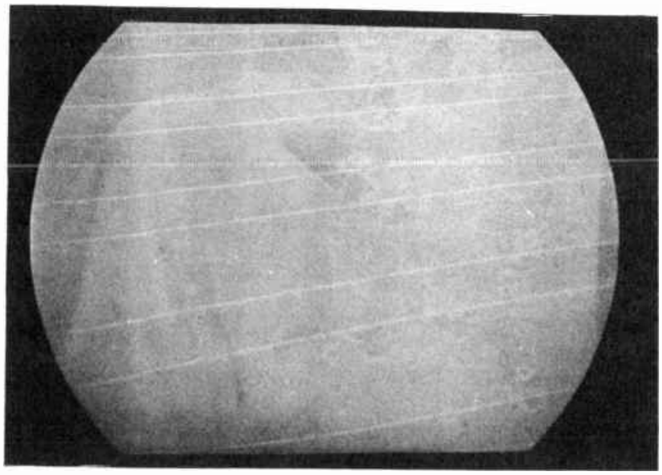

Fig. 20. Retrace lines appearing as pairs indicate poor interlacing.

the completed frame of two fields will be spaced equally apart. Otherwise, lines traced during one field will be too close to those traced during preceding and following fields, and between these closely spaced pairs of traces the gaps will be too great and may be noticeable in pictures. On small picture tubes the results of faulty interlacing seldom are noticed, but the larger the screen the worse the effect.

Faulty interlacing or pairing of trace lines may cause sloping outlines or edges of objects in pictures to appear zig-zag rather than smooth. Definition may appear poor along lines which are nearly horizontal in pictures, because of wide separations between paired traces. Definition may appear poor on vertical and nearly vertical outlines, because light and dark shadings along paired traces blend together and destroy sharp contrasts.

Faulty interlacing may be identified by examining trace lines of pictures with a magnifying glass, provided focus is sharp. Another method is as follows: Tune in a picture on the strongest available channel. Do not use a raster, for then there would be no sync signals to control the starting of field lines. Alternately reduce contrast and increase brightness until vertical retrace lines are clearly visible. If the receiver has vertical retrace blanking, the lead carrying blanking pulses probably will have to be disconnected from the picture tube grid-cathode circuit. Adjustment of the vertical hold control will change spacing between vertical retrace lines. Adjust this hold control for most nearly even spacing.

If retrace lines thus observed are equally spaced, or if spacing changes uniformly from top to bottom, as in Fig. 19, interlacing is satisfactory even though not perfect. If pairs of lines are quite close together, with relatively wide separations between pairs, as in Fig. 20, interlacing is faulty. Before checking for trouble in the receiver, try other channels; a received signal might be temporarily at fault. Strong noise interference sometimes causes faulty interlacing while the interference continues. Receiver trouble usually is in the sync section or in vertical oscillator circuits.

Vertical Oscillator Circuits.

Tube weak, or plate voltage too high or too low.

Ripple in oscillator plate voltage, varying the instant at which the oscillator is triggered. Check decoupling or filtering on the B-plus line to the oscillator.

Capacitor or resistor defective, of wrong value.

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Grid circuit conductors too close to conductors carrying vertical deflection pulses, with the strong pulses preventing weaker input sync pulses from correctly triggering the oscillator. Grid circuit conductors too close to circuits carrying horizontal deflecting pulses.

Elements of vertical integrating filter, or its connections, close to parts carrying vertical deflecting pulses, such as the vertical output transformer.

Sync Section.

Tube weak, or operated with wrong element voltages.

Plate or grid voltages on one or more tubes not such that picture signals completely separated from sync pulses. This may prevent build-up of the vertical sync pulse from commencing at the same voltage level for alternate fields.

Sync pulses excessively amplified in some stage, or not properly limited or clipped. The vertical sync pulse may build up so strongly as not to be dissipated during equalizing pulses.

Vertical Integrating Filter.

First filter capacitor too large. This is the capacitor to ground or B-minus.

Resistance in series with input to filter too small.

Any capacitors or resistors open, shorted, leaky of wrong value.

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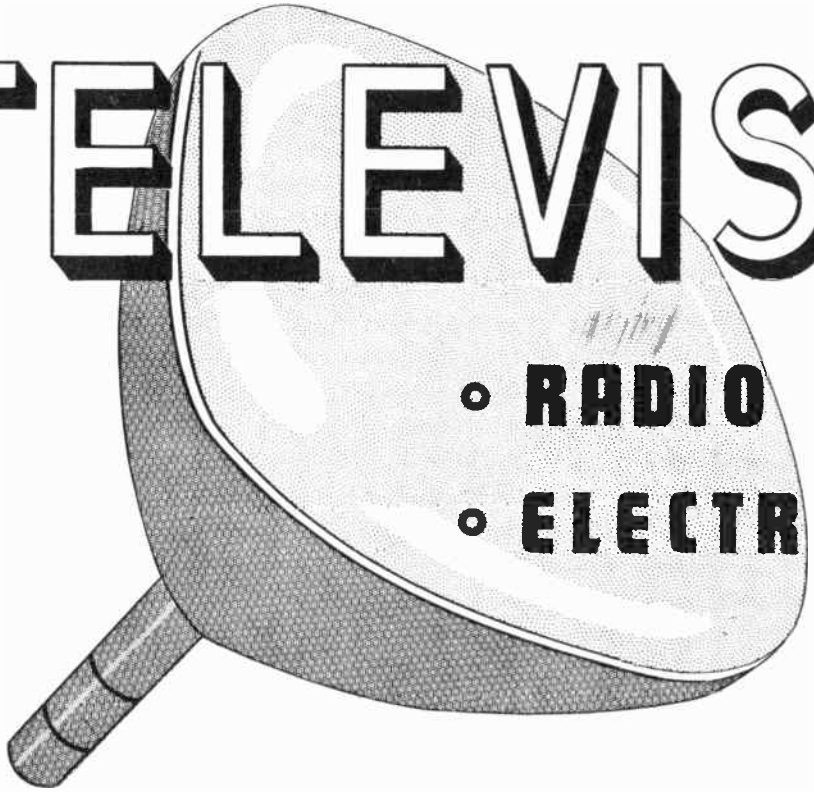
TELEVISION



- RADIO
- ELECTRONICS

LESSON 84—PICTURE AND PATTERN ANALYSIS—PART 2

Coyne School

practical home training

Chicago, Illinois

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Lesson 84

PICTURE AND PATTERN ANALYSIS—PART 2

This lesson continues with our system of trouble shooting by an examination of faults appearing in pictures and patterns as a means for determining existing troubles. When commencing work on a receiver displaying faulty pictures always make three preliminary tests. 1. Try all the operator's controls, to note whether they produce normal results. 2. Tune to each active channel, one may be temporarily in trouble. 3. If the fault is such as might result from misadjustment of a service control, try adjusting that control for a correction.

It is entirely possible that some faults illustrated and described may result from unusual or peculiar troubles not mentioned in any of the lists. The list include troubles which are most probable, and those which may occur in receivers having circuits and parts of generally accepted designs. An unusual design, such as might be used in only one make or model of receiver, may have troubles peculiar to that one design.

All this means that picture and pattern analysis is not a positive and never-failing method of putting your finger on any and every television receiver trouble. It will, however, save a great deal of time in determining the more common causes for faulty pictures. After that it is necessary to apply your knowledge of television receiver principles.

ROLLING PICTURES, VERTICAL MOVEMENT. Fig. 1.

Vertical oscillator and sweep frequency is not in time with vertical sync pulses of received signals. Pictures that roll or move upward indicate internal sweep frequency lower than that of received signals, or less than 60 cycles per second. If pictures move downward, the internal sweep frequency is higher than that of received vertical sync pulses, or is greater than 60 cycles per second.

Noise And Interference.

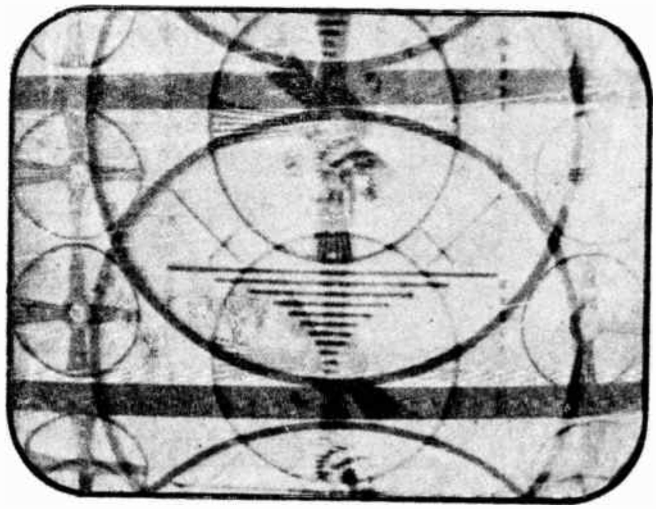

Fig. 1. Vertical roll.

Noise pulses, from external sources or from within the receiver, tend to affect vertical sync more than horizontal sync, because horizontal sync systems have automatic frequency controls while very few vertical sync systems have such a control.

High noise level with relatively weak signals. Causes and remedies are explained in the lesson on "Noise in Television Pictures".

Sparking or arcing in the high-voltage power supply section.

Ripple voltage or hum voltage reaching the video amplifier ahead of the sync takeoff, reaching parts of the sync section which carry vertical pulses, or the vertical oscillator circuit. Check for strong ripple voltage on B-plus lines to these sections, examine decoupling of filter capacitors, and check for heater-cathode leakage in sync section tubes as the most probable troubles.

Horizontal sync pulses reaching vertical oscillator circuits. Check for faulty decoupling capacitors and resistors on B-plus or boosted-B lines to the vertical oscillator and output amplifier circuits.

Vertical Oscillator And Its Circuit.

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Oscillator or oscillator-discharge tube weak. Many receivers have vertical oscillator and output amplifier tubes of improved designs which, when replaced with otherwise similar tubes, may allow vertical sync difficulties.

Oscillator voltage too high or too low, either of which may so change the free running frequency as to make synchronization difficult.

Resistors in grid circuit or discharge circuit open, shorted, of wrong values.

Capacitors open, shorted, leaky. These troubles make large changes of free running frequency.

Defective feedback transformer, or poor transformer connections, on a blocking oscillator.

Vertical Hold Control Circuit

Capacitors leaky, of poor quality, or possibly too close to chassis metal.

Long leads so close to chassis metal as to greatly increase stray capacitance.

Resistors too great; will cause pictures to roll upward.

Resistors too small or shorted; will cause pictures to roll downward.

Control potentiometer terminals shorted, shunt resistors faulty, unit defective internally.

Vertical Integrating Filter.

Capacitor leaky, shorted, wrong value. May make vertical hold adjustment very critical, and allow momentary rolling of pictures.

Resistors shorted, open, wrong value.

Other Troubles.

See following section, "Sync Faults, Vertical and Horizontal".

PICTURE MOVEMENT, HORIZONTAL
Figs. 2, 3, and 4

Horizontal oscillator and sweep frequency not in time with horizontal sync pulses of received signal. Pictures may move continually in producing effects illustrated, or may move into such positions only during a short period after the receiver is turned on, or may change to such positions and appearances after normal operation for various periods of time.

Fig. 2. This indicates horizontal sync trouble.

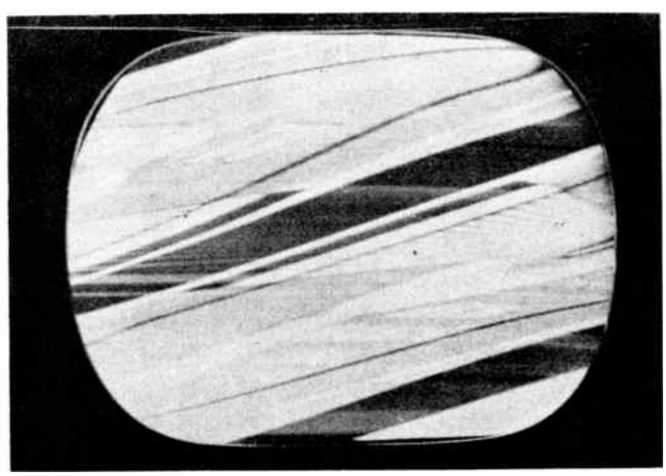

Fig. 3. This also indicates horizontal sync trouble.

Downward slope from left to right (Fig. 2) indicates that the internal sweep frequency is somewhat higher than that of received sync pulses, while the opposite slope (Fig. 3)

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indicates internal sweep frequency somewhat too low. When there are too many pictures or patterns on the screen, and when they overlap (Fig. 4) the internal sweep frequency is some simple fraction of the normal horizontal sync frequency, such as half frequency for two pictures, one-third frequency for three pictures, and so on.

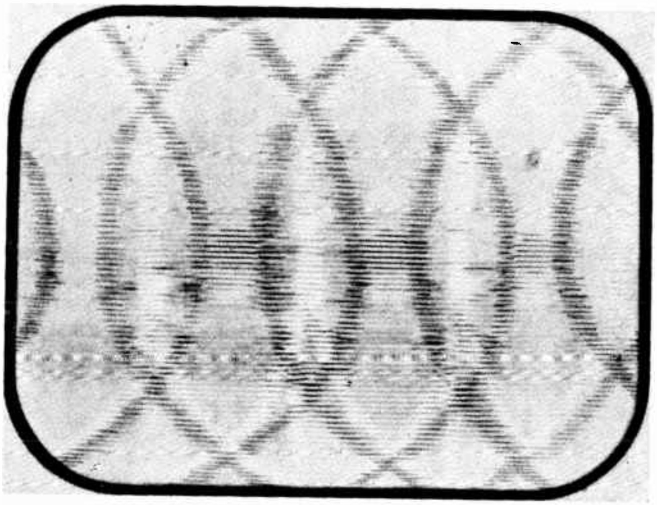

Fig. 4. Horizontal sweep frequency is holding at the wrong value.

Knowing whether the internal sweep frequency is too high or too low, and knowing what circuit factors determine the free running frequency of oscillators, are helps in determining just what kind of trouble probably is present.

Horizontal Oscillator And Its Circuit.

Oscillator or oscillator-discharge tube weak or otherwise defective.

Tube element voltages too high or too low. Either will alter the free running frequency of the oscillator.

Coupling capacitors either open or leaky.

Sawtooth capacitor leaky, too great capacitance, or possibly too little capacitance.

Resistor in series with sawtooth capacitor shorted or grounded, or may have much too small capacitance.

Horizontal Hold Control Circuit.

Capacitor leaky.

Resistor open, shorted, of wrong value.

Long leads too close to chassis metal, alter stray capacitance and free running frequency of oscillator.

Control potentiometer terminals shorted, shunt resistor defective, control unit defective internally.

Horizontal Afc Circuit.

Control elements misadjusted. The type of adjustment and how it should be made depend on the kind of afc system used in the receiver.

Tube weak or otherwise defective.

Tube element voltages wrong, on control tubes other than diodes.

Capacitors leaky, shorted, of wrong value.

Resistors open, poor connections, shorted.

Unbalance in resistor or capacitor combinations on the two sections of a twin diode control tube.

Other Troubles.

Misadjustment of stabilizing, locking, or frequency control unit in the oscillator plate circuit. This is a common cause for inability to hold horizontal synchronization with the horizontal hold control turned all the way in one direction or the other.

Interference from vertical deflecting pulses. Check dressing of leads and condition of filter and decoupling elements in horizontal and vertical deflecting systems and in B-plus leads which supply voltage and current to both systems.

Misadjustment of horizontal drive or horizontal linearity control is a possible cause for difficulty in horizontal synchronization.

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See also the following section, "Sync Faults, Vertical and Horizontal".

SYNC FAULTS, VERTICAL AND HORIZONTAL.

Various troubles in sections and circuits from the tuner through the sync section may affect vertical synchronization, horizontal synchronization, or both. These circuits carry both kinds of sync pulses. If synchronization is difficult to maintain unless the contrast control is well advanced, trouble may exist in any circuits which carry vertical and horizontal sync pulses.

Troubles which contribute to sync failure when other defects are present include low or fluctuating power line voltage, and low B-voltages due to faults in the d-c power supply and B-plus distribution lines.

Sync Section.

Tube weak, or heater-cathode leakage in some tube.

Tube element voltages too high or too low. May prevent proper separation of picture signals from sync pulses, or cause excessive limiting or clipping of sync pulses.

Microphonic tubes. Try tapping the tubes very lightly. If this causes vertical roll or horizontal slipping, try a new tube.

Coupling capacitors, leaky, shorted, open.

Resistors open, wrong value, poor connections.

Loss of sync pulse strength in path from sync takeoff to first tube in sync section. Check for resistances too great, capacitances too small, poor connections.

Video Amplifier and Detector Circuits.

Tube weak, or has cathode-heater leakage.

Excessive ripple in plate or screen voltage.

Tubes overloading, to limit sync pulses. Check plate voltages, screen voltages, grid biases, and condition of capacitors and resistors in amplifier grid circuits.

Amplifier plate load or detector load resistance too great.

Video detector weak, either a tube or a crystal diode.

D-c Restorer Circuit.

Restorer troubles affect synchronization when the restorer is also a sync take-off tube.

Tube weak or otherwise defective.

Resistor from restorer cathode to ground open or too high resistance.

I-f Amplifier and Tuner.

Lack of gain. Weak tube, Tube element voltages wrong.

Cathode-heater leakage in any tube.

I-f alignment such as to bring video marker too low on response, allowing too little gain at sync pulse frequencies. This trouble probably is not causing sync difficulty if heavy lines in pictures are sharp and distinct.

Feedback and regeneration in i-f amplifier. Indicated by high, sharp peaks on the frequency response.

Tuner alignment may be such as to reduce the gain at low video frequencies.

Agc Circuit.

Agc voltage too negative with weak received signals.

Agc voltage varying irregularly or too rapidly with changes of strength in received signals, or due to defective capacitors or resistors in agc circuits. Measure d-c voltage on the agc bus while sync difficulty is present. Vibration of the meter pointer, observed with a magnifying glass if neces-

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sary, indicates trouble in a control tube, in capacitors, resistors, or connections in the agc circuits.

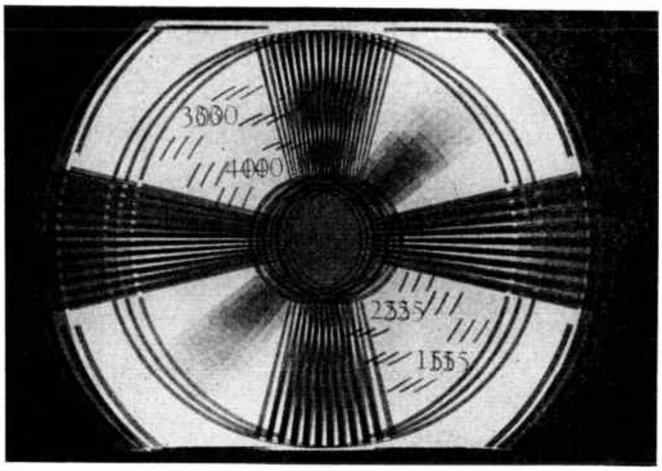

Fig. 5. Pictures jitter or jump sideways.

JITTER, HORIZONTAL. Fig. 5.

A jittery or jumping picture is one which shifts rapidly back and forth through small distances to the left and right. Common causes are as follows.

External or internal noise pickup, strong and continual. For causes and remedies refer to lesson on "Noise In Television Pictures".

Received signal may be temporarily at fault. Try other channels.

Switch contacts dirty, rough, loose, bent. Examine contacts in the tuner. Depending on the types of circuits, there might be trouble in local-distant or sensitivity controls, or possibly in a TV-Phono-Radio selector switch.

Defective contacts between tube sockets and base pins. Try moving tubes slightly to one side and back while in their sockets.

Microphonic tubes. Test by very light tapping while watching for jitter.

Tubes with intermittent internal shorts. This trouble should show up during the light tapping for microphonic effects.

Afc tube weak or otherwise defective.

Afc system varying the correction voltage too much or too rapidly. Check condition and values of resistors and capacitors in the frequency control circuits.

Noise filter between afc tube and horizontal oscillator. Check capacitors and resistors for wrong values, shorts, leakage.

Agc circuit may have loose connections, defective bypass capacitors. Check all along the agc bus, commencing at the tube furnishing agc voltage.

Feedback of horizontal deflecting pulses from anywhere beyond the sweep oscillator to any point on the grid circuit or input circuit. The stronger pulses on the output side interfere with synchronizing action of the weaker input pulses. Check decoupling or bypass capacitors in the output circuits. Check dressing of leads, including those to the deflecting yoke.

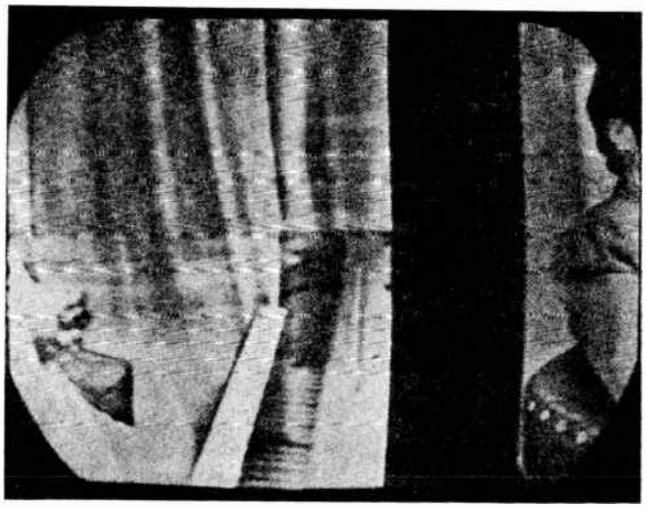

Fig. 6. A horizontal blanking bar appears as a vertical dark band.

SPLIT PICTURES, LEFT AND RIGHT. Fig. 6

The picture is divided into two parts by a vertical dark bar which represents the horizontal blanking interval. To the left of this vertical bar appears the portion of the picture that should be at the right, and to the right of the bar is the portion of the picture that should be at the left. The trouble is in

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horizontal synchronization, with the internally produced sweep frequency lower than that of horizontal sync pulses in the received signal.

Horizontal frequency control misadjusted. This control may be called lock, phasing, stabilizing, or simply the frequency control.

Afc circuit. Defective tube. Capacitor open, leaky. Reversed leads to the two sides of a horizontal phase detector or discriminator tube.

Horizontal hold control circuit. Too much resistance, which delays triggering of the horizontal oscillator.

Fig. 7. A vertical blanking bar appears as a horizontal dark band.

SPLIT PICTURES. TOP AND BOTTOM. Fig. 7.

The picture is divided into two parts by a horizontal dark bar which represents the vertical blanking interval between fields and frames. Above the bar appears the portion of the picture that should be at the bottom, and below the bar is the portion that should be at the top. There is trouble with vertical synchronization. The vertical oscillator is operating at a frequency lower than that of vertical sync pulses in received signals.

Heater-cathode leakage in the vertical oscillator tube or in a tube in the sync section.

Vertical hold control circuit. Too much resistance, which delays triggering of the vertical oscillator. Too great coupling capacitance between sections of a multivibrator oscillator may have the same effect.

Sawtooth capacitor too large.

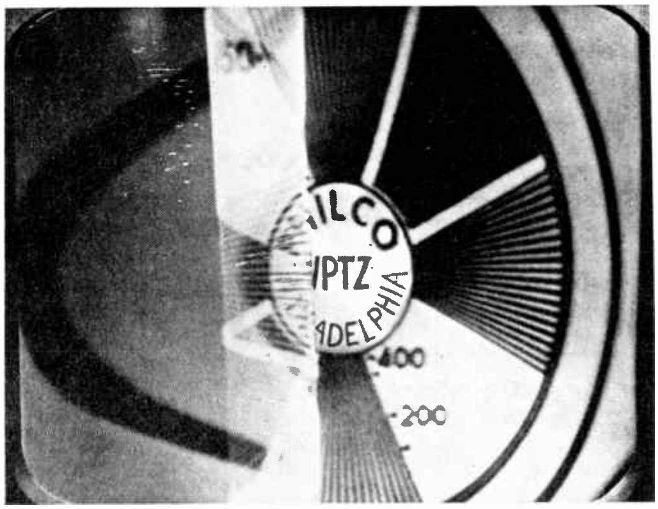

Fig. 8. The pattern is folded horizontally.

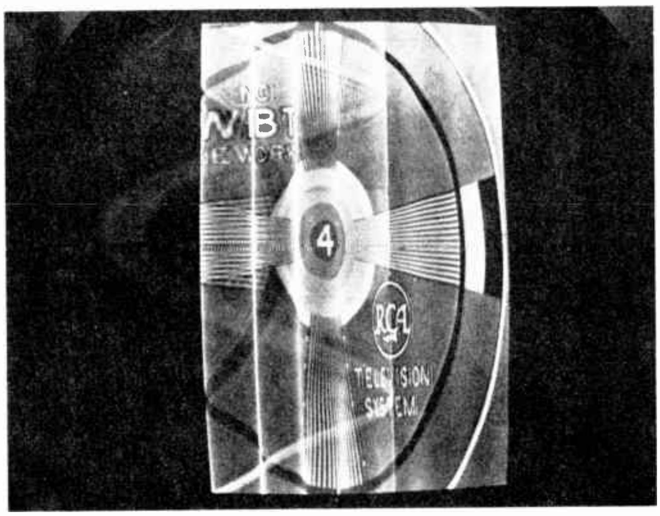

Fig. 9. One large horizontal fold and several minor ones.

FOLDS, HORIZONTAL. Figs. 8 and 9.

Only part of the picture or pattern is clearly recognizable, although more or less distorted and compressed horizontally. The remainder, usually less than half, appears to be stretched horizontally and folded back over the first portion. The folded part is indistinct, usually with only shadowy out-

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lines. There may be only one fold (Fig. 8) or there may be several (Fig. 9) to give the distinct portion of the picture a corrugated appearance.

The horizontal retrace time, due to discharge of the sawtooth capacitor in the horizontal oscillator-discharge tube circuit, actually is longer than the time allowed for horizontal retrace in received signals. The folded portions of pictures, which are indistinct and shadowy, occur during periods in which the picture tube beam should be blanked.

Damper Tube And Circuit.

Tube defective.

Capacitor on low-side circuit of damper open or disconnected.

Linearity control inductor in damper circuit shorted, otherwise defective of wrong type or wrong inductance.

Lead from horizontal output transformer and damper to the deflecting yoke has poor connections or is allowing leakage of current through faulty insulation.

Damper plate or cathode, depending on type of circuit, connected to a tap on the horizontal output transformer at which horizontal pulse voltages are not strong enough for rapid damping and retrace.

Boosted B-voltage to the horizontal output transformer and amplifier plate too low.

Frequency Control Circuits.

Afc tube weak or otherwise defective.

Afc control misadjusted. This is a control which operates in the circuits of the afc tube, or between that tube and the horizontal oscillator.

Insufficient feedback to afc tube from horizontal sweep circuit. Series capacitor too small, or shunt capacitor too large. Series resistor too great, or shunt resistor too small. The feedback lead may be connected to the wrong point on the horizontal output transformer or other parts of the sweep circuits.

Unbalance in resistors on the two sections of a horizontal phase detector or discriminator, or resistors connected wrong.

Misadjustment of a horizontal frequency control in the plate circuit of the horizontal oscillator.

Other Troubles.

Too much resistance in the grid return lead of the horizontal output amplifier.

Too much capacitance has been connected across part of the horizontal output transformer or across a width control inductor when increasing the width of pictures.

The horizontal output transformer may be of a type causing inherently long retrace time. Some two-winding transformers cause longer retrace times that otherwise equivalent autotransformers.

Fig. 10. This is a vertical fold.

FOLDS, VERTICAL. Fig. 10.

Pictures are compressed between top and bottom to occupy only part of the screen height and leave dark areas below, above, or both below and above the pictures. Folding may be apparent in that part of the picture which is visibly superimposed on the remainder, or the effect may be only a decided

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lightening of that portion of the picture over which another part is folded.

Vertical oscillator circuit. Capacitors leaky or of wrong values, resistors too small or shorted, in grid or cathode circuits of the vertical oscillator.

Vertical hold control fixed resistors or potentiometer of wrong values or defective.

Vertical output amplifier grid resistor too small.

Leaky coupling capacitor between vertical oscillator plate and amplifier grid.

Leaky capacitors in vertical integrating filter.

Sync section. A tube which feeds to the vertical integrating filter may be weak or otherwise defective.

Fig. 11. Tear out occurs during momentarily failure of horizontal sync.

TEAR OUT. Fig. 11.

Tear out occurs nearly always across the top of the screen, where picture details disappear in irregular bars and lines. The effect lasts for only a moment or two each time it appears. Horizontal synchronization is lost or is not quickly restored after the end of each vertical blanking interval, or at the beginning of each field of picture signals.

This trouble is not likely to occur when horizontal afc systems and noise suppression tubes and circuits are operating effectively. Therefore, when there are frequent tear outs, these sections or circuits should be checked for defective tubes, capacitors, resistors, and connections. Other causes follow.

Strong external interference of the spark type.

Steady sparking or arcing in the high-voltage power supply.

Lack of gain in i-f or video amplifier sections, with contrast control advanced too far in an effort to compensate for insufficient gain.

Microphonic tube in tuner, i-f amplifier, video amplifier, or sync section. Such a tube may allow tear out when the receiver is jarred. While contrast is turned only moderately high, and preferably while receiving rather weak signals, tap each tube lightly.

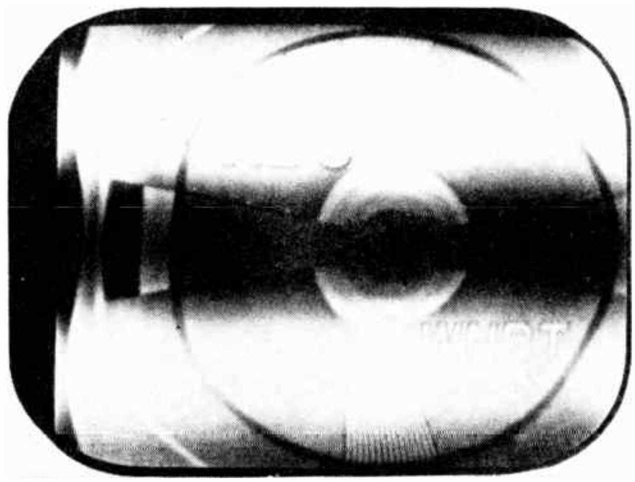

Fig. 12. Hum bars.

HUM BARS. Fig. 12.

These alternate dark and light horizontal bars result from voltage at hum frequency, 60 to 120 cycles, getting into tubes or circuits anywhere between the tuner and the grid-cathode signal input of the picture tube. Causes and remedies for these bars are explained in detail in the lesson on "Hum And Sound In Pictures".

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The most common cause for a single dark bar and single light bar is cathode-heater leakage. The most common cause for two dark bars and two light bars is excessive 120-cycle ripple voltage.

If hum bars appear on a raster as well as on pictures, check first for trouble in the video amplifier section. If bars do not appear on a raster, but only on pictures, check first for trouble in the i-f amplifier section, in r-f amplifier circuits of the tuner, and in d-c restorer circuits.

Should these checks fail to locate the trouble, refer to the lesson mentioned.

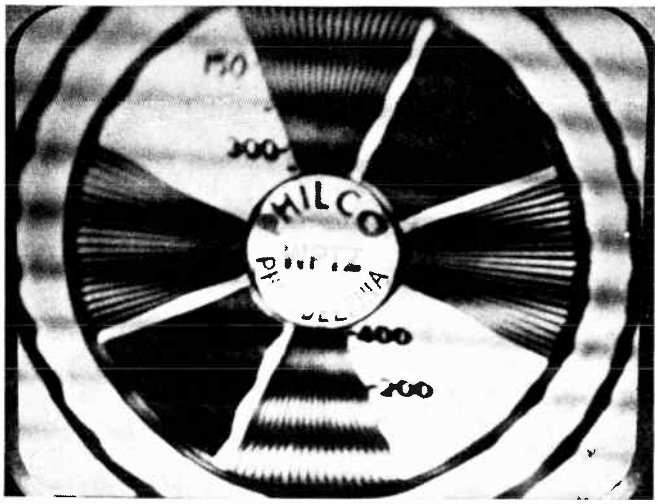

Fig. 13. Sound bars.

SOUND BARS. Fig. 13.

More than two pairs of alternate dark and light horizontal bars result from voltage at a sound or audio frequency higher than 120 cycles reaching tubes or circuits between the tuner and grid-cathode signal input to the picture tube. Detailed explanations of causes and remedies for sound bars are in the lesson on "Hum And Sound In Pictures". A brief summary follows.

Tuning Or Alignment

Fine tuning or continuous tuning adjusted to bring sound too high on the i-f response.

I-f amplifier section, or r-f oscillator in tuner, aligned to bring sound too high on i-f response.

Trap Adjustments.

Misadjustment of traps for accompanying sound, for adjacent sound.

Other traps intended for shaping the i-f response may be adjusted to bring sound too high on the i-f response.

Microphonic Tube.

R-f oscillator or horizontal afc tube most likely to cause sound bars.

Other tubes carrying video signals and sync pulses. First check r-f, i-f, and video amplifiers, then vertical and horizontal oscillators.

Tune to an inactive channel. If bars remain, or appear when receiver jarred, the trouble probably is in oscillators or in tubes following the oscillators, since they produce a raster in the absence of received sync pulses.

Sound Section.

With dual sound systems, takeoff alignment incorrect. The takeoff acts similarly to a trap for accompanying sound.

Series plate-cathode B-supply system. Lack of filtering or decoupling between cathodes of sound section tubes and plate-screen lines for other tubes. Check capacitors and resistors.

External Interference.

Any a-m radio signals which are sound or tone modulated. Radio amateur, police, point-to-point, and other transmitters.

Radiation from nearby TV receiver.

Sound bars shift and weave while interfering signal is modulated. The bars disappear while the signal is not modulated.

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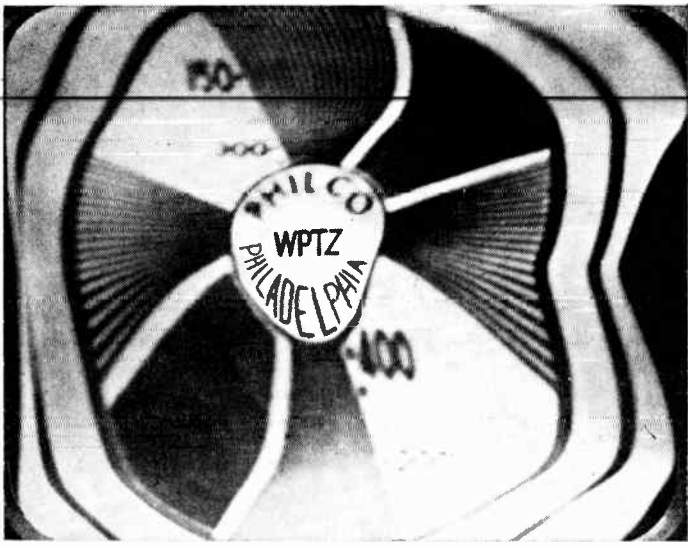

Fig. 14. Low-frequency hum voltage is affecting the sweep circuits.

WAVES, VERTICAL. STRONG AT RIGHT.
Fig. 14

Waves extending between top and bottom of pictures may be of smooth form, like a sine wave, or may be zig-zag shape with a hacked out appearance at the right. Such waves usually are most noticeable at the right and become smoother toward the left. In addition to the wavy effect there may be rather wide horizontal bands which are alternately dark and light, like hum bars. As people and other objects move, they will appear to shift and bend.

One Complete Vertical Wave.

Cathode-heater leakage, usually in tubes of these positions or sections. Horizontal oscillator. Horizontal afc tube. D-c restorer tube. I-f amplifier. R-f amplifier.

D-c power supply rectifier defective, unbalanced.

Coupling between vertical and horizontal sweep circuits. Check filter and decoupling capacitors and resistors in these circuits.

Strong 60-cycle magnetic field, usually from the low-voltage power transformer, too close to any parts of the picture tube.

Two Complete Vertical Waves.

Two waves are due to 120-cycle hum voltage reaching the sweep circuits, directly or indirectly. Circuits most often affected are those of the horizontal oscillator, the sync section, or the sweep section on the output side of the oscillator. Check power supply filtering, also decoupling capacitors and resistors on B-plus lines to the circuits mentioned.

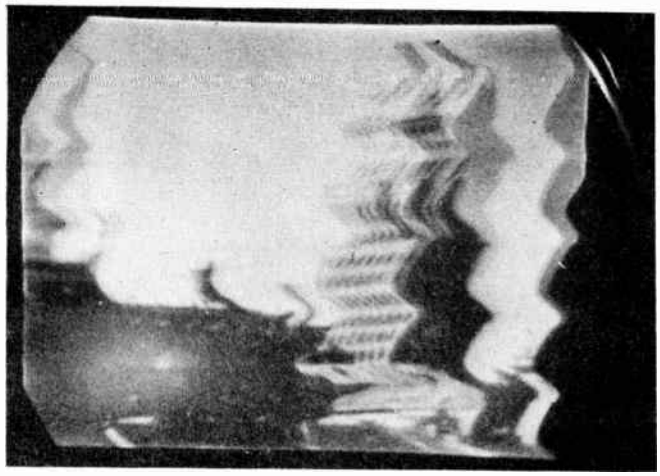

Fig. 15. There is waviness all over the picture.

WAVES, VERTICAL. ALL OVER
Fig. 15

When waves run vertically between top and bottom of the picture, and extend more or less with uniform strength all the way across, the trouble probably is one of the following. Sometimes the waves are of ragged shape, with sharp changes of direction.

Capacitors open, much too small, or disconnected in any leads on the grid circuit of the horizontal oscillator. This includes coupling capacitors and capacitors to ground.

Horizontal afc system varying its correction voltage too much. The probable cause is a ripple voltage or voltage at any higher frequency reaching the afc tube or its connected capacitors or resistors.

Resistor in series with horizontal output amplifier grid is too great.

Coupling between vertical and horizontal coils in the deflecting yoke. A damping re-

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sistor across a vertical coil may be open, disconnected, or of too great resistance. A capacitor or capacitor-resistor combination across a horizontal coil may be open or of wrong values. The yoke coils themselves may be defective.

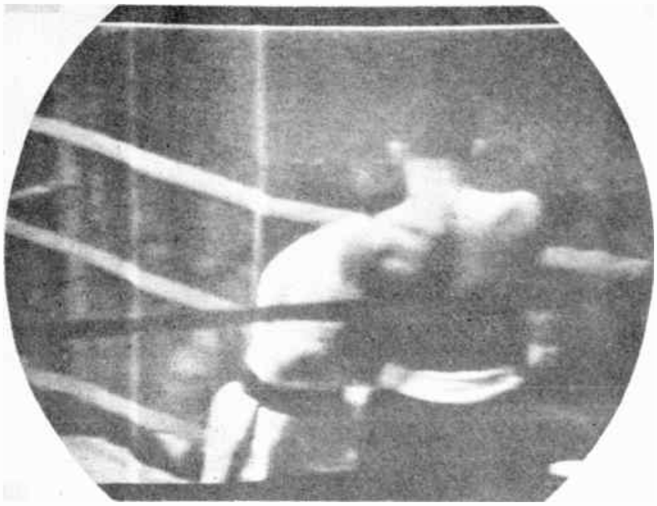

Fig. 16. A bright line extends across the top of pictures.

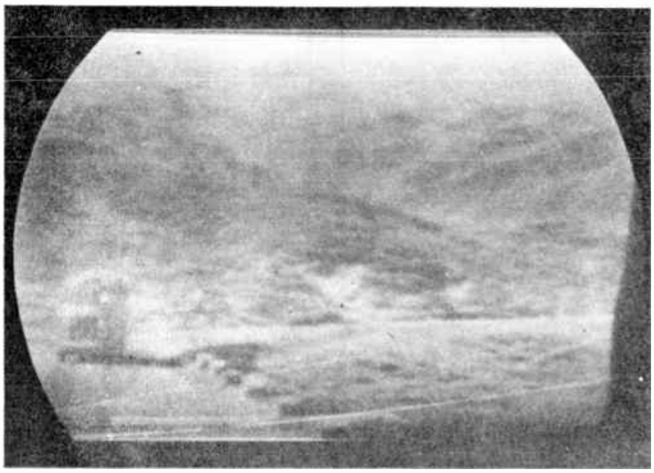

Fig. 17. The top of the picture is brighter than it should be.

BRIGHT LINE OR BAND AT TOP.

Figs. 16 and 17

When these faults appear it usually is found that vertical size and vertical linearity controls have been misadjusted in an attempt to improve pictures. After the real trouble is located, these two controls will require correct adjustment.

Misadjustment of both vertical height control and vertical linearity control may in itself cause a bright horizontal line or narrow band across the extreme top of the screen.

Vertical output amplifier tube weak.

Low B-voltage to the vertical sweep section. Check B-plus lines to vertical output transformer, vertical output amplifier, and vertical oscillator. If boosted B-voltage is used for the vertical oscillator-sweep section, check the damper tube and its low-side or output circuit elements for trouble.

Vertical output transformer. Leads shorted, grounded, poor connections. The transformer windings may be internally shorted or grounded. Such troubles usually prevent obtaining pictures of normal height.

Vertical output transformer and deflecting yoke not matched, not designed to work together.

Vertical coils in yoke, defective, not furnishing enough vertical deflecting flux.

Vertical retrace blanking circuit. Capacitors open or much too small sometimes cause a bright line or narrow band across the top of pictures.

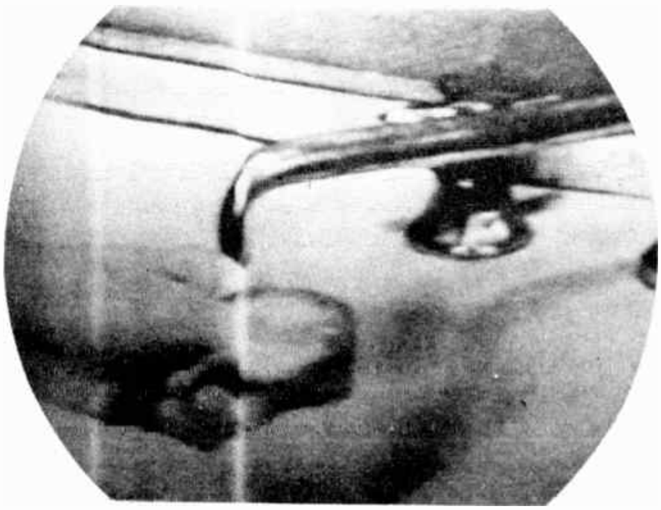

Fig. 18. Bright vertical lines may mean too much drive.

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BRIGHT LINE OR BAND VERTICALLY.
Fig. 18.

Horizontal deflection of the electron beam is not at a uniform rate, but slows slightly at the point along each trace where the bright line or band appears. The beam remains there a little too long, to cause excessive brightness.

Horizontal drive control adjusted for too little capacitance, too much drive. This is the most common cause for a bright vertical line.

Horizontal Oscillator Circuit.

Tube weak, or plate voltage too high or too low.

Defective capacitor or resistor in grid circuit.

Resistor of wrong value or otherwise faulty in circuit from oscillator-discharge tube to B-supply voltage.

Sawtooth capacitor too large.

Horizontal Output Amplifier Circuit.

Tube weak.

Leaky coupling capacitor between amplifier grid and oscillator-discharge plate.

Defective capacitor or resistor, or units of wrong value, anywhere in the amplifier grid circuit. Check the drive capacitor.

Width Control. A width control inductor on the horizontal output transformer may be connected to tap terminals between which are too many turns of the transformer winding.

Damper Circuit. Troubles in the damper circuit may cause what appears to be a single vertical bright band, but upon close examination it usually may be seen that there are two or more alternate bright and dark bands. Refer to the trouble section "Alternate Bright and Dark Vertical Bands", and the sub-heading "Damper Circuit".

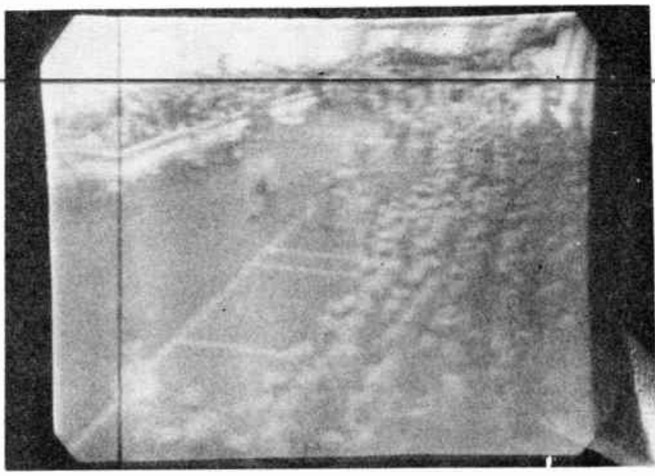

Fig. 19. High-frequency oscillation causes dark vertical lines.

DARK LINE OR LINES, VERTICAL
Fig. 19.

Thin vertical lines, either smooth or of ragged and broken appearance, most often result from high frequency oscillations or interferences that affect horizontal traces. When such trouble results, from faults of the horizontal output amplifier it usually is referred to as Barkhausen oscillation. These lines usually show only on pictures, not on a raster, and are more apparent with the contrast control turned high.

Control Adjustments. In some cases the dark vertical lines result from misadjustment of horizontal drive, horizontal linearity, and width controls.

Horizontal Output Amplifier.

Screen voltage too high, causing plate current close to or possibly in excess of maximum rated value.

Tube defective. A tube which causes trouble in one receiver often operates satisfactorily in another.

Remedies which may overcome the trouble are as follows: A fixed non-inductive resistor of 47 ohms or more connected directly in series with the grid of the horizontal output amplifier. An r-f choke of not more than five microhenrys in series with the plate or cathode of the damper tube. Such

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a choke is used in many sets. A device similar to a single ion trap magnet held by its springs around the top of the horizontal output amplifier and rotated (while the set is turned off) until a position is found at which the horizontal lines disappear. Some single ion trap magnets are suitable.

Dressing.

Antenna transmission line to the tuner may be too close to high-voltage power supply circuits or horizontal sweep circuits.

I-f amplifier circuits close to parts of horizontal sweep circuits.

Poor connections anywhere in the high-voltage power supply, allowing continual slight arcing.

Defective Units.

Either the horizontal output transformer or the deflecting yoke may be internally defective.

ALTERNATE LIGHT AND DARK BANDS, VERTICAL
Figs. 20 and 21.

Alternate light and dark vertical bands commence at the left of pictures and become rapidly fainter toward the center. The cause is oscillation, at the natural frequency of horizontal coils in the yoke, not being immediately damped. Instead of oscillations being damped at the end of the horizontal retrace period, they continue while the beam travels toward the center of the screen. The beam travels first too slowly, for a light band, then too rapidly, for a dark band.

Bands caused by lack of damping show more clearly on a raster than on pictures, as is apparent upon comparing Figs. 20 and 21, To identify faults of this type, look first at a picture, then at a raster.

In bands due to lack of damping there are no sharp lines. Close examination always will show more than one band of each shading. The bands always commence at the left side of the screen. People and objects appear narrower and then wider as they move through light and dark bands. This trouble sometimes is called ringing.

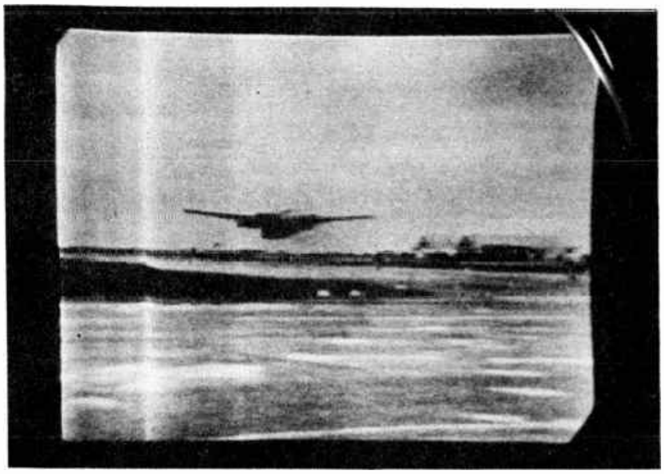

Fig. 20. Alternate light and dark vertical bands denote poor damping.

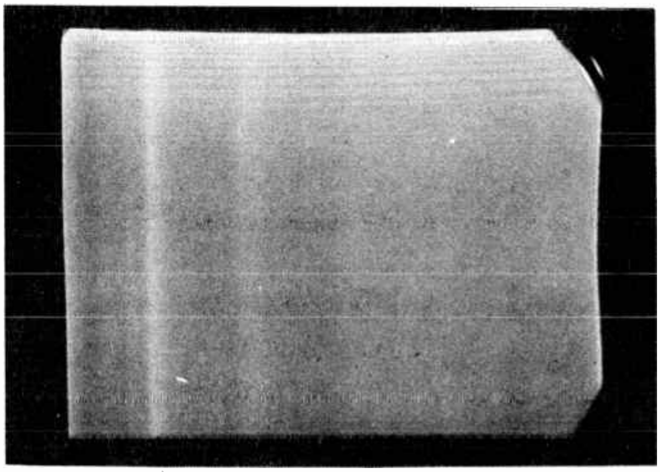

Fig. 21. The alternating bands as they appear on a raster.

Damper Circuit.

Damper tube weak.

Poor connections or any other cause for high resistance in series with the damper circuit.

Capacitor from the damper and yoke circuit to B-plus supply line open, disconnected, or too small.

Capacitor from damper output or low side to ground or B-minus is leaky.

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Damper high side, plate or cathode according to type of circuit, connected to terminal on horizontal output transformer at which pulse voltages are too weak.

Linearity control inductor in damper circuit of wrong value, usually too much inductance.

Linearity control resistor between damper plate and cathode open, disconnected, too much resistance.

Horizontal Output Transformer And Yoke.

Capacitor across horizontal coil in yoke open, too small capacitance, leaky.

Yoke leads connected to wrong terminals on horizontal output transformer.

Transformer and yoke not matched, Either or both of wrong type.

Yoke internally defective.

Other Troubles.

Horizontal output amplifier tube weak.

Video amplifier frequency response has sharp peaks, usually due to regeneration, but sometimes caused by faulty decoupling in grid circuits or other troubles.

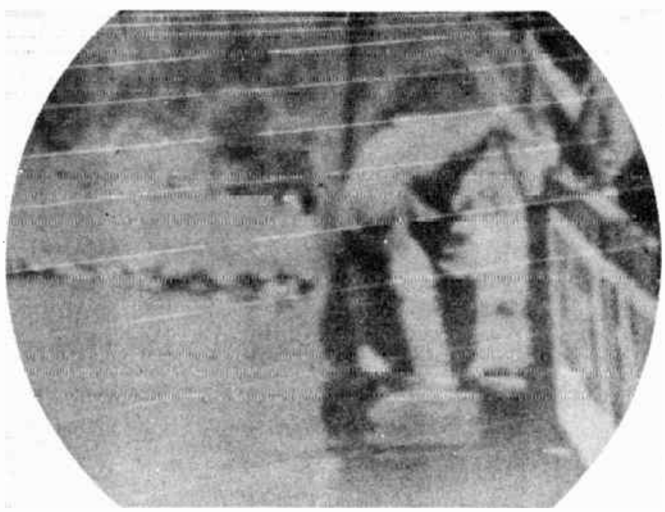

Fig. 22. Vertical retrace lines.

SLOPING BRIGHT LINES. Fig. 22.

These lines, which slope upward from left to right, are caused by the electron beam as it travels a zig-zag upward course during the vertical blanking periods between fields. They are called vertical retrace lines.

If the receiver has no retrace blanking circuit, the brightness control is turned too high, or the contrast control too low, or both.

Vertical hold control misadjusted.

Video amplifier tube weak. Plate or screen voltage too low.

Retrace blanking circuit trouble. Poor connections. Series capacitor too small. Series resistor too great.

Picture tube not sufficiently negative to cathode. Check for troubles in the brightness control circuit. Leaky coupling capacitor in line from video amplifier to picture tube signal input.

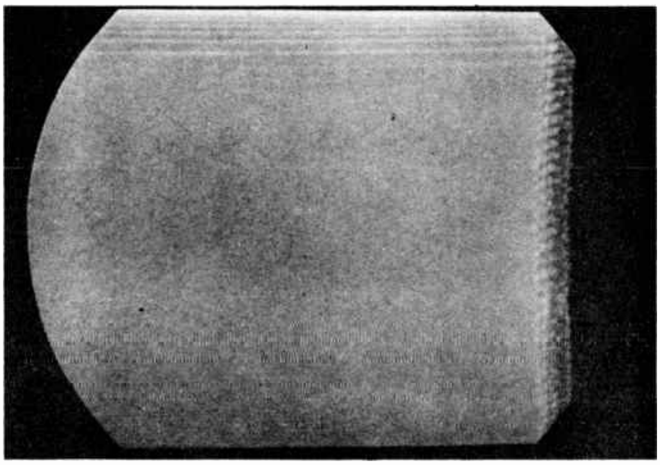

Fig. 23. Horizontal deflection distances are not uniform.

RAGGED EDGE. Fig. 23.

A ragged edge, especially noticeable at the right and sometimes extending well back into the picture area, may result from any erratic variations in any voltage which affects horizontal deflection. Common causes include slight arcing at connections, and oscillation at natural frequencies much higher than the horizontal line frequency.

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Loose or corroded connections in low-voltage d-c power supply or on B-plus distribution lines. Look especially for filter and decoupling capacitors having faulty connections to ground. Electrolytics with insulated negative may have defective connections to B-minus. Check all circuits carrying strong pulsating voltages which may cause arcing, as at the input to a power supply filter.

Intermittent shorts or opens in resistors or capacitors. Suspect any resistor which appears to have been overheated. Old electrolytics may be the trouble.

Horizontal oscillator tube, or afc tube, with high resistance internal short.

Microphonic tubes that vibrate while the ragged edge appears. Jar the receiver while watching the picture edge. If the trouble becomes worse, it might indicate loose connections as well as microphonic tubes.

Oscillation at high natural frequencies may occur in the horizontal output amplifier tube. Refer to trouble section, "Dark Line Or Lines, Vertical," under the sub-head, "Horizontal Output Amplifier".

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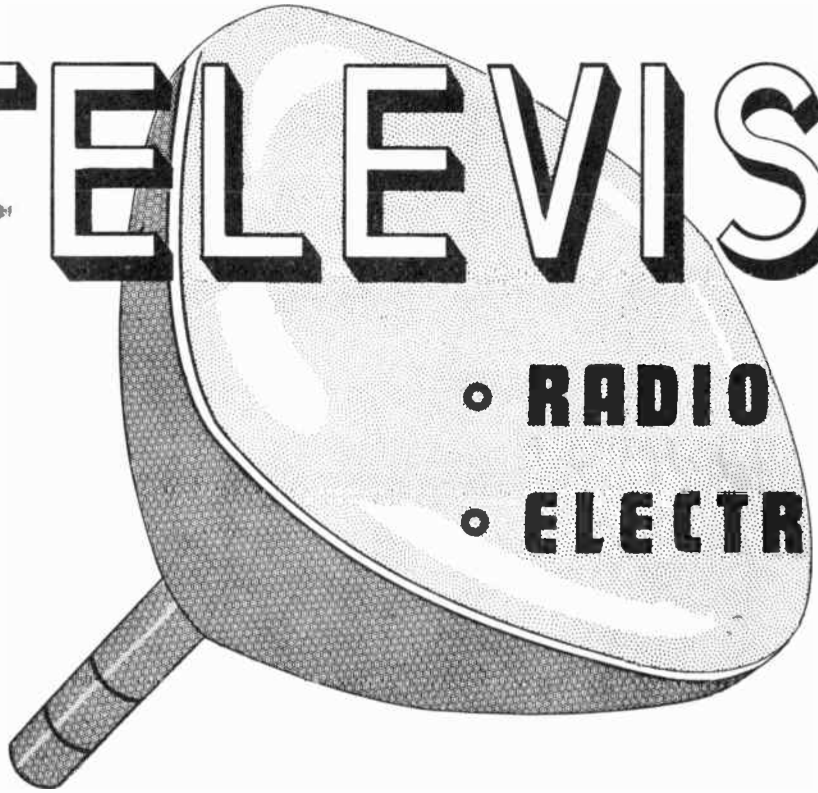

• RADIO
• ELECTRONICS

LESSON 85—PICTURE AND PATTERN ANALYSIS—PART 3

Coyne School

practical home training

Chicago, Illinois

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Lesson 85

PICTURE AND PATTERN ANALYSIS–PART 3

This is the third and final lesson dealing with identification of troubles by analysis of the effects they cause in pictures and rasters. Doubtless you have noticed that some of the suggested remedies would call for modifications of circuit design in substituting parts of different values, and in other changes. This is permissible when you understand the probable effect of a change, and when you have testing apparatus and sufficient knowledge of television principles to make such modifications without running into other troubles.

Many receivers of given make and model are improved by making circuit and parts changes in the later "runs" of production. Certain improvements appear desirable in the light of experience, and after actual field use of sets by thousands of owners. When you happen to work on a receiver from one of the early runs, replacement of parts such as capacitors and resistors with original values may not correct the trouble, because it is something later eliminated by changes of design. This is one of the reasons why our lists of troubles and remedies often suggest using more or less capacitance or resistance, or suggest other alterations, in an effort to overcome certain faults.

While attempting to locate causes for faulty pictures by working through lists of troubles, keep in mind that two or more troubles sometimes combine their effects for a result which is difficult to identify as due to any one separate trouble. This difficulty usually may be overcome by operating the receiver on as many channels as possible, on different types of programs, such as live, wire line, and motion picture reproductions, and in general by taking your time in observing picture faults before commencing to make substitutions or repairs.

CONTRAST LACKING. Fig. 1.

Pictures are weak. They appear washed out, and have an all-over gray tone. If brightness is reduced in attempting to bring out blacks and dark grays, the entire picture becomes too dark.

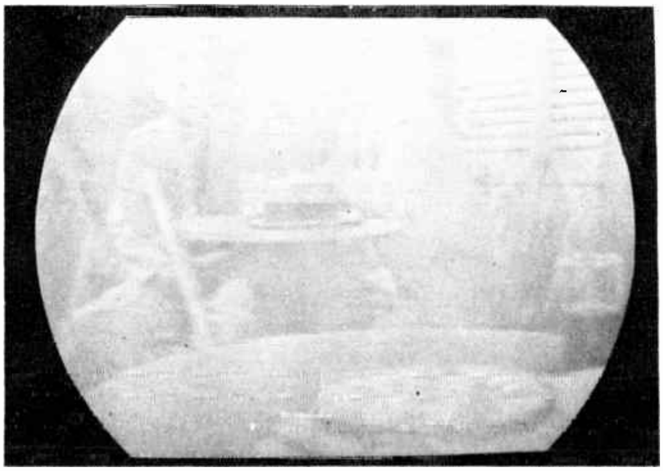

Fig. 1. Contrast is lacking, although there is plenty of brightness.

The trouble may result from weak signals or lack of gain in the receiver. If signals are weak, the fault called "Snow" usually is more noticeable than lack of contrast. Careful adjustment of a fine tuning or continuous tuning control may improve contrast. Otherwise refer to following lists of troubles.

<u>Video Amplifier And Detector Circuits.</u>

Amplifier tube weak, operated with low screen voltage or low plate voltage.

Grid bias may be insufficiently negative, allowing grid current. There should be zero potential difference across the ends of grid return resistors when measured with a VTVM.

Video detector weak, either tube or crystal diode. Detector load resistance too small.

Amplifier plate load resistor too small.

Peaking inductors open.

World Radio History

D-c restorer tube weak, or operated with wrong element voltages. Resistors on the ~~restorer cathode wholly or partially shorted.~~

I-f Amplifier.

Tube weak, operated with low plate or screen voltage.

Agc voltage remaining too negative on weak received signals.

Alignment wrong, with video i-f marker too low on response.

Tuner And Antenna

Tube weak, operated with wrong element voltages.

Misalignment of r-f, mixer, or oscillator may cause lack of gain.

If contrast is lacking on strong signals, agc voltage may remain insufficiently negative, allowing the r-f amplifier to overload.

Check all connections of transmission line at receiver end and also at antenna.

Picture Tube.

Poor connections anywhere in the grid-cathode circuit, or in leads coming to the picture tube socket.

Picture tube emission weak. Check this by trying a booster for heater voltage.

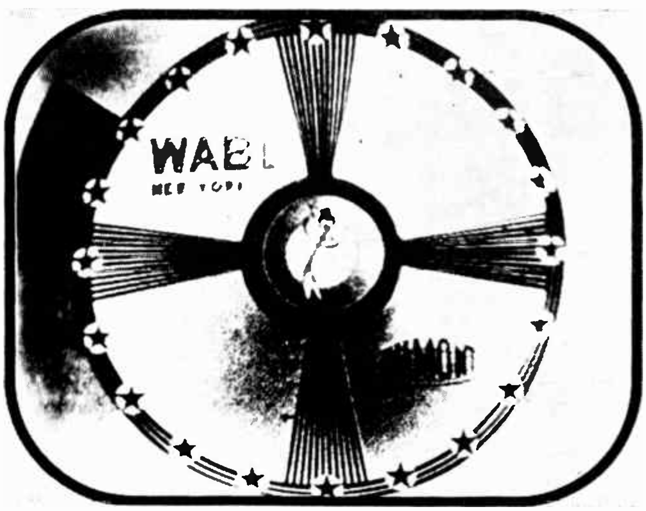

Fig. 2. There is too much contrast, intermediate gray tones are lacking.

CONTRAST EXCESSIVE. Fig. 2.

~~Pictures are all black and white, with~~ intermediate grays and tone shadings absent.

Faulty connections, resistors, or capacitors in brightness control circuit, including the control potentiometer itself. Makes it necessary to advance the contrast control too far in order to have bright pictures. Picture tube grid may remain excessively negative to the cathode at all settings of brightness control.

Picture tube second grid or first anode open circuited. Check the lead to socket and base pin 10 of the tube.

Agc system maintaining grid biases too negative. Check for leaky bypass capacitors, shorts from agc bus to ground or B-minus, poor connections along the bus, agc amplifier tube weak.

Contrast control bypass capacitor leaky or shorted, other shorts or grounds on cathode of video amplifier tube, defective control potentiometer.

Leaky coupling capacitors in video amplifier or i-f amplifier section, maintaining grid voltages insufficiently negative.

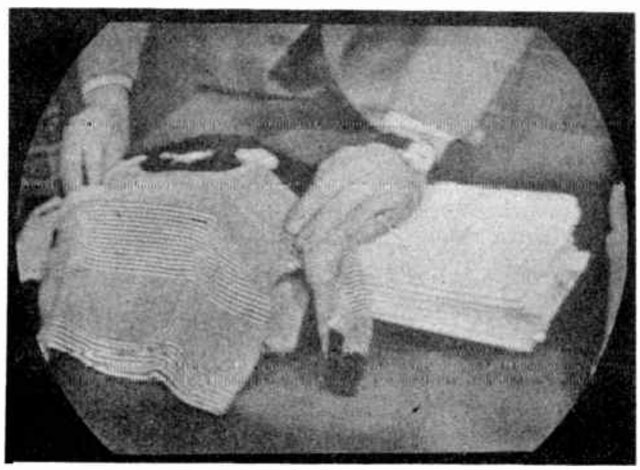

Fig. 3. Brightness is lacking, although contrast is satisfactory.

BRIGHTNESS LACKING. Fig. 3.

B-plus voltage too low. Check condition of the d-c power supply.

World Radio History

A-c power line voltage low.

Dust or soot on picture tube face and protective glass or plastic in cabinet.

Ion trap magnet not adjusted for maximum brightness. Magnet weak, or of wrong type for picture tube.

Tubes weak in i-f amplifier or tuner. These tubes have plate and screen voltages too low, or grid biases may be too negative. Check action of the agc system.

I-f amplifier misaligned, with video i-f marker too low on the response. This often causes dark backgrounds in all pictures.

Tuner selector switch contacts dirty or corroded.

B-plus voltage on brightness control circuit such that picture tube grid too negative to cathode at all times.

If pictures are best at one setting of the brightness control, and become dark with the control turned either direction, check connections of a width control inductor or capacitor on the horizontal output transformer. Such units may be connected across too many turns of the transformer winding.

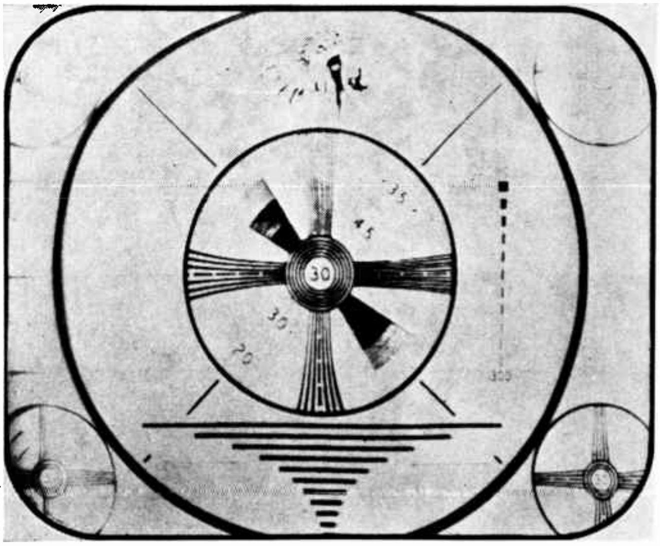

Fig. 4. Brightness is excessive, with contrast satisfactory.

BRIGHTNESS EXCESSIVE. Fig. 4.

Brightness which cannot be reduced to a level allowing good picture reproduction usually is due to troubles in the brightness control circuit.

B-voltage on control circuit too high or too low, depending on the type of circuit.

Connections open, loose, shorted.

Bypass capacitor leaky, shorted. May prevent variation of brightness by control.

Series resistor, or control potentiometer, open, shorted, of wrong value.

Video amplifier coupling capacitor leaky.

Oscillation in i-f amplifier section. The picture tube screen becomes brilliantly white, with no pictures or trace lines visible. The set must be turned off at once, to prevent permanent damage to the picture tube screen.

Voltage too great on picture tube second grid or first anode, base pin 10.

Picture tube cathode-heater leakage. Internal high-resistance short between grid and cathode. These troubles may prevent variation of brightness by means of the brightness control.

BRIGHTNESS FLUCTUATES

When brightness sometimes increases and again decreases on the same program or same scene in a program, some of the following troubles may be present.

D-c Restorer Circuit.

Tube weak or otherwise defective, with erratic emission. There may be an internal short between plate and cathode.

Cathode circuit resistors open, shorted.

Agc Circuit.

Control tube weak or otherwise defective.

World Radio History

When pictures remain momentarily dark after strong noise interference, check for incorrect values of resistors or capacitors at the control tube or other source of agc voltage. The time constant is too long.

Picture Tube Circuits.

High-voltage filter capacitor leaky.

If brightness gradually increases after receiver turned on, and tends to become excessive, check the d-c return of the picture tube signal input element, grid or cathode. Follow all the way from the tube socket to ground or B-minus, looking for opens or very high resistance.

SHADOWS. Fig. 5.

These often are called neck shadows, because they result from the electron beam striking the inside of the picture tube neck before reaching the screen. Another name is corner shadows.

First, carefully adjust the ion trap magnet for maximum brightness of pictures, regardless of the effect on shadows. Then adjust the centering to eliminate shadows. Centering may be by means of moving a focus coil or PM focus magnet, or by adjustment of a PM centering magnet, or by adjustment of centering controls which alter the flow of direct current in the deflecting yoke coils. Finally, the ion trap magnet may be slightly readjusted to any point within a range that

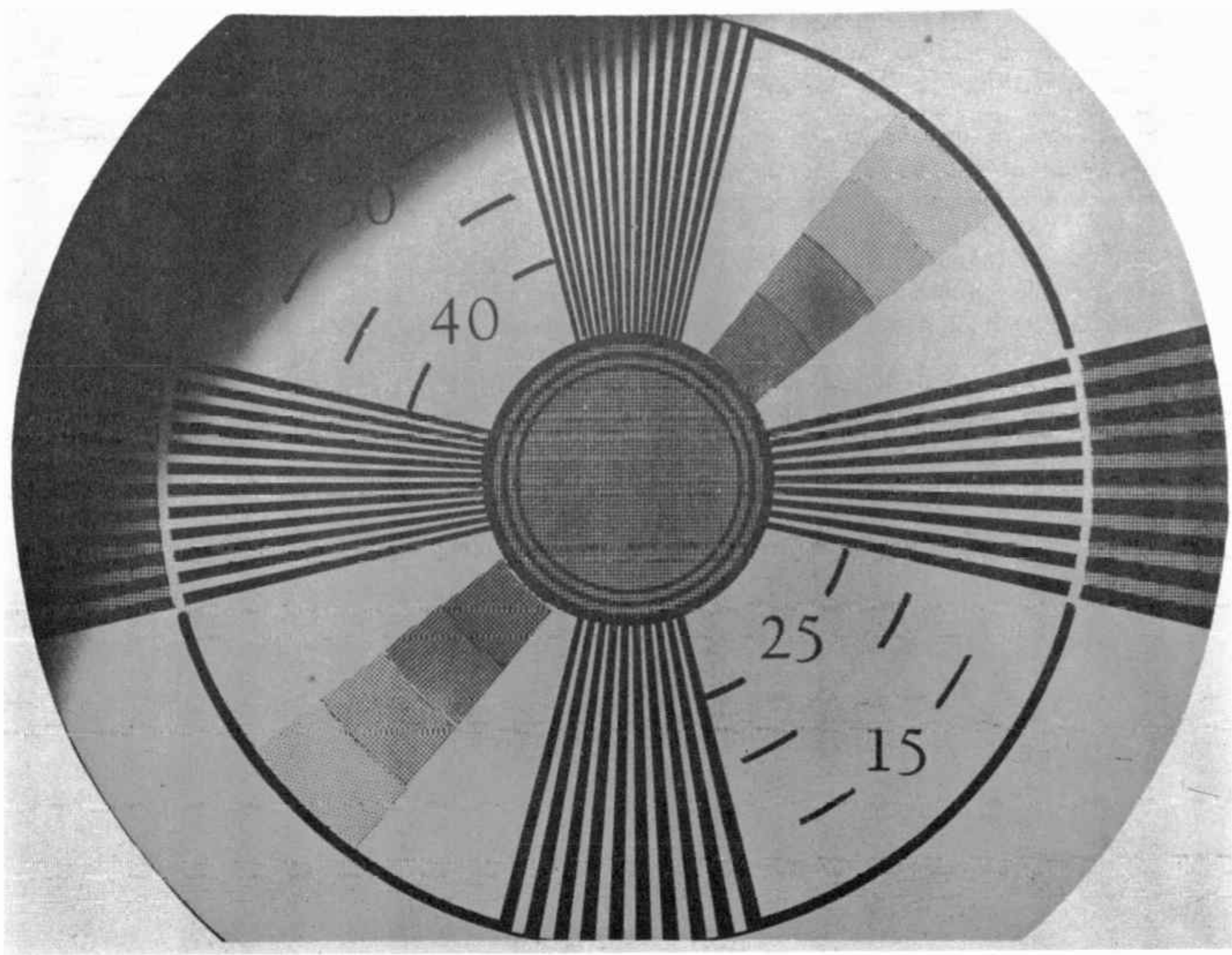

Fig. 5. The electron beam strikes the picture tube neck.

World Radio History

does not reduce brightness, provided this re-adjustment helps eliminate a shadow. If the shadow remains, check for the following troubles.

Focus Coil Or PM Focuser.

Too far back from rear end of deflecting yoke.

Not centered (concentric) around neck of picture tube.

Leads reversed to focus coil. The coil field combines with field of ion trap magnet to displace the electron beam.

Picture Tube And Accessories.

Yoke too far back from flare or cone of picture tube.

Centering magnet on electrostatically focused picture tube too far forward or back on the tube neck.

Sometimes rotation of the picture tube around its neck axis helps to eliminate shadowing.

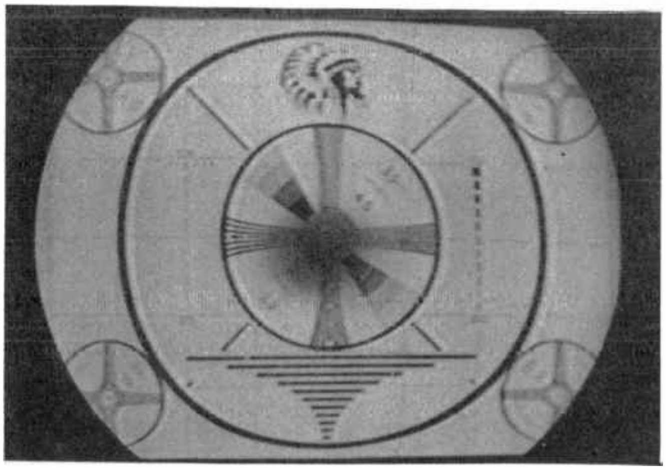

Fig. 6. There is an ion burn near the center of the screen.

ION BURN. Fig. 6.

The phosphor coating or screen material inside the face of the picture tube has been permanently damaged by misadjustment of an ion trap magnet, with the wrong adjustment allowed to continue for some time. All pictures appear darkened where the burn has occured. If the effect is too objectionable, the only remedy is a new picture tube.

Fig. 7. Vertical deflection is reversed.

Fig. 8. Horizontal deflection is reversed.

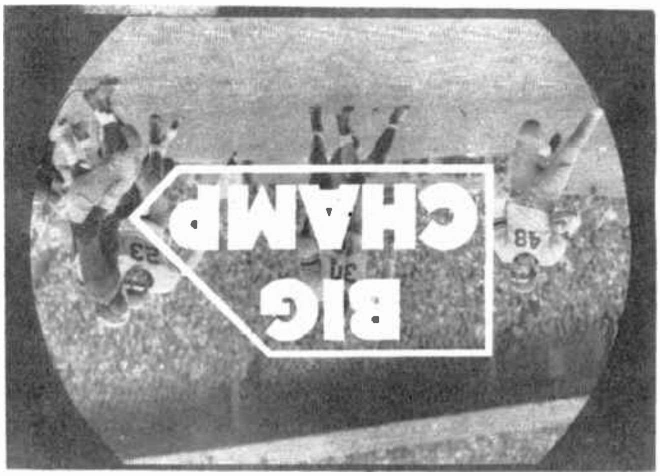

Fig. 9. Both vertical and horizontal deflections are reversed.

World Radio History

REVERSED PICTURES. Figs. 7, 8, and 9.

Connections are interchanged to vertical coils in the deflecting yoke, to horizontal coils, or to both pairs of coils. The lead which should go to one end of a pair of coils actually is in the opposite end, and the lead which should be on that opposite end is on the first one.

The reversal of leads may be at the yoke, at a plug type cable connector, or at connections to the vertical and horizontal output transformers.

If only vertical leads are interchanged, pictures appear as in Fig. 7. Any lettering will be upside down, but letters will be in their correct order from left to right.

In only horizontal leads are interchanged, pictures appear as in Fig. 8. Lettering will be right side up, but the order of letters will be reversed from right to left.

With vertical and horizontal leads both reversed, pictures will be upside down and reversed from right to left. If you turn your head to look at the pictures upside down, everything will appear in correct relative positions.

Fig. 10. Pictures are too narrow, although height is correct.

WIDTH TOO NARROW. Fig. 10

Width, or horizontal size, is affected not only by adjustment of a horizontal size or width control, but also by adjustment of horizontal linearity and horizontal drive controls. Since each of these three controls affects the other, all should be adjusted at the same time when width cannot be corrected by the horizontal size control alone.

Width depends on amplitude or strength of sawtooth current in the horizontal deflecting coils of the yoke, and on sawtooth voltages that produce this current. Changing any adjustment connected to or coupled to the horizontal output transformer, in an effort to increase width, may at the same time increase the high voltage to the picture tube anode. This higher anode voltage tends to make pictures somewhat narrower, because the electron beam is more difficult to deflect.

Width Control Inductor.

Adjusted for too little inductance, slug too far out of winding.

Connected to wrong terminals of horizontal output transformer, across too many turns.

Shorted inductor winding.

Control inductor of wrong type, not enough inductance.

Width Control Capacitor.

This is a capacitor connected across part or all of the secondary of the horizontal output transformer.

Leaky, shorted, disconnected, open.

Too little capacitance.

Horizontal Oscillator Circuit.

Tube weak, or otherwise defective or not suited to oscillator service.

Plate voltage too low. Check connections, resistors, and other parts on the B-plus line for oscillator or discharge tube plate.

World Radio History

Sawtooth capacitor leaky, too much capacitance.

Horizontal Output Amplifier Circuit.

Tube weak or otherwise defective.

Screen voltage too low. If screen voltage is increased check the plate current to avoid exceeding the allowable limit of power dissipation.

Boosted-B voltage too low. This voltage is applied through the horizontal output transformer to the amplifier plate. Do not attempt measuring voltage at the plate. Check the damper tube and its low-side circuit elements.

Sawtooth voltage of too little amplitude at the amplifier grid. If not already done, check the horizontal oscillator tube, also all connections and parts between plate of the oscillator or discharge tube and the grid of the horizontal output amplifier. Pay especial attention to coupling capacitors and the drive control.

Amplifier grid bias too negative. Check resistors and capacitors in the cathode-bias circuit.

Amplifier grid return resistor too low value, shorted.

Damper And Boosted-B Circuit.

Tube weak or otherwise defective.

B-plus voltage from low-voltage d-c power supply too low. This is the B-voltage applied directly or indirectly to the damper, and boosted by damper action.

Capacitors on low side of damper circuit leaky, shorted. Excess capacitance to ground or B-minus from the low side of the damper will reduce width, but this is a most unlikely trouble.

Horizontal Output Transformer.

Terminals or leads shorted to ground, or have poor connections.

Yoke leads, or others, connected to wrong terminal taps on transformer.

Transformer and yoke not matched. Either or both may be of the wrong type.

Yoke And Leads.

Connections loose, corroded. Any cause for abnormally high resistance or impedance in series with horizontal deflecting coils.

Capacitor across a horizontal coil open, disconnected. This usually causes pictures to be wedge shaped rather than uniformly narrow from top to bottom.

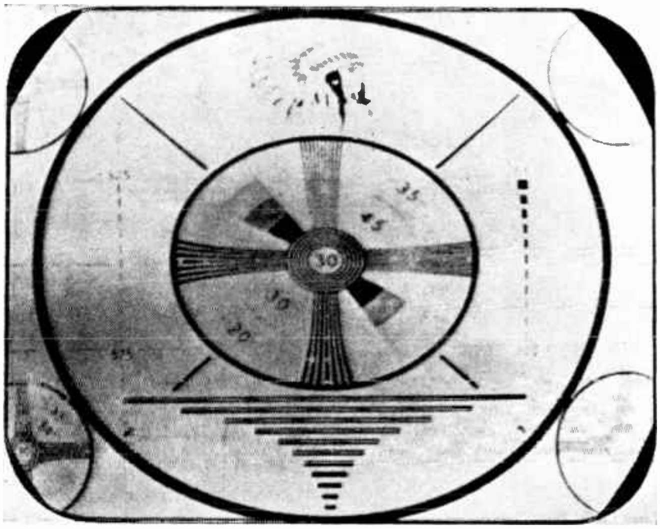

Fig. 11. Width is somewhat too great, with height correct.

WIDTH TOO GREAT. Fig. 11.

Many of the troubles which cause excessive width are, in a general way, the opposites of troubles causing too little width, as listed under the preceding heading, "Width Too Narrow". Do not forget that controls for horizontal size, linearity, and drive must be suitably adjusted in relation to one another. Misadjustment of any one of the three may make pictures too narrow.

Width Control Inductor And Capacitor.

Inductor disconnected, open circuited.

Adjusted for too much inductance, slug too far into winding.

World Radio History

Inductor connected across wrong terminals of horizontal output transformer, across too few turns of the transformer winding.

Inductor of wrong type, has too much inductance.

Capacitor on output transformer winding has too much capacitance.

Horizontal Output Amplifier Circuit.

Screen voltage too high. Check the B-supply line for the screen. If necessary, use more resistance in series with the screen.

Amplifier grid bias not sufficiently negative. Check resistors and capacitors in the cathode-bias circuit.

Amplifier grid return resistance too great, resistor disconnected or open.

Sawtooth capacitor, on line between horizontal oscillator and amplifier, has too little capacitance.

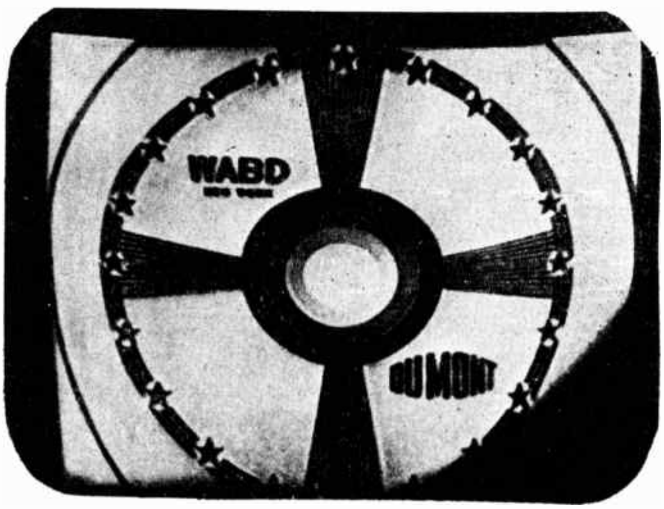

Fig. 12. Lack of height, with width approximately correct.

HEIGHT TOO LOW. Fig. 12.

Vertical linearity control may be misadjusted, or height and linearity controls not correctly adjusted in relation to each other.

Vertical Size Or Height Control Circuit.

Connections loose, corroded, high resistance.

Series resistors partially open, too much resistance.

Bypass or decoupling capacitor shorted, leaky.

Control potentiometer defective, high resistance.

Vertical Oscillator Circuit.

Tube weak, or operating with plate voltage too low.

Coupling capacitor or bypass capacitor leaky, shorted, of wrong value.

Sawtooth capacitor too large, leaky.

Feedback transformer defective, on blocking oscillator.

Vertical Sweep Circuit.

Output amplifier tube weak. Operated with voltage too low on plate or screen, or with grid bias too negative.

Coupling capacitors or bypass capacitors leaky, shorted, of wrong value.

Sawtooth voltage too weak at output amplifier grid. Check all parts of the circuit between vertical oscillator plate and amplifier grid.

Vertical Output Transformer

Opens, grounds, or shorts in external connections, or in the windings.

HEIGHT TOO GREAT. Fig. 13.

Check adjustments of height and vertical linearity controls.

When controls are adjusted as well as possible, excessive height ordinarily indicates too great voltage at the plate of the vertical oscillator tube. Check for series resistors shorted or of wrong values, wrong connections to B-plus supply lines, partially shorted control potentiometer.

World Radio History

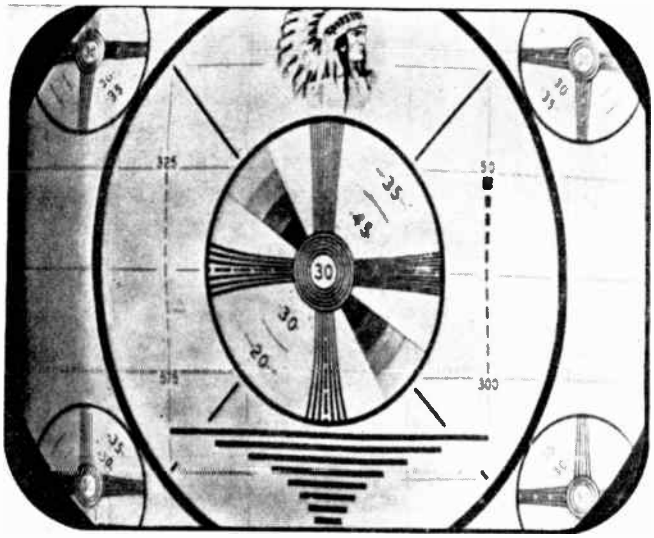

Fig. 13. Height is too great, while width is correct.

Fig. 14. The picture is too small in both height and width.

WIDTH AND HEIGHT TOO SMALL. Fig. 14.

B-voltage too low on entire receiver, or at least to horizontal and vertical oscillators and sweep sections. Check condition of low-voltage d-c power supply rectifier, also filter capacitors, resistors and chokes. Check voltage dropping resistors and decoupling capacitors in the B-voltage distribution lines.

A-c power line voltage may be low during periods when pictures are too small.

Damper circuit troubles, when boosted-B voltage is applied to both horizontal and vertical oscillators, to vertical output amplifier, and to screen of horizontal output amplifier. The damper tube may be weak. Check damper circuit capacitors, resistors, and a linearity control inductor. Look for poor connections and other causes for high resistance anywhere in the damper circuit.

High-voltage on the picture tube might be excessive, although this would be an unlikely cause for pictures noticeably small.

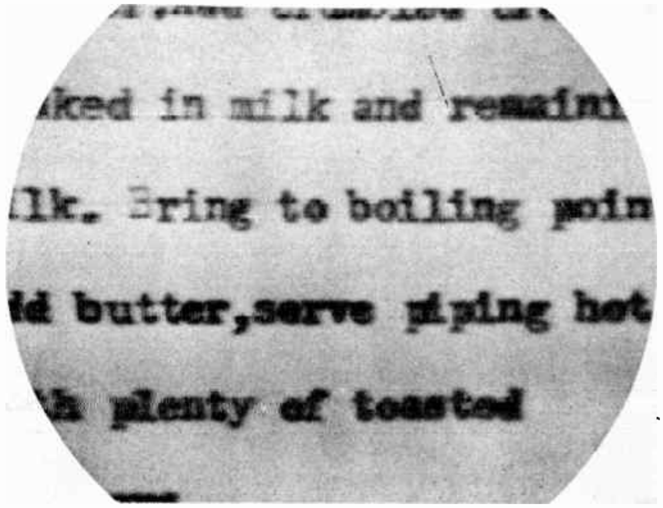

Fig. 15. The picture is too large in both width and height.

WIDTH AND HEIGHT TOO GREAT. Fig. 15.

The probable cause is low voltage on the picture tube second anode or ultor, allowing the electron beam to be deflected too far in all directions.

Check the entire high-voltage power supply system. Look especially for a leaky high-voltage filter capacitor, or a shorted high-voltage filter resistor, strange as this may seem as a cause for pictures too large. Check the high-voltage rectifier tube, also all connections leading to the picture tube anode terminal. Sparking or arcing anywhere in the high-voltage power supply circuits will lower the anode voltage.

Capacitance to ground from the high side of the damper circuit, plate or cathode, will allow excessively large pictures. Such trouble might result from misconnection of a filter capacitor in the high-voltage supply, or of a capacitor across part of the horizontal output transformer winding.

World Radio History

SIZE FLUCTUATES

Width and height may become greater or less with changes of the brightness control, or of d-c type centering controls, or at all times.

Brightness Varies Size

This indicates low voltage at the second anode or ultor of the picture tube. Check all parts of the high-voltage power supply for poor connections, weak rectifier tube, defective cable connector, and other faults. The effect is called blooming.

Centering Varies Size.

Check all parts of the centering control circuit, especially the bypass capacitor across the control potentiometer terminals. The potentiometer may be defective.

Continual Expansion And Contraction.

This effect, often called breathing, ordinarily results from beating of a 60-cycle magnetic field from the low-voltage power load must not be too great, for that would re- the yoke. The two fields are more or less out of phase. The remedy would be to move the power transformer, or use a transformer with an external copper band acting as a shorted turn.

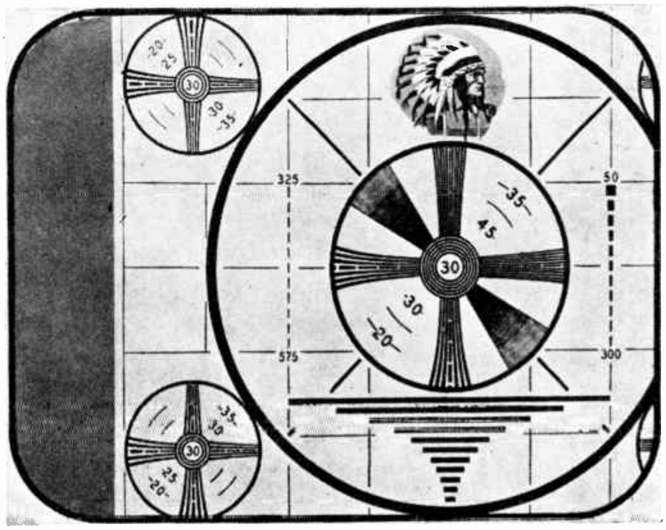

Fig. 16. Pictures are too far to the right, faulty centering.

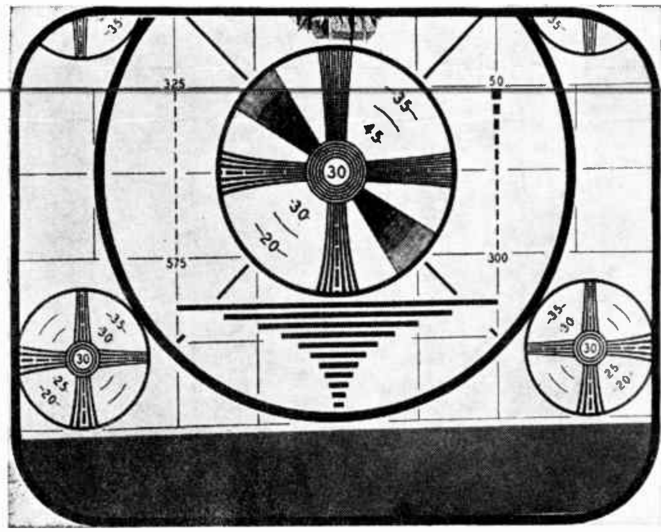

Fig. 17. Pictures are too high in the mask, faulty centering.

CENTERING WRONG. Figs. 16 and 17.

Pictures maybe too far to the right (Fig. 16) or they might be too far to the left. In other cases pictures might be too far up on the screen (Fig. 17) or they could be too far down. Horizontal and vertical centering may be wrong at the same time.

Horizontal, Vertical, Or Both At Once.

Focus coil or PM focuser. Not concentric with picture tube neck. Too far back from yoke, or possibly too far forward. Leaks reversed to focus coil. Focus coil or magnet turned front for back.

PM centering magnet. Rotated to wrong position around picture tube neck. May be weak, possibly from having been so close to the yoke as to be partially demagnetized by magnetic deflecting fields.

Yoke tilted on picture tube neck, or too far back from flare of tube.

Ion trap magnet misadjusted. This usually causes lack of brightness, or shadows, rather than difficulty in centering.

D-c centering control circuit trouble. Check connections, resistors, bypass capacitors, potentiometers.

Only Horizontal Centering.

World Radio History

Wrong adjustment or horizontal hold control.

Horizontal frequency or afc misadjustment. Lock controls, stabilizing controls, phasing controls, and others in the afc or horizontal oscillator circuits can prevent centering when misadjusted.

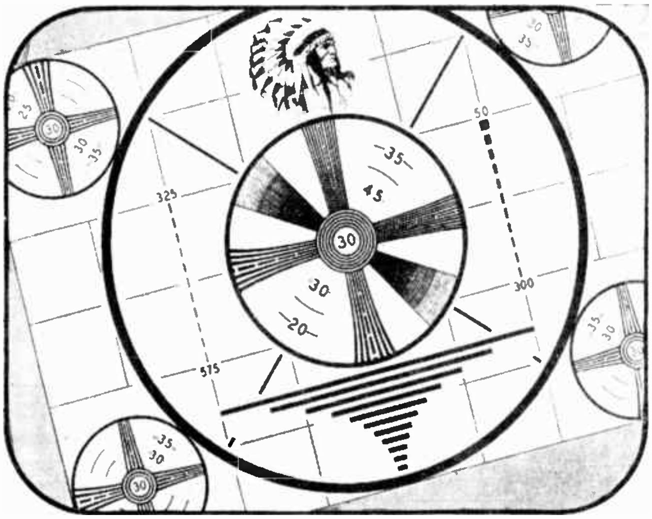

Fig. 18. The pictures are tilted.

TILTED PICTURES. Fig. 18.

Pictures are rotated to the left or right on the screen of a picture tube operated with magnetic deflection, and in the mask opening. This may be called a skew.

The deflecting yoke ahould be rotated in its bracket the same direction that the picture is to be rotated for making a correction. Were the picture tube to have electrostatic deflection, the entire tube would have to be rotated.

Focus coil or PM focuser. Too close to the yoke, whereupon adjustment of focusing usually tilts the pictures. Leads to a focus coil may be interchanged. A coil or PM focuser may be turned front for back.

BENDING OR PULLING. Fig. 19.

Lines which should be vertical at the top of pictures bend to the right or left. The amount or direction of bending may change with variations of background lighting or with movement of people and objects in pictures.

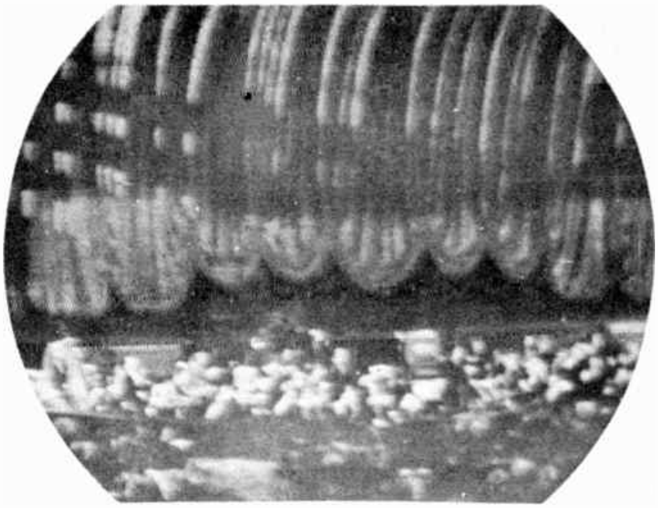

Fig. 19. Bending of lines which should be straight at the top of pictures.

As a rule there is at the same time a slight folding which causes light-toned shadowy outlines to move near one side or the other of pictures, most noticeably on areas which normally are dark.

Adjustment of the horizontal hold control usually is critical; a slight change one way or the other may alter the amount of bending, or may make the fault disappear temporarily. Bending at the top of pictures, as now being considered, does not appear on the raster.

The usual cause for bending is that horizontal sync pulses applied to the afc circuit are too weak, are of irregular strength or amplitude, or are of ragged and excessively peaked waveform. The electron beam is not instantly brought into horizontal synchronization at the end of vertical blanking and at the beginning of each field. In the absence of other more noticeable picture faults, troubles which cause bending most often are in the afc section or in the sync section, or in horizontal frequency controls.

Frequency Controls.

Check the adjustment of a horizontal stabilizing control, horizontal lock control, and of any other controls in the horizontal oscillator or afc circuits.

Horizontal Afc Circuit.

World Radio History

Tube weak or otherwise defective for this application.

Circuit unbalance, delivering the wrong correction voltage. Check values of resistors and capacitors. Use a VTVM to measure correction (biasing) voltage applied to the horizontal oscillator while feedback pulses from the sweep circuit temporarily are cut off by disconnecting a feedback lead. The d-c voltage should be no more than about one-half volt.

Vertical sync pulses getting into the afc circuit. Check decoupling or filtering capacitors and resistors on lines from sync section to afc circuit.

Ripple voltage or audio voltage reaching the afc circuit.

Sync Section.

Tube weak or otherwise defective.

Voltage too high or too low on any tube element. Plate voltages on sync separators, limiters, and clippers are quite critical in most receivers.

Coupling capacitor leaky.

Load resistor or voltage divider resistor in a plate circuit too great or too small. This would affect the shaping of sync pulses.

Signal input to the first tube in the sync section too strong or too weak. This is likely to prevent separation of picture signals from sync pulses with too much input, or to unduly weaken the sync pulses with too little input. Check capacitors and resistors on the line to the first sync tube.

Video Amplifier Circuit.

Troubles in this circuit, from video detector to sync takeoff, may cause bending.

Tube weak.

Plate or screen voltage too low. Grid bias not sufficiently negative when plate and screen voltages are normal.

Plate load resistance too small, reducing the gain at low video frequencies. The plate load must not be too great, for that would reduce high-frequency gain.

Coupling capacitor open, too small to pass low video frequencies without excessive attenuation, leaky.

I-f Amplifier and Tuner Sections.

Misaligned, to bring video carrier or video i-f markers too low on the frequency response. This weakens the sync pulses.

Agc system not maintaining grid voltages sufficiently negative, thus allowing excessive signal input to the video amplifier and overloading of that amplifier to cause sync pulse limiting.

Incorrect adjustment of agc threshold control, or delay control.

LINEARITY POOR, VERTICAL.
Figs. 20 and 21.

Poor vertical linearity causes some objects in pictures to appear too high while other objects in the same picture appear too low, or compressed top to bottom. The most common cause is misadjustment of vertical linearity and height controls, with either of these controls set incorrectly in the first place, and the other adjusted (incorrectly) in an attempt to make pictures high enough to fill the mask area. Faults in some receiver circuits may cause similar effects.

Linearity Control Circuit.

Bypass capacitor open, leaky, too little capacitance.

Series resistor of wrong value.

Control potentiometer defective.

Vertical Oscillator Circuit.

Tube weak or otherwise defective.

Plate voltage too low or too high. Check condition of height control potentiometer and

World Radio History

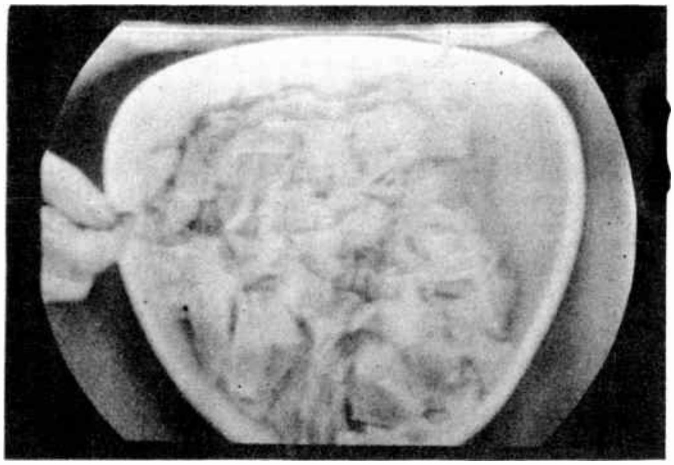

Fig. 20. The cooking dish actually is circular, but appears compressed at the top.

Fig. 21. Everything near the top of pictures appears too high.

of capacitors and resistors in the oscillator plate circuit.

Sawtooth capacitor too large, too small, leaky.

Peaking resistor in series with sawtooth capacitor of wrong value, shorted.

Vertical Output Amplifier Circuit.

Amplifier tube weak or otherwise defective.

Plate or screen voltage too low. Grid bias too negative.

Defective capacitor or resistor in lines between amplifier grid and oscillator plate. Look for opens, shorts, wrong values, leaky elements.

If not already examined during checking of the linearity control circuit, look at the cathode resistor and bypass capacitor.

Vertical output transformer defective. Shorts or grounds on transformer leads.

Supply Voltages.

Ripple voltage getting into circuits of vertical oscillator or amplifier.

B-plus voltage too low to these circuits.

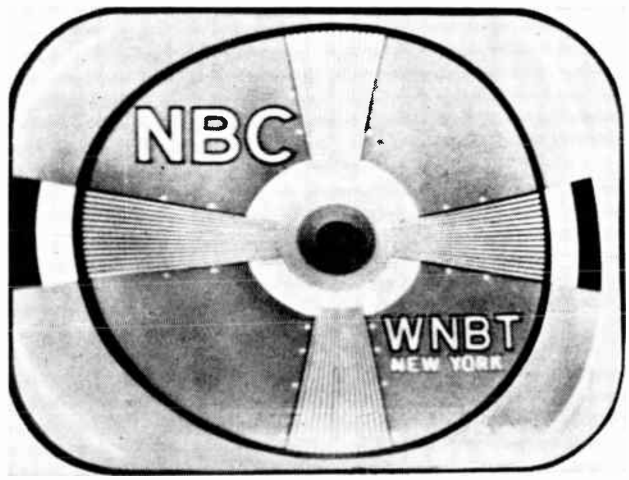

Fig. 22. There is a moderate degree of horizontal non-linearity.

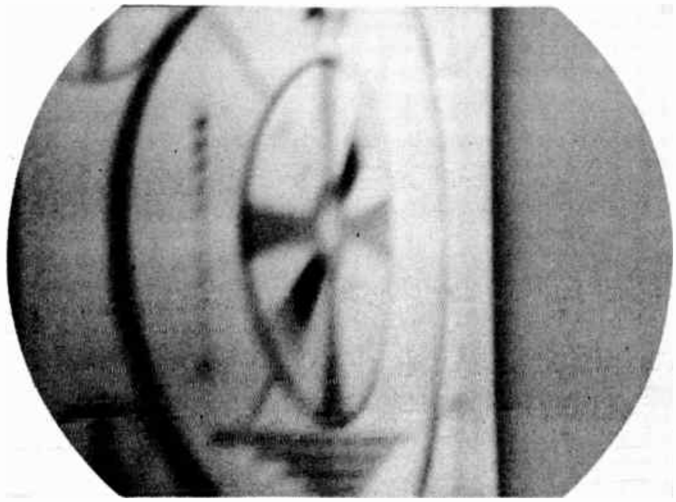

Fig. 23. Extreme horizontal non-linearity, indicates serious trouble.

World Radio History

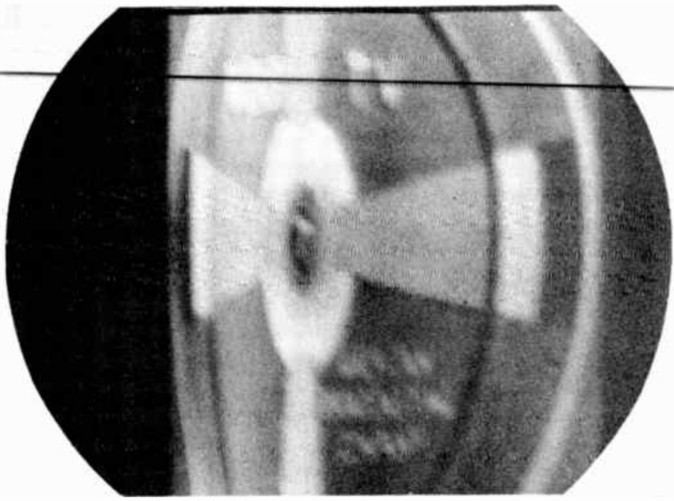

Fig. 24. Another example of extreme horizontal non-linearity.

LINEARITY POOR, HORIZONTAL
Figs. 22, 23, and 24

Different portions of the same picture are abnormally wide while others are too narrow. There is stretching and compressing in a horizontal direction. There may be only moderate non-linearity, as in Fig. 22, or extreme distortion as in Figs. 22 and 23. Moderate non-linearity usually may be corrected by correct adjustment of controls for horizontal linearity and for width, possibly with some readjustment of the drive control at the same time. All three of these controls ordinarily must be adjusted during a single service operation. Extreme non-linearity, Figs. 22 and 23, nearly always means troubles in receiver circuits other than service controls.

When there is only slight non-linearity, examine pictures from other channels before making any adjustments. Linearity may differ slightly between stations, and making correction for one channel might cause more distortion on other channels.

Linearity Control.

Capacitors at ends of control inductor shorted, open, too much or too little capacitance.

Inductor shorted, or of wrong type.

Resistor between damper cathode and plate of wrong value, open, poor connections.

Width Control.

Inductor on horizontal output transformer misadjusted, usually for too little inductance.

Inductor of wrong type, too much or too little inductance.

Horizontal Oscillator Circuit.

Tube weak, or operated with plate voltage too high or too low.

Sawtooth capacitor of wrong value or defective.

Peaking resistor in series with sawtooth capacitor of wrong value or defective.

Horizontal Output Amplifier Circuit.

Tube weak.

Screen voltage wrong, usually too low.

Amplifier grid return resistor too small, partially shorted.

Bypass capacitor for cathode or for screen too small, open, leaky.

Capacitors defective on line between amplifier grid and oscillator plate. Check the drive capacitor and other capacitors to ground or B-minus.

Damper Circuit.

Tube weak or otherwise defective, possibly a slight internal short.

Capacitor or resistor on low side circuit open, wrong value, otherwise defective.

Damper plate or cathode connected to wrong terminal of output transformer.

Horizontal Output Transformer And Yoke Coils.

Leaky or otherwise defective capacitor between low side of yoke coils and B-plus or boosted -B supply line.

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Yoke leads connected to wrong terminals or taps on output transformers.

Transformer and yoke not of types designed to work together, inductances not matched. Improvement sometimes results from using different tap connections on the transformer.

Yoke coils shorted or grounded internally, leads shorted or grounded.

Output transformer defective in windings.

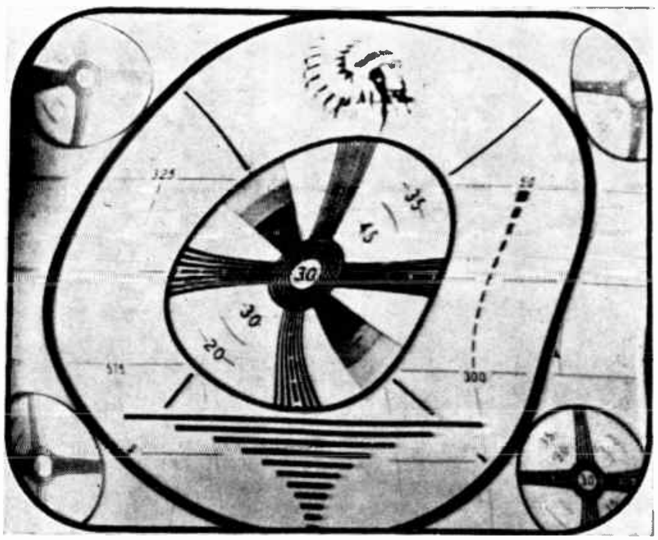

Fig. 25. Pictures may be non-linear in several directions at once.

LINEARITY POOR, VARIOUS DIRECTIONS
Fig. 25.

A fault such as shown by the photograph often results from turning the contrast control too high. If this control has to be so far advanced that distortion occurs, there probably is lack of gain in amplifiers from the tuner through to the one on which is the contrast control, although trouble may be in amplifiers between the contrast control and picture tube. Check for weak amplifier tubes in the tuner, the i-f amplifier section, and the video amplifier section.

Magnetic Fields.

Picture lines may be pulled one way or another by strong magnetic fields near any part of the picture tube. Check the following.

PM speaker or speaker with field coil, or choke in the d-c power supply.

Any steel objects inadvertently left close to a PM focuser or to an ion trap magnet.

Brackets supporting the yoke and other accessories on the picture tube neck, or metal brackets at the face end of the picture tube, may be magnetized.

Metal cone of a picture tube may be magnetized.

Note: A pocket compass may be used to detect permanent magnetization of any parts made of steel. The compass needle will be strongly attracted to such parts. Demagnetization requires suitable equipment.

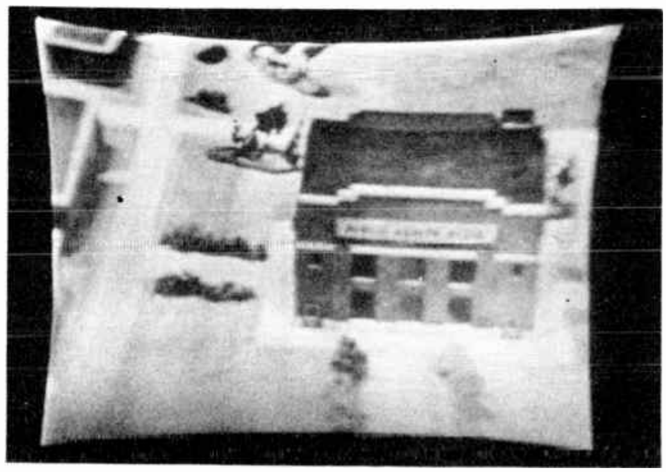

Fig. 26. This is called the pincushion effect.

PINCUSHION EFFECT. Fig. 26.

Corners of pictures appear pulled out, while sides, top and bottom bow inward. This fault may occur with picture tubes having cylindrical face plates. It is corrected by altering the positions of two small permanent magnets located on opposite sides of the picture tube close to where the neck joins the flare. The two magnets are supported by brackets designed to allow movement toward or away from the picture tube, or upward or downward or at angles.

Adjustment of the correction magnets is a matter of trial and error. Loosen any locking device that holds the magnets in posi-

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tion, then move them one way and another until both sides of pictures or a raster are vertical, with top and bottom horizontal.

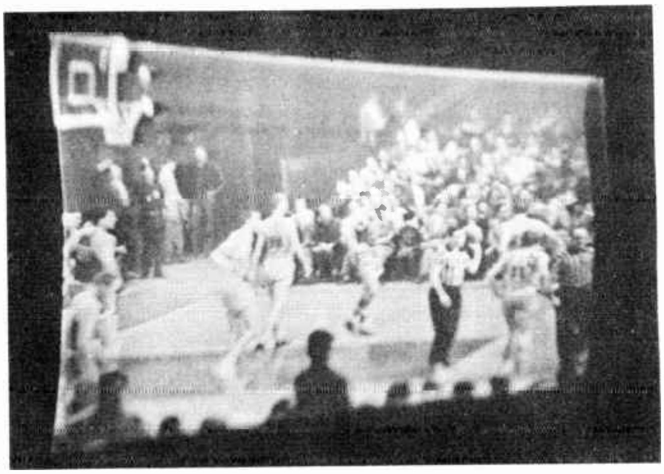

Fig. 27. There is trouble in vertical deflecting circuits or coils.

Fig. 28. The trouble is in horizontal deflecting circuits or coils.

WEDGE SHAPED PICTURES.
Figs. 27 and 28

Pictures have less height on one side than on the opposite side, or are not of the same width at top and bottom. There is tapering from one side to the other, or between top and bottom. The effect sometimes is called keystoning.

Accessory Troubles.

If the fault is not very bad, if there is only moderate tapering, check first for the following causes.

Focus coil or PM focuser in wrong position on picture tube neck or tilted with reference to the axis of the picture tube.

Ion trap magnet in wrong position on tube neck. Adjust the magnet for maximum brightness.

Deflecting yoke not centered (concentric) with picture tube neck, or possibly tilted with reference to the picture tube axis.

Yoke Troubles.

If pictures have less height on one side than on the other side, Fig. 27, trouble exists in the vertical deflecting coils or their circuit. If pictures are not of the same width at top and bottom, Fig. 28, trouble exists in the horizontal deflecting coils or their circuit. In any case of severe wedging, one coil of a pair is producing less deflecting field strength than the other coil of that pair. Check for the following troubles.

One coil of a pair, or its connections, shorted or open. The trouble may be in the winding itself.

Capacitor or resistor across one coil of a pair shorted, or wrong value, or the capacitor may be leaky.

Coils displaced in the yoke structure. Usually requires a new yoke.

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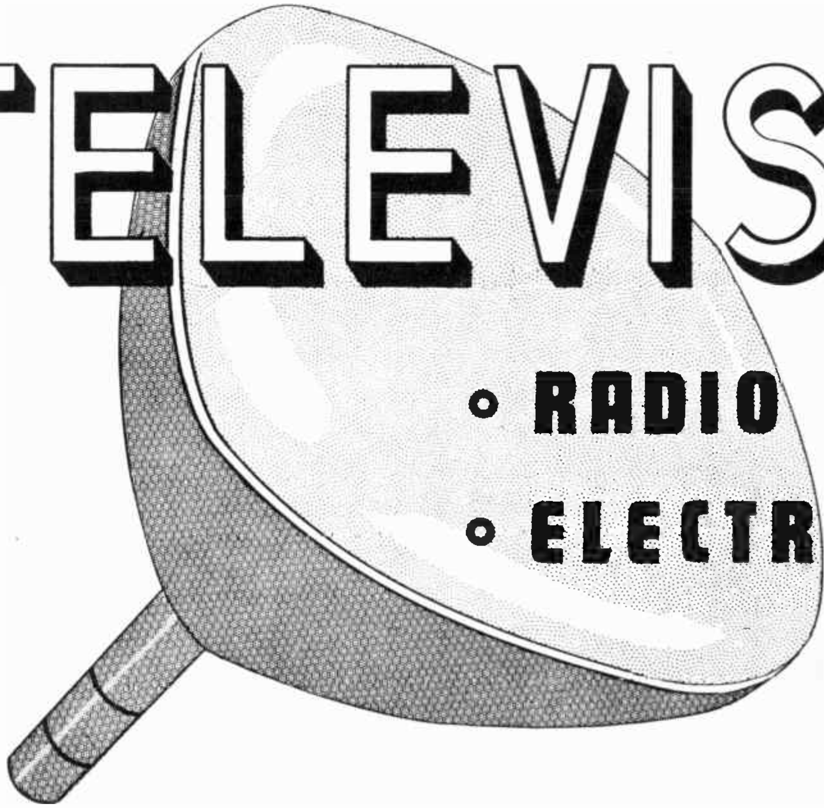

- RADIO
- ELECTRONICS

LESSON 86 — TUBE TESTS AND REPLACEMENTS

Coyne School

practical home training

Chicago, Illinois

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Lesson 86

TUBE TESTS AND REPLACEMENTS

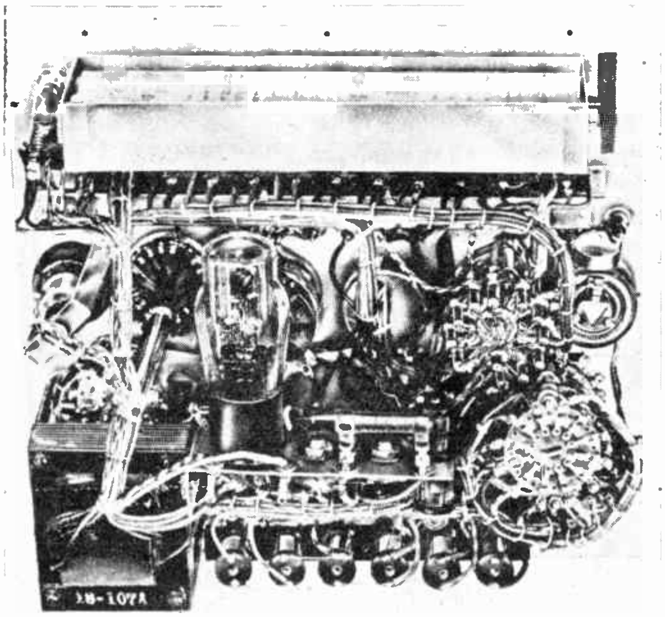

Fig. 1. There are many switches and intricate wiring connections in a tube tester.

Of all the reasons for faulty pictures, the one most often mentioned in lists of possible troubles is a weak or otherwise defective tube. It is for this reason that television service technicians so often commence their search for trouble by temporarily replacing any tube which they suspect of causing difficulty. There is no other test for faulty tubes quite so certain as replacement with another tube known to be good.

Alongside many service benches you will see a rack containing popular types of tubes, other than picture tubes, ready for use as temporary replacements. These are not necessarily new tubes; more probably they have operated well in other receivers, and thus are known to be good.

In the case of servicing sound radio receivers, the first step may be to check all suspected tubes with the help of a tube tester. This is good practice also when servicing television sets. A tube which checks weak or bad in a tester nearly always will fail to operate well in receiver circuits, except, perhaps, where plate currents normally are very small. But even though the tube checks as good, it still may give poor performance in circuits handling carrier or intermediate frequencies, or in certain frequency control circuits.

Tube testers most often measure or indicate the following characteristics and faults: 1. Either cathode emission, mutual conductance, or some combination or modification of these characteristics. 2. Cathode heater leakage. 3. Shorts between elements. 4. Excessive gas.

In order to handle all common types of tubes the test instrument must provide a wide range of voltages for heaters and filaments. There must be sockets for all kinds of receiving tube bases and numbers of base pins. Switching arrangements must apply suitable voltages to all tube elements. Many testers have provisions also for checking pilot lamps, ballasts, and such special purpose tubes as electron-ray types.

<u>EMISSION TESTING:</u> Fig. 2 is a somewhat simplified diagram of circuits such as often used for emission testing. There is a d-c current meter whose readings indicate whether a tube is good, doubtful, or definitely bad. The meter is a moving coil d-c type, rather than an a-c type, because the tube being tested allows electron flow only from its cathode to other elements, and thus acts as a rectifier to allow only pulsating direct current through the meter. This action often is called "self-rectification". An adjustable shunt on the meter allows measurements on tubes taking large or small currents.

In addition to the octal socket shown on the diagram there would be others for all kinds of tube bases. Socket lugs for tube base pins of each given number are connected to element selector switches just as the single socket is connected in the diagram. That is, base pins numbered "1" on all tubes are connected to the number 1 selector

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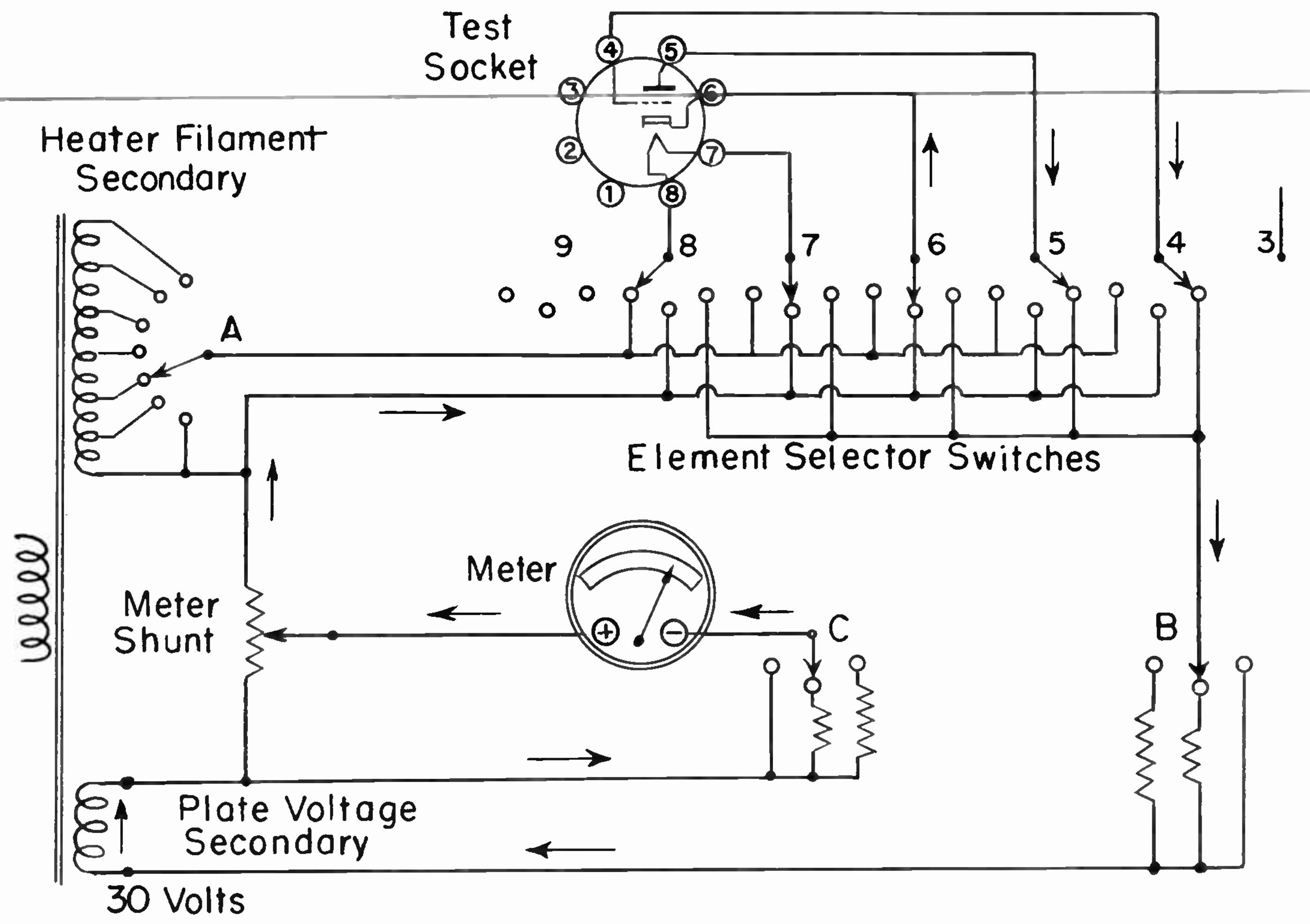

Fig. 2. Many emission testers have circuits generally similar to those shown here.

switch, all pins numbered "2" are connected to the number 2 selector switch, and so on. Each element selector switch has three positions; one for picking up plate voltage, a second for the cathode connection, and a third for heater or filament voltage. No matter how the internal elements of a tube are connected to its base pins, the switches allow connecting that element to a correct voltage.

One side of the heater is connected to the cathode. The other side of the heater is connected through its element selector and switch A to the correct voltage tap on the heater-filament secondary winding of the transformer. All tube elements other than cathode and heater are connected together by their element selector switches, and through switch B to the plate voltage secondary winding of the transformer. Resistors on switch B are selected to limit the current as may be necessary for battery operated tubes, small diodes, and other types designed for small emissions.

Electron flow for the elements of the triode shown in the octal socket of Fig. 2 is indicated by arrows on the diagram. The portion of the total electron flow that goes through the meter is determined by resistors on switch C and by the meter shunt potentiometer. Current thus is limited to the range of the meter movement, but is proportional to total emission current in the tube being tested.

Manufacturers of tube testers issue lists of tube types showing how switches and other controls are to be adjusted for testing each kind of tube. As a rule, these adjustments are such that amplifier tubes are shown as good when emission is no less than 70 per cent of average emission for all new tubes of the same type. Rectifiers and diodes are

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shown as good when their emission is no less than 80 per cent of the average for new tubes. Tubes of other types are shown as good when emissions are up to some value known to be satisfactory for each kind of tube. Emission greater than 100 per cent of average may indicate an exceptionally active cathode, but is just as likely to mean that the tube is gassy.

Cathode currents drawn during emission tests usually are greater than currents during normal operation of the tube. Consequently, emission indicated during a test may vary quite widely with little or no effect on performance of the tube in receiver circuits. Unfortunately, there are cases in which test emission is within limits for a good tube, yet the tube may be defective. An example would be a tube on whose cathode are hot spots which deliver excessive electron flow while other portions, all of which are controlled by the grid, are deficient in emission.

A tube having low emission may or may not have satisfactory mutual conductance. If normal operation of the tube in receiver circuits requires large plate current, and emission is down, mutual conductance will also be down. This because lack of emission raises plate resistance, and the greater plate resistance lowers the mutual conductance in a tube or any given structure and amplification factor. On the other hand, if a tube normally operates with small plate current, mutual conductance may be satisfactory even though emission is so low as to cause a bad test indication. Any tube showing poor emission during a test is likely to have life shorter than normal.

MUTUAL CONDUCTANCE TESTING. As explained in the lesson on "Signal Amplification", mutual conductance is a measure of how much alternating plate current results from a given alternating voltage applied to the grid. Mutual conductance, in microhms, is equal to the number of microamperes of a-c plate current per volt of a-c signal applied to the grid.

A mutual conductance test must provide the features shown by Fig. 3, or their practical equivalents. An adjustable a-c voltage is applied to the grid, which is biased by adjustable d-c voltage Eg. Adjustable d-c voltages of suitable values are applied to plate and screen. Bypasses with capacitors Cb and other decoupling arrangements are like those in receivers.

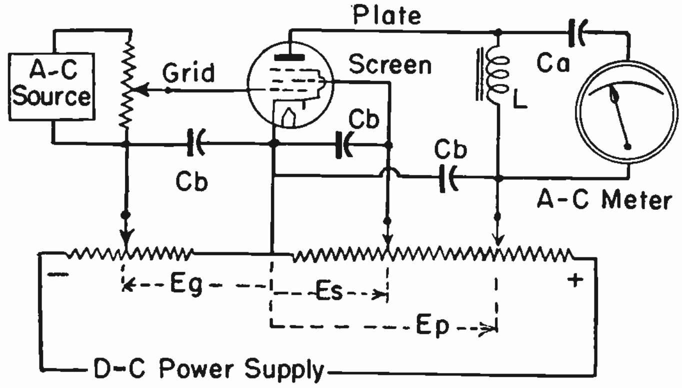

Fig. 3. A basic circuit for measurement of mutual conductance.

In the plate circuit is a high-impedance choke L which freely carries the d-c component of plate current, but forces the a-c component to pass through low-reactance capacitor Ca and an a-c current meter whose scale is graduated in microhms. The meter may be a rectifier type, or, in some testers, a dynamometer type.

At first thought it would seem that tests for mutual conductance could be carried out with information given in manufacturers' data on typical operation of a tube, which includes normal values of mutual conductance or transconductance. To do this the test circuit would have to be adjusted to furnish plate voltage, screen voltage, grid bias, and load resistances of the exact values given in tube data.

With service types of mutual conductance testers it is more common practice to set up certain operating conditions by adjustment of controls and switches, and to check against the value of mutual conductance which should result from these settings. A tube usually is considered to be satisfactory when its measured mutual conductance is no less than 70 per cent of the average in new tubes of the same type.

To obtain reliable measurements of mutual conductance it is especially necessary

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to apply rated plate voltage to triodes, rated screen voltage to pentodes and beam power tubes, and to have a plate load such that plate current is close to that which flows during normal operation of the tube in receiver circuits. Grid bias voltage is critical for mutual conductance tests. Mutual conductances will be about the same with any value of emission greater than the minimum which would cause rejection in an emission tester.

Mutual conductance testers of service types include all additional tests found on other instruments; including cathode-heater leakage, element shorts, and presence of excessive gas.

COMPOSITE TESTS. Tube testers may combine emission testing with some modification of a true mutual conductance test. Fig. 4 illustrates principles often employed.

The chief feature to be noted is relative polarities of plate and grid with reference to the cathode of the tube tested. The cathode is connected to tap A on a transformer secondary. The grid receives a-c voltage from end connection B, and the plate from end connection C. Since grid and plate are connected to opposite ends of the same winding, their polarities always are opposite. During each half-cycle in which the plate is positive the grid will be negative, and during intervening half-cycles while the plate is negative the grid will be positive.

During half-cycles in which the plate is positive and the grid negative, the tube operates normally, and plate current is controlled by negative grid voltage. During opposite half-cycles there will be no plate current, in spite of the positive grid, because the plate is negative. Consequently, plate

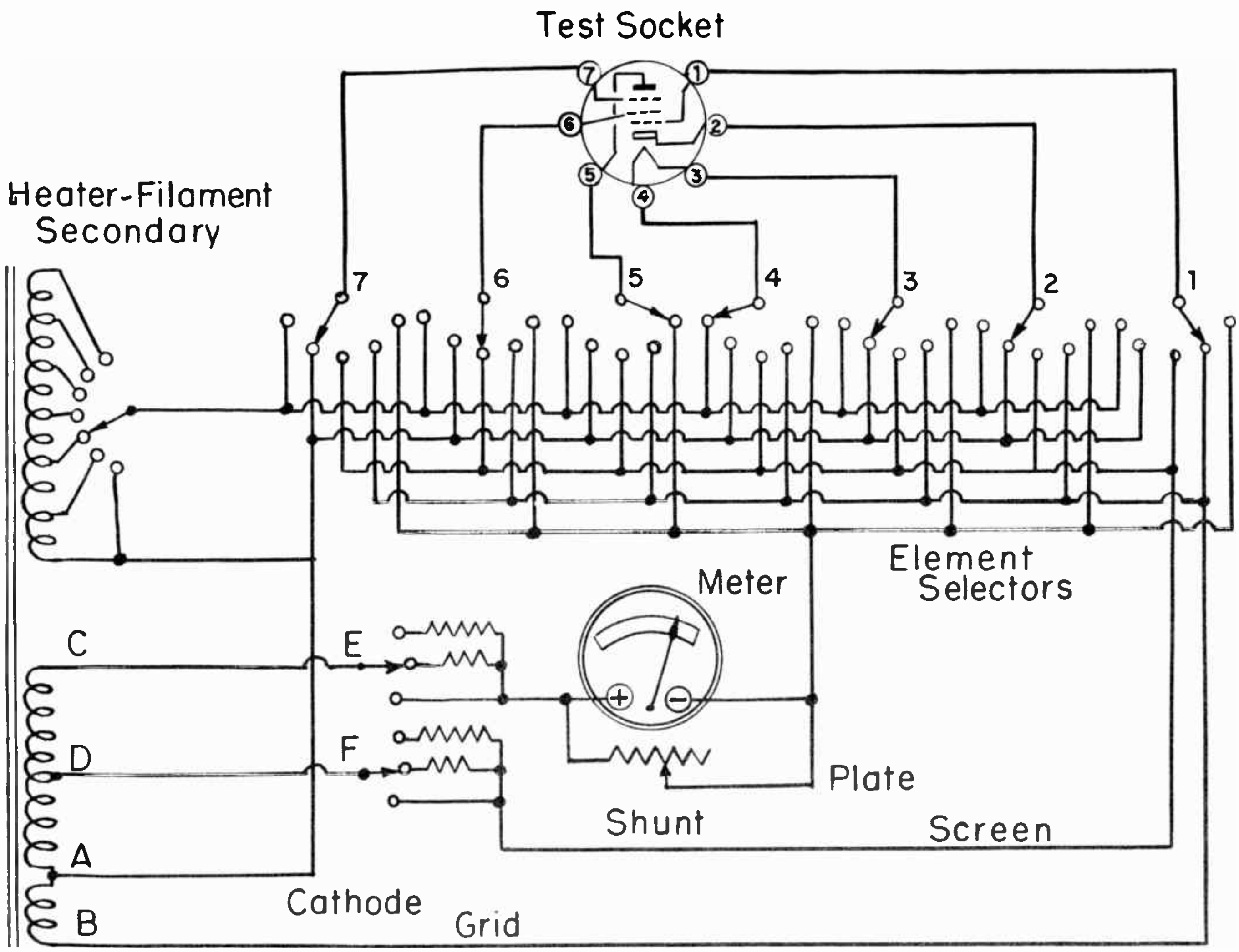

Fig. 4. This circuit allows checking the ability of grid voltage to control plate current.

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current flowing in the meter is that with the grid negative.

Screen voltage is taken from tap D on the transformer. Because this tap is on the same side of the cathode connection as is the plate tap, plate and screen voltages will be of the same polarity during all half-cycles. Suitable loads and voltage dropping are provided by resistors on switches E and F. Element selector switching may be of any type.

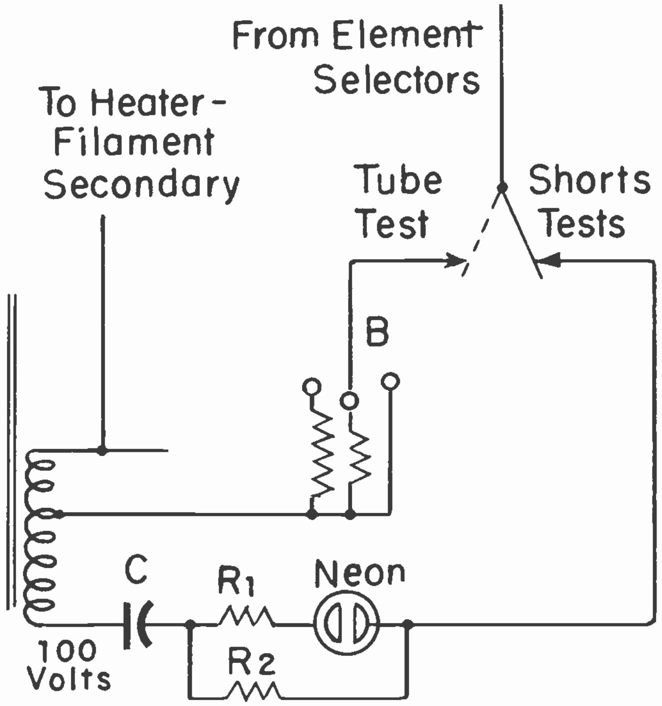

Fig. 5. A method for detecting shorts and leakages with a neon lamp as the indicator.

LEAKAGE AND SHORTS TESTS. Fig. 5 is a circuit often used for locating leakages or shorts between tube elements, illustrating the manner in which this shorts test might be added to the emission testing circuits of Fig. 2. The same shorts test could, of course, be added in a generally similar way to any other tube testing circuits.

The transformer secondary which furnishes voltage for emission or other tests is extended to provide about 100 a-c volts for the shorts test. In the line from the element selector switches has been inserted a two-way switch. This switch, in its broken-line position, connects the element selectors through switch B and resistors to the 30-volt point on the transformer secondary, for emission testing as in Fig. 2. In its full-line position the added switch connects the element selectors and corresponding tube elements to the shorts test circuit.

The shorts test circuit, between the 100-volt transformer lead and the added two-way switch, consists of a neon lamp in series with resistor R1, of a shunt resistor R2, and of series capacitor C. Shorts or leakage paths between elements of tubes being tested will allow current to flow in the neon-lamp, whose electrodes then glow to indicate that trouble exists.

Series resistor R1 prevents excessive current in the neon lamp in case of a low-resistance short. Shunt resistor R2 bypasses enough current around the lamp to prevent its glowing on very small alternating currents which pass through stray capacitances in wiring and other instrument parts. A small bypass capacitor sometimes is used instead of resistor R2.

Both resistors in the neon circuit help prevent glow of the lamp on conduction current that flows from the heated cathode to other elements of the tube tested. There is conduction current because the testing voltage is alternating, and during half-cycles which make the tube cathode negative and other elements positive, this conduction current flows in the neon circuit. But high series resistance in the neon circuit keeps conduction current small, and the shunt resistor bypasses so much of it around the lamp that there is no glow. However, additional current due to leakage or shorts between tube elements does make the lamp glow.

In some instruments a rectifier furnishes direct voltage for testing of shorts and leakages. The polarity of this direct voltage in the test circuit is such as to make the cathode positive and other elements negative in a tube being tested. Then there can be no conduction current, and the neon lamp will glow only when current flows in a short or leakage path.

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In still other instruments the presence of shorts or leakage paths between tube elements is indicated not by a neon lamp but by the same meter used for measurements of emission or mutual conductance. The meter pointer drops back onto the "Bad" portion of the scale when there are shorts or leakages. Reduction of meter reading is brought about in various ways, as by allowing reduced resistance of a short to shunt the meter, or by allowing short circuit current to make the grid more negative in a triode that controls meter current during shorts tests.

Resistances, voltages, and currents in any circuit for checking shorts and leakages are of such values that trouble is indicated only when resistance of the leakage path is less than some selected value. A common limit is 250,000 ohms, with trouble indicated only when leakage resistance is less than this value. Some instruments have an adjustment for leakage sensitivity, to allow trouble indications on high-resistance shorts or only on low-resistance shorts when desired.

Fig. 6 illustrates how element selector switches may be used for making leakage and shorts tests. The line from element selectors, which is connected to a transformer tap furnishing voltage for other kinds of tests, now is connected to the leakage detection circuit. Element selectors are of the same type shown in earlier diagrams, but might be of any other style suitable for test purposes.

The heater of the tube being tested for shorts is connected to the source of heater voltage through selectors 3 and 4 of Fig. 6. The heater or filament must be lighted, because oftentimes a trouble appears only when heat causes tube elements to expand and close a leakage or short circuit path.

All except one of the elements in a tube being tested are connected together and to one side of the shorts test circuit. The one remaining element is connected to the other side of the shorts test circuit. Then a short or leakage between that one element and any other will cause trouble to be indicated. During a complete test of any one tube, each element is temporarily separated from all the others.

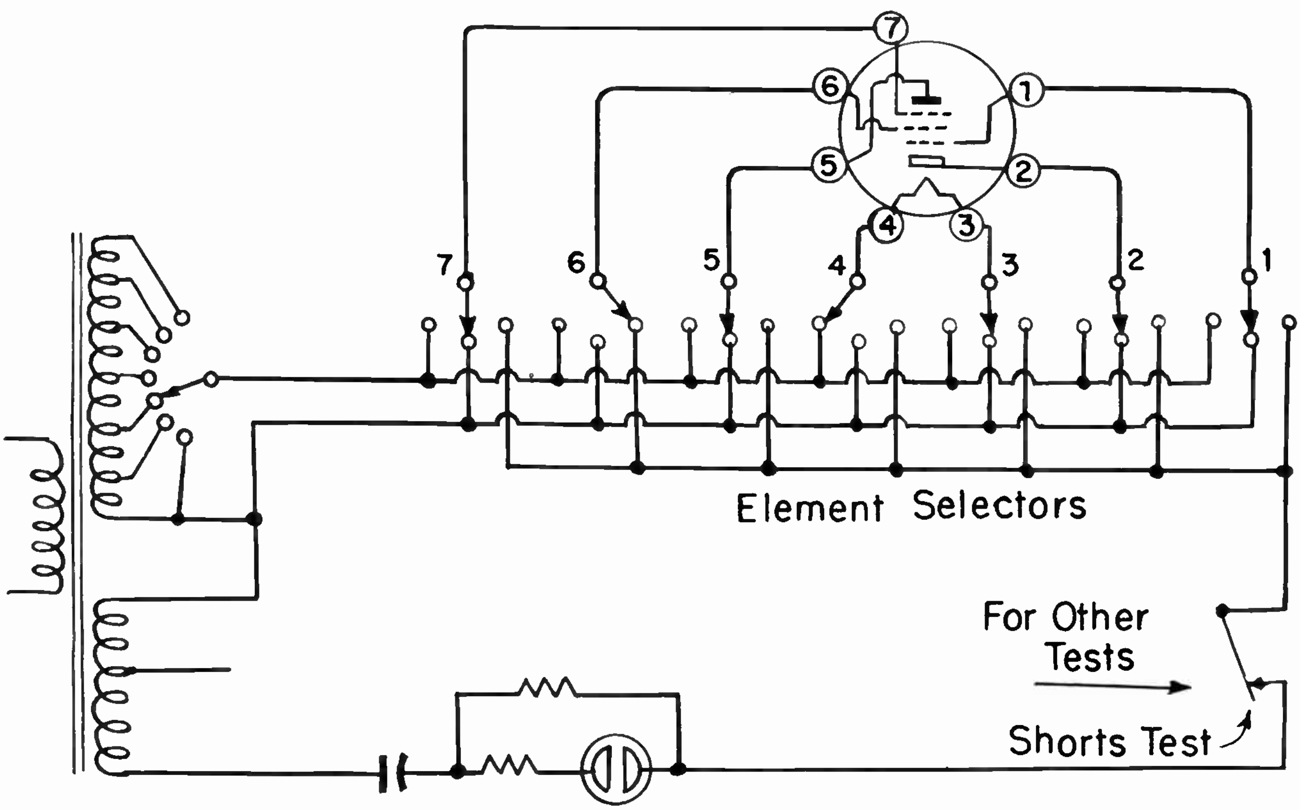

Fig. 6. How tube elements may be connected when testing for shorts and leakage.

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In Fig. 6 the separated element is the screen, on pin 6 and selector switch number 6. The screen alone is connected to the line which runs through the shorts indicator circuit to one end of the transformer winding. All other active elements are connected together through their selector switches, and to the other end of the transformer winding. If there is a short circuit or leakage path between the screen and any other element, the neon lamp will glow. If there is no short or serious leakage from the screen of the tested tube the lamp will remain dark.

A tube being tested for shorts should be lightly tapped. Flickering of a neon lamp or vibration of a meter pointer indicates loose elements or intermittent shorts. When there is a capacitor in the neon lamp circuit the lamp may flash momentarily as element selectors or other switches are manipulated. This indicates only that the capacitor is discharging or charging through the neon lamp, it does not indicate trouble in the tested tube.

Any tube which shows leakage between any elements other than cathode and heater ordinarily should be rejected, no matter how high the leakage resistance. Leakage resistance between internal elements has the same effect as would an equal resistance connected between the same elements outside the tube. This will change plate loads, grid return resistances, screen voltages, and other circuit constants, Frequency response may be unduly broadened.

How much cathode-heater leakage may be tolerated depends on the circuit in which the tube is used. If a cathode is connected directly to ground in the receiver, or is bypassed to ground by a capacitor having very low reactance at 60 cycles, cathode-heater leakage is unlikely to cause trouble even though leakage resistance is only a few thousand ohms.

If the tube cathode is connected to a bias resistor, a trap, an r-f choke, or an interstage coupler, cathode-heater leakage resistance less than a quarter-megohm probably will cause sound bars and other troubles. It is advisable to reject the tube.

A voltage amplifier or a oontrol tube in whose grid circuit there is high resistance or impedance can stand for very little, if any, cathode-heater leakage. Leakage resistance greater than a quarter megohm often is troublesome in such tubes. The grid circuit for a power amplifier tube ordinarily has relatively small resistance or impedance. Consequently, cathode-heater leakage resistance as small as ten to twenty thousand ohms may cause no trouble in a power amplifier tube.

GAS TESTS. Excessive gas may appear in old tubes because gases originally held in metal parts gradually escape into the evacuated space. This process is hastened if a tube is overheated by excessive plate current and power dissipation, or by excessive heater voltage and current. Gas may appear also because of very slow leakage of air into the envelope.

Excessive gas tends to make grid biases less negative, thus increasing plate and screen currents, increasing power dissipation and heating, and helping to release still more gas. Increased plate currents may allow oscillation in voltage amplifier circuits, and severe distortion of signals in other circuits.

Fig. 7 illustrates what happens in tubes with no more than normal amounts of gas, and in those having excessive gas. Normally we have the condition of diagram A Grid current pulses, due to the grid being momentarily positive on peaks of signal alternations, flow downward in grid resistor Rg, and bias the grid negatively.

Excessive gas, in diagram B, allows ionization, as explained in the lesson on "Service Oscilloscopes". Positive ions are attracted to the negative grid, and neutralize to a greater or less extent the normal negative charge on the grid. The grid becomes less negative, and plate current tends to increase. At the same time, negative electrons flow through resistor Rg to the grid, in an effort to neutralize the positive charge of the ions. This grid current, commonly called gas current, is in a direction opposite to that of normal grid current in diagram A.

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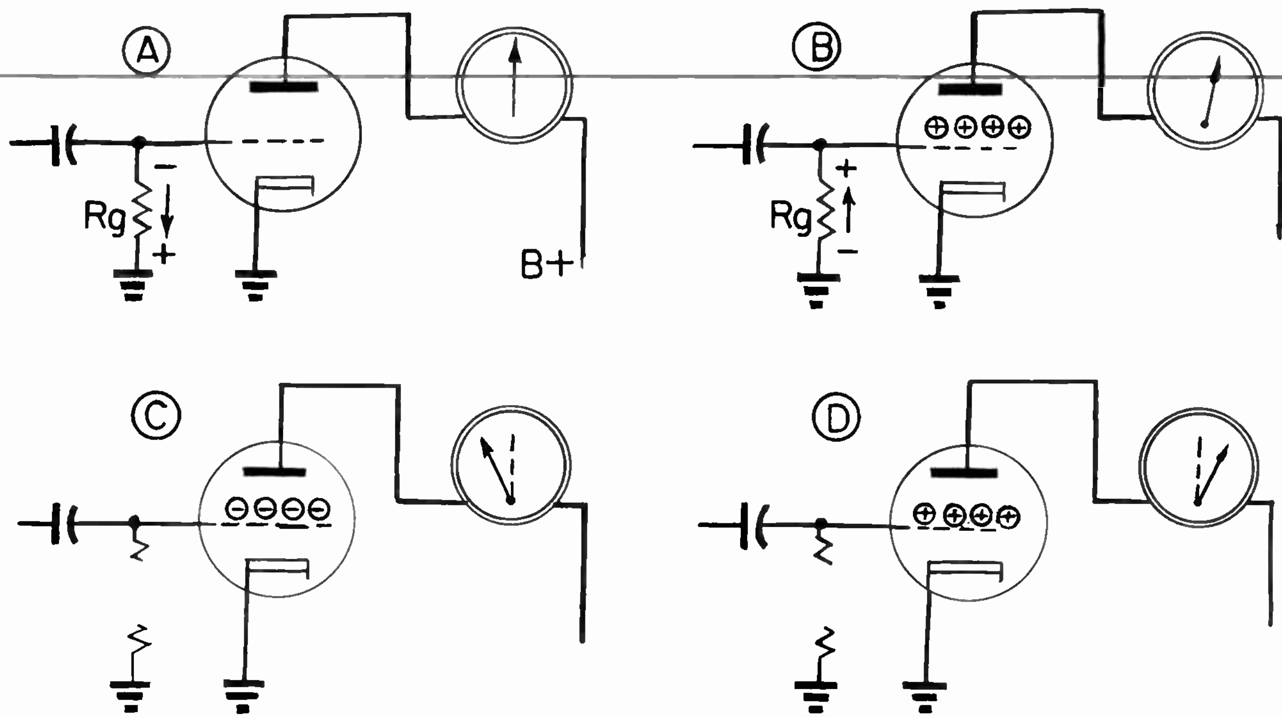

Fig. 7. The effects of gas in a tube, and the principle of one method of making gas tests.

In diagram C we have opened the grid return circuit of the tube in which there is no excessive gas. Electrons from the space charge, which flow through resistor Rg in diagram A, now have nowhere to go. These electrons accummulate on the grid, making the grid too negative, and causing reduction of plate current.

In diagram D the grid return has been opened on the tube containing excessive gas, and in which there is ionization. Positive ions on the grid, which in diagram B are partially neutralized by electron flow through Rg, now remain of full strength and cause the grid to become less negative, or even positive. There is resulting increase of plate current.

Comparison of diagrams C and D of Fig. 7 makes it clear that presence of excessive gas may be detected by opening the grid return path or by inserting very high resistance in the grid return. Such a test is provided by the circuit of Fig. 8. Grid return resistor Rg is of one megohm or greater resistance. During tests other than for gas this resistor is shorted by the closed switch. Upon opening the switch, high resistance in the grid circuit causes the effects shown at C and D

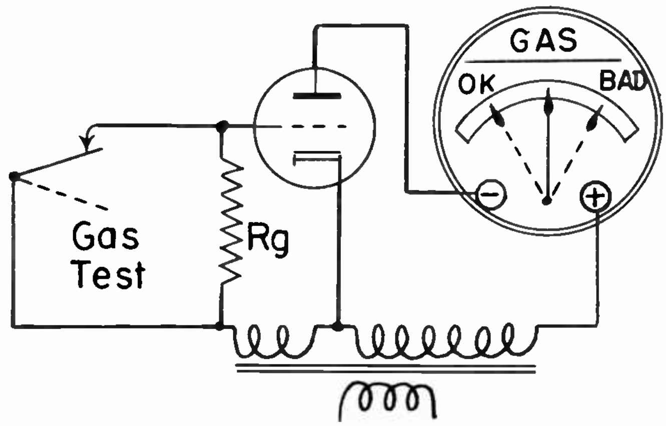

Fig. 8. Connections for a gas test.

of Fig. 7. The plate current meter, which would be the meter used for other tests, may have dial markings to indicate normal or excessive gas.

With another method of testing for excessive gas a d-c microammeter is connected in series with the grid return circuit. Reversed grid current, as at B of Fig. 7, indicates the presence of gas. Whether a tube should be rejected depends on its type and the amount of gas current. Voltage amplifiers, oscillators, and control tubes might be defective when gas current is as much as one

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microampere, while various types of power tubes might be satisfactory with 10 or more microamperes of gas current when the tubes are operated with element voltages such as used in receiver circuits.

In voltage amplifiers, control tubes, and oscillators only a slight excess of gas may cause serious trouble. Such tubes should show a decided drop of plate current when the grid return is opened or made of high resistance. Likelihood of gas trouble increases with higher resistance in the grid circuit. Consequently, such tubes never should be operated with grid circuit resistance greater than the recommended maximum except in the few cases where biasing is to be by contact potential.

More gas may be tolerated in power tubes than in voltage amplifiers unless grid circuit resistance is unusually high. Very high plate voltages, or plate currents near maximum limits may increase gas trouble since these things tend to increase ionization. During a gas test, power tube plate current should show some drop, or, at least, should show no increase if the tube is to be considered satisfactory.

Rectifiers and diodes cannot be checked for excessive gas with any of the methods involving grid effects on plate currents. More than usual quantities of gas in a power rectifier may cause a blue glow to appear in the spaces between cathodes and plates. Considerable gas seldom causes serious trouble.

A bluish glow on the glass envelope of a rectifier or power tube does not indicate gas. It is merely an effect of fluorescence within the tube.

A tube whose envelope has become filled with air, usually because of cracks in the glass, may become very hot without the heater or filament showing any glow or light. The envelope of such a tube often appears milky white all over or in spots.

OSCILLATOR TUBES. A tube which checks as good on all tests applied by service instruments may fail to oscillate. Whether any particular tube will oscillate depends largely on the operating frequency, on the type of circuit, on losses in inductors and capacitors, and on internal capacitances of the tube. Variations of internal capacitance may cause large changes of frequency, since it is these capacitances that do much of the tuning in television amplifier circuits.

Service types of tube testers have no provision for measuring inter-electrode capacitances, which usually have values between two and ten mmf. Capacitances so small as this might be measured, if necessary, by connecting between appropriate base pins a coil of known inductance, then measuring the resonant frequency of the combination. Knowing the frequency and the inductance, it is possible to compute the capacitance.

The usual check for oscillation is measurement of d-c grid voltage with a VTVM while the tube is operating in its regular circuit. When an r-f oscillator tube is oscillating, its grid usually is negative to the cathode by at least $2\frac{1}{2}$ volts, and when not oscillating the grid ordinarily is at less than 1 volt negative. Grids of sweep oscillators will be still more negative, possibly 10 to 25 volts with reference to the cathode during oscillation, and only a few volts negative, or zero, when not oscillating.

A tube usually is a satisfactory oscillator when its emission tests little if any below normal or average, or when mutual conductance is average or better. This is on the assumption that there are no serious leakages, no excessive gas, and that inter-electrode capacitances are at least approximately correct for the application.

REPLACING DEFECTIVE TUBES. If the filament or heater of a low-voltage power rectifier burns out, install a new tube but watch it carefully in a darkened room or the dark interior of the cabinet when first turning on the power. Should the rectifier plates commence to turn dull red with heat, immediately turn off the set and locate the severe overload which surely exists, probably as a short circuit or an accidental ground.

When tubes other than rectifiers have low emission it may be due to old age, but

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may be the result of wrong d-c voltages on plates or screens, or wrong a-c voltages on heaters. Check these voltages. Excessive voltages increase plate currents to values which damage cathode materials. Look also for heater voltages much lower than normal, which, combined with normal or high voltages on plate or screen, may damage a cathode by working it at saturation currents with no space charge.

A tube which fails completely or fails to operate satisfactorily in one position may work well in another position of the same receiver, or in the same position of another receiver. For instance, a tube may fail as an r-f or i-f amplifier, yet be all right in the sync section, or may fail as a sweep oscillator and work well in some other position. Don't overlook the fact that taking a tube out of its socket and putting it back may clean the contacts to restore normal operation.

When replacing r-f amplifiers or oscillators, i-f amplifiers, and 4.5-mc sound amplifiers, the first replacement may not allow good reception. Try another tube. Usually it is possible to find a new tube which operates satisfactorily without realigning any circuits - if you have enough tubes to try.

An excellent method of checking for weak amplifier tubes is to use an oscilloscope for observing the signal from some one station as the signal appears at the video amplifier output or picture tube signal input. Override the agc voltage with three volts or more. Then replace tubes in the tuner, the i-f amplifier, and video amplifier, one at a time. If signal sync pulses increase in height, the new tube is increasing the gain. Do not change stations.

Should a new tube increase pulse height as much as 20 per cent, the original tube probably is defective and the new one should be used in place. Two or three new tubes often will double or more than double the overall gain.

If it is not convenient to use an oscilloscope, connect a VTVM as a d-c voltmeter across the video detector load. Override the agc voltage. Detector load voltage will increase with every improvement of gain. This method allows checking all amplifiers from the tuner through the detector itself, but does not extend to video amplifiers which are beyond the detector load.

<u>TUBE SUBSTITUTIONS.</u> Now we shall talk about substituting one type of tube for another type in an effort to obtain greater gain or to improve some other performance factor. Better types of tubes appear continually, and many present types were not available to designers of earlier receivers. Older receivers sometimes may be made to perform better by substitution of tubes in some positions. Unfortunately, it seldom is possible simply to pull out one kind of tube and put in a different kind without making various circuit changes. Some examples will illustrate many of the problems.

Doubtless you have noticed that in many recent sets the i-f amplifiers are 6CB6 or 6CF6 miniature pentodes, while most of the older sets have 6AU6 or 6AG5 miniature pentodes in these positions. The 6AU6's and 6AG5's often are operated with grid biases about 1 volt negative, while 6CB6's and 6CF6's have biases around 2 volts negative. Plate currents for all these types are in the 9 to 11 ma range, and plates and screens usually are supplied with 125 to 150 d-c volts.

Were each of the four types of i-f amplifiers operated with 150 volts on the plate, 150 volts on the screen, and with signals and negative grid biases first of 2 volts and then of 1 volt, performances would be approximately as in the accompanying table.

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I-F AMPLIFIER PERFORMANCE						
	6AU6		6AG5		6CB6-6CF6	
Mutual cond., micromhos.	4050	5400	4400	5300	6200	9000
Bias volts	- 2	- 1	- 2	- 1	- 2	- 1
Plate ma.	5.9	10.6	6.0	11.0	10.9	18.5
Screen ma.	2.2	4.2	1.8	3.0	3.2	5.5
Cathode ma.	8.1	14.8	7.8	14.0	14.1	24.0
Plate watts.						
Actual	0.88	1.6	0.9	1.65	1.64	2.78
Allowable	3.0	3.0	2.0	2.0	2.0	2.0

As always, we obtain greater mutual conductance or transconductance with increased plate currents. But it is necessary to watch plate dissipations, in watts. When using the smaller bias and greater plate current, the 6AU6 still works well below its rated power limit, the 6AG5 is about as close to the limit as we care to come, but the 6CB6 and 6CF6 are away over the limit and would not last long. Therefore, the latter two tubes could not be operated for 9000-micromho mutual conductance.

Before considering any substitution it is necessary to check base pin connections of tubes involved. All the i-f amplifiers now being considered are miniatures with 7-pin bases, so all would fit the same sockets. But basing connections are different, as shown by Fig. 9. Below each diagram are listed several i-f pentodes having the same basing. Note that pins for heater, control grid, screen, and plate always are in the same positions, but there are differences between connections for cathodes and suppressors. Cathodes usually are connected through a biasing resistor to ground, and separate suppressor pins directly to ground. In the 6AG5 the suppressor is internally connected to the cathode, the cathode is connected to pins 2 and 7, and either of these pins may be connected through a biasing resistor to ground. No tube of any one group could be substituted for a tube of any other group without rewiring the socket.

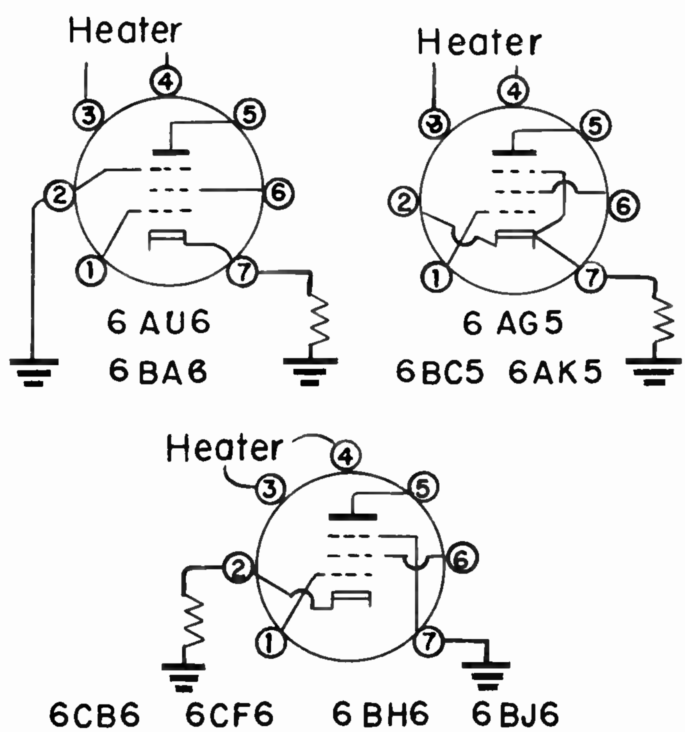

Fig. 9. Basing connections must be compared, and changed when necessary, if one type of tube is substituted for another type.

Tubes in any one group might be intercharged without rewiring, but there might be other difficulties. For example, the 6AU6 is a sharp cutoff pentode and the 6BA6 is a remote cutoff type. The 6AG5, 6BC5, and 6AK5 actually are interchangeable. The 6BC5 gives somewhat greater transconductance than the 6AG5. The 6AK5 may prove to be a better r-f amplifier, but the others us-

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ually are better as i-f amplifiers. There would be little difference between a 6CB6 and a 6CF6, although the latter might be a little better for intermediates in the 40-mc range. The 6BH6 and 6BJ6 should work with less negative bias than the other two. The 6BJ6 is a remote cutoff type, while all others in this group are sharp cutoff types.

You might get into trouble when substituting something so simple as a 5Y3 filament-cathode power rectifier for a 6AX5 heater cathode power rectifier, although both give practically the same electrical performance. Socket wiring would have to be changed to accomodate the different elements. Then the difficulty might arise as follows.

Filament-cathode rectifiers heat to full emission in about two seconds, then furnish full voltage to B-plus lines. This voltage will be abnormally high in filter, bypass, and blocking capacitors until heater-cathode tubes in the receiver reach emission temperature and draw plate and screen currents. This may take eight or nine seconds.

Heater-cathode rectifiers take longer for their cathodes to reach emission temperature, and voltage output remains relatively low until other heater-cathode tubes have time to heat and draw current. B-plus voltages will not go so high. Were some capacitor voltage ratings only enough for normal operation those capacitors might be punctured or their lives shortened by the higher voltage with a filament-cathode rectifier.

Here is a list of items to be checked when planning tube substitutions.

1. Socket type. Miniature 7-pin and 9-pin types are not the same size. Lock-in sockets are smaller than some octals, larger than other octals.

2. Base pin connections. May be such as to call for rewiring.

3. Heater voltage and current. The power transformer usually can handle greater current for one or possibly two parallel heaters, but not for many without overloading. Series heaters may require changes such as explained in an earlier lesson.

4. Plate currents and voltages. Differences call for changes in dropping resistors, possibly for connection further back toward the power supply to avoid upsetting other B-voltages on the original supply line. Usually will require a change of bias. Watch for excessive plate or screen power dissipations.

5. With pentodes or beam power tubes watch screen voltages, since screen and grid bias voltages determine plate current, transconductance, and gain of pentodes.

6. Bias changes. For triodes compute bias resistance from plate current and bias volts, for pentodes and beam tubes use the sum of plate and screen currents.

7. Inter-electrode capacitances. These are important in all circuits where tuning is by adjustable inductors and combined stray, distributed, and tube capacitances. Slight differences in capacitance may be handled by realignment, but large changes may prevent resonance with any available adjustments.

8. Shielding. If the original tube has an internal shield, and the substitute has not shield, it may be necessary to add an external shield to prevent feedback, peaking of responses, and possible oscillation.

PICTURE TUBE TESTS

CHECKING THE HEATER. When the heater of a picture tube fails to light, first make sure that socket and base pin connections are clean and tight. Then check for an open heater, in this manner. Remove the socket from the tube base and connect an ohmmeter to base pins 1 and 12, which are on opposite sides of the locating key. A heater which is not open will, when cold, allow the meter to read practically zero ohms. An open heater will show infinitely great resistance.

Should your tests indicate an open heater, or if the heater intermittently lights and goes out while the set is turned on, there is the possibility that the trouble is in the base pin

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connections rather than in the heater itself. It is worth while to resolder the base pins. Since the tube is no good with an open heater, resoldering can do no harm and may do good.

Unless you have previously soldered base pins, experiment first with a discarded small tube of any type. Wrap the glass envelope with cloth, then crack it open with a hammer. Remove the elements and the glass press to expose wire leads which go into the base pins. Hold the base in a vise, grasp the inner end of a wire lead with pliers, and apply a clean, hot soldering iron to the tip of the corresponding pin until the wire pulls out. Note that solder is only near the tip of the pin and on the end of the wire lead.

To resolder a picture tube base pin leave the tube in its regular brackets. Hold the tip of a hot iron on one side of the tip end of a heater pin, and after giving the tip a few moments to heat, touch the end of a piece of rosin core solder to the end of the tip. Unless the iron is good and hot it may overheat the entire pin and loosen it in the base before the solder runs. Allow a little solder to run into the end of the base pin. If you get enough solder on the outside of the pin to prevent the socket from fitting, remove the excess with a pocket knife or fine file.

Again check the heater with your ohmmeter. If resistance is near zero, the trouble has been removed. If resistance still is infinite, resolder the second heater pin, then make another resistance test. Should the heater still be open the remedy is a new picture tube.

When the ohmmeter shows that a heater which fails to light is not open, measure heater voltage at the socket openings by connecting a low-range a-c voltmeter as at A in Fig. 10. If the meter prods will not enter the socket openings use short lengths of solid wire for extensions. Zero or very low voltage calls for checking the heater supply lines leading to the picture tube socket.

ELEMENT VOLTAGES. When the picture tube heater lights, but you can get neither pictures nor raster, test the high voltage on the second anode. This should be done with a high-voltage probe on the VTVM.

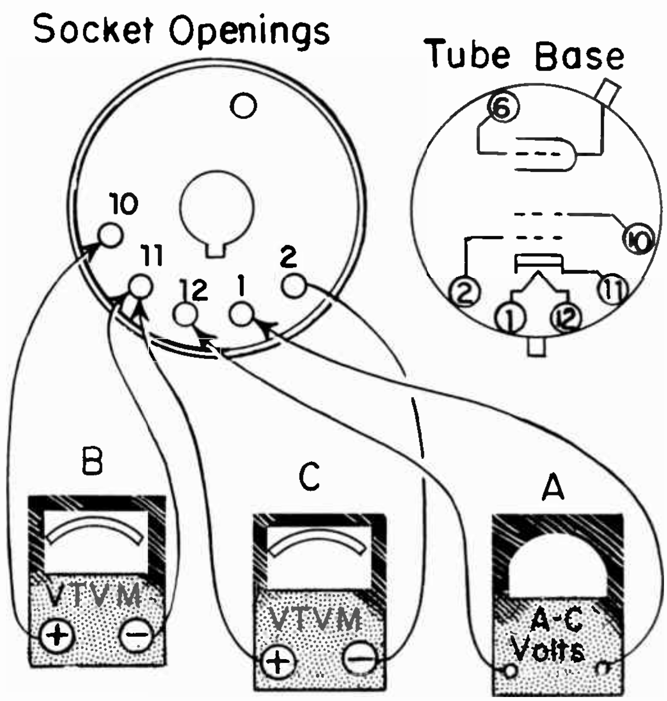

Fig. 10. Measurements of operating voltages at the socket openings of a picture tube socket.

Most tubes will produce a raster or dim pictures with anode voltage as low as three or four thousand. If voltage is low, look for trouble in the high-voltage power supply system.

If you have no high-voltage probe, make a spark test from the second anode connector to the terminal on the picture tube. A spark less than about 3/16 inch long usually means trouble in the high-voltage power supply. Should voltage measurement or a spark test indicate sufficient anode voltage to produce a raster, but the screen still remains dark, proceed with other tests illustrated by Fig. 10.

Using the VTVM as a d-c meter, connect its negative or common lead to opening number 11 in the picture tube socket, and the positive lead to opening number 10, as at B on the diagram. This allows measuring voltage supplied to the second grid. Unless there is series resistance of several megohms somewhere in the circuit to this grid, an unlikely condition, the reading should be 250 volts or more. If voltage is low or zero, check the entire circuit which supplies voltage to the lead for number 10 opening of the

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socket. Lack of voltage on the second grid will keep a picture tube dark.

With the VTVM still as a d-c voltmeter make the connections of diagram C, with the meter negative to socket opening number 2 and positive to opening number 11. This allows reading negative voltage of the control grid with reference to the cathode. Operate the brightness control. With this control adjusted for minimum brightness the meter should read at least 40 volts, and usually will read 50 volts or more. Control adjustment for maximum brightness should give a reading in the neighborhood of 10 volts. Should grid voltage remain higher than about 40 or 50 volts at all times, it probably is remaining beyond the point of beam cutoff, and certainly is keeping the screen abnormally dark. In this case, check the entire brightness control circuit, also other connections in the grid-cathode circuit of the picture tube.

Unless some definite trouble has been located, you now will have determined (a) that the heater and its voltage are OK, (b) that there is sufficient high voltage for the second anode, (c) that the second grid is receiving enough voltage, and (d) that there is proper regulation of control grid voltage with reference to the cathode. The next checks will be for leakages and shorts.

LEAKAGES AND SHORT CIRCUITS. Base pin and element connections for making tests of leakages and shorts are shown in Fig. 10. Use an ohmmeter, or the VTVM on its ohmmeter function, with the highest resistance range. The receiver must be turned off, as when making all ohmmeter tests. Keep one lead from the instrument on any one base pin while connecting the other lead to each remaining base pin and to the second anode terminal, one at a time. All tests, even between heater and cathode, should show infinite resistance.

The very low voltage applied by the ohmmeter, combined with the fact that all tube elements are cold, makes it unlikely that this method will disclose any trouble less serious than dead short circuits between elements. Still, a check for dead shorts is worth while in avoiding the need for further tests, should a short be found.

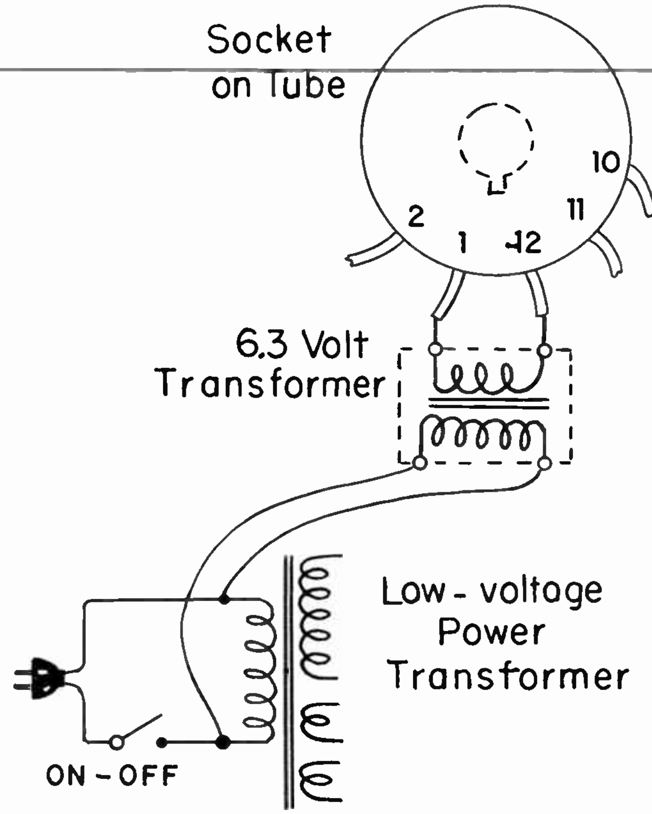

Fig. 11. Using an additional heater transformer on a picture tube in which there is cathode-heater leakage.

If there have been symptoms of cathode-heater leakage in the picture tube, ill effects may be avoided by the method of Fig. 11, provided signal input is to the picture tube grid, not to the cathode.

Obtain a small 6.3-volt heater or filament transformer. Mount this transformer on the chassis or picture tube bracket. Disconnect socket leads 1 and 12 from the heater circuit in the chassis and connect them to the 6.3-volt secondary of the new transformer. Connect the 110-120-volt primary of the new transformer to the primary leads of the low-voltage power transformer, so that the added transformer will be turned on and off by the receiver switch. Do not ground any terminal of the heater transformer. This method of isolating the picture tube heater can be used only in sets having heaters connected in parallel, not in series.

EMISSION TESTS. Should trouble still remain, it is in order to check emission ability of the picture tube cathode. This may

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be done by measuring cathode current with a d-c current meter reading up to 500 microamperes or to 0.5 milliampere. Such ranges and scales are found in most volt-ohm-milliammeters. A line which carries only direct current in the cathode return is opened, and the meter connected in series. The positive terminal of the meter goes to the picture tube cathode, and the negative terminal to the other side of the opened line.

The kind of grid-cathode circuit on the picture tube makes no difference, just so long as you connect the meter to carry all of the d-c current flowing in the cathode, and no other current. Fig. 12 shows at A and B two fairly typical circuits with which signal input is to the cathode, and at C a circuit with signal input to the grid of the picture tube. The current meter might be connected in series with any of the leads shown by heavy lines, but nowhere else. Just where you open the circuit is a matter of convenience; it depends on layout of wiring and connections in the chassis, or on the manner in which the cable from the picture tube socket joins circuits in the chassis.

Tests are made with the receiver in operation, and with all regular voltages applied to picture tube elements, including high voltage to the second anode. Since the meter is in low-voltage lines, no special precautions are necessary with reference to insulation or shock hazards.

Tune the receiver to an inactive channel. Were transmitted signals received during tests, cathode current would increase on light toned picture scenes and would decrease on dark tones. Accurate current measurements could not be made.

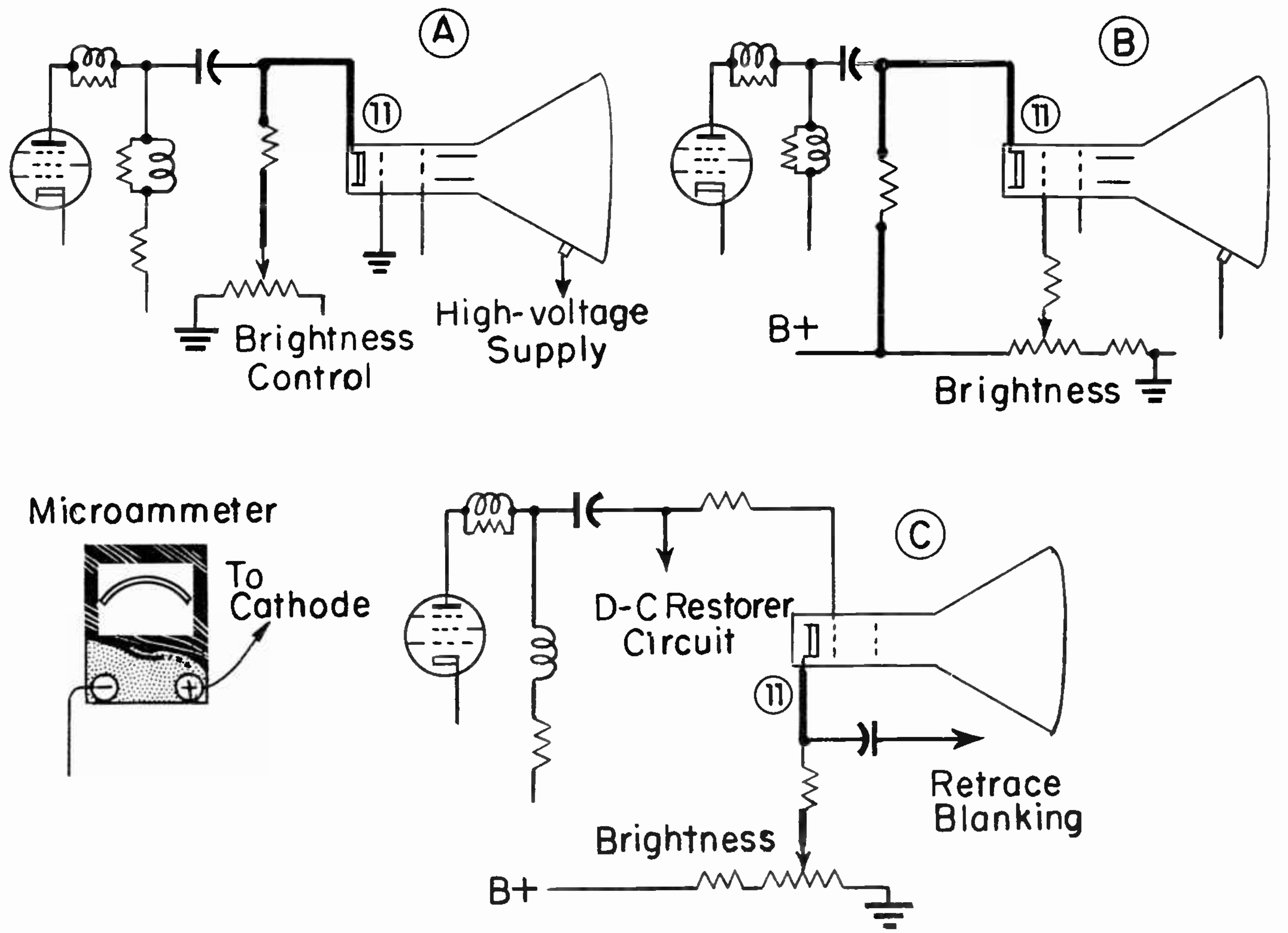

Fig. 12. Heavy lines show where a current meter may be connected for checking cathode emission of a picture tube.

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Adjustment of the contrast or picture control varies cathode current in many receivers. Therefore, set the contrast at minimum and leave it there.

If there is no cathode current at all, and especially if the tube has a history of intermittent operation, the cathode lead may be open in the base pin. Then it is a good idea to do a resoldering job on pin number 11, in the manner described earlier in this lesson.

It is assumed, as specified in a preceding paragraph, that all regular voltages are applied to picture tube elements. Unless there are suitable voltages on the second anode, on the second or accelerating grid, and on the heater, cathode current may be abnormally low or zero.

When all element voltages are correct, or nearly so, and when the brightness control is turned to maximum, cathode current should reach a maximum of at least 100 microamperes, and normally will be up around 150 microamperes or slightly more. It is reasonably safe to assume that smaller cathode current means lack of emission ability.

Except in tubes of 12-inch and smaller sizes, in tubes with aluminized screens, and in a few other types, cathode emission is fairly independent of tube size. The great majority of picture tubes, when operated with the same voltages on control grid and second grid, and with second anode voltages appropriate for the tube, will allow emission currents of very nearly the same value. This is true of sizes all the way from 14 to 27 inches.

BOOSTING THE HEATER VOLTAGE. Cathode emission too low for satisfactory pictures often may be increased by raising the heater voltage and thereby raising cathode temperature. The operation is not always successful, but many times it will extend the useful life of a picture tube as much as a month or for several months of steady use before emission finally gives out. Attachments for raising heater voltage are called emission boosters, tube brighteners, and by other similar names.

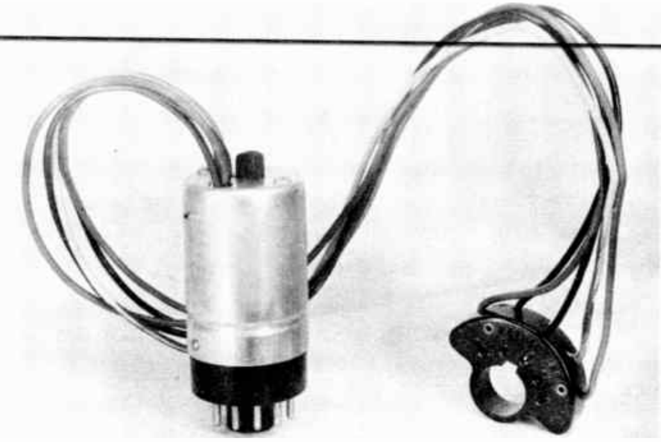

Fig. 13. A booster for picture tube heater voltage and cathode emission.

One of the many boosters on the market is pictured by Fig. 13. This unit includes an autotransformer connected through leads to a socket which takes the place of the original socket on the picture tube. On the transformer housing is a dummy tube base with pins on which the original socket fits.

Booster connections are shown by Fig. 14. Leads for control grid, cathode, second grid, and for a focusing anode if used, run from the original socket through the booster, its cable, and attached socket to the base of the picture tube. Heater leads from chassis circuits go to primary taps of the autotransformer in the booster. Secondary taps go to the heater in the picture tube.

The booster illustrated has a high-low switch for applying to the tube heater either a voltage 25 to 30 per cent higher than voltage from the receiver heater circuit, or else a voltage only about 15 per cent higher. Some boosters provide only a single raised voltage about 25 per cent above normal. Others allow choice between three or more voltages, one of which may have no step-up ratio.

Boosters containing autotransformers are siutable for use on heaters wired in parallel, but not for series heaters. Other styles having transformers with insulated primary and secondary may be used whether heaters are in parallel or in series. Types with insulated primary and secondary may be

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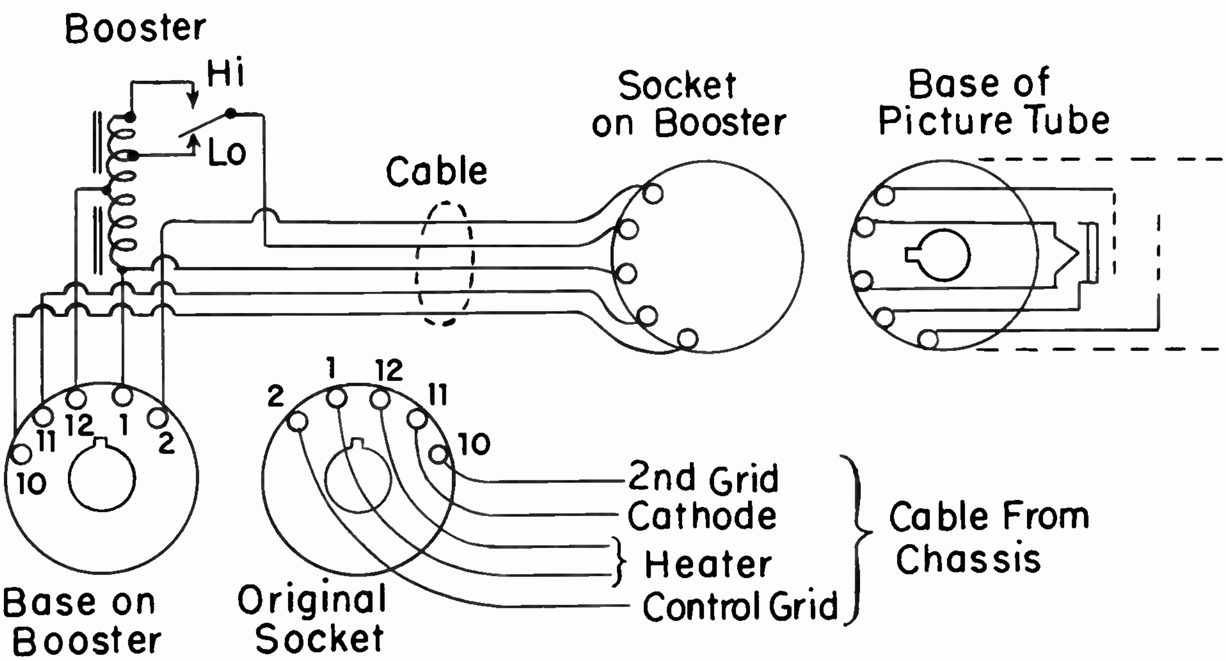

Fig. 14. Connections made by one style of booster between picture tube base pins and the original socket.

used not only as boosters, but also for preventing ill effects of cathode-heater leakage, in the manner shown by Fig. 11. A booster costs more than a small heater-voltage transformer, but is much easier to install.

Any booster remains on the picture tube until emission finally becomes too low, even with the raised heater voltage. Then the picture tube is discarded, and the booster used for future jobs.

CATHODE REJUVENATION. Instead of raising heater voltage and keeping it raised so long as the picture tube remains serviceable, it may be sufficient to use a process called rejuvenation, reactivation, or restoration. This refers to temporarily raising the heater voltage in an attempt to restore at least most of the original electron emitting ability of the cathode material.

There are various methods of restoration, which differ in details. A fairly common way is as follows.

1. With all anode and grid voltages removed or made zero, the heater is operated for about one minute at 9 to 10 volts. This is called flashing.

2. The control grid, or both control grid and second grid, are made positive to the cathode while the heater is operated at no more than 10 to 15 per cent above normal voltage. During this period the cathode current is measured. Measurement may be as explained in connection with Fig. 12, or in any suitable manner.

3. Cathode current should increase more or less gradually, and reach a steady value within one to two hours. Then heater voltage is dropped to normal, voltages on control grid and second grid are removed or made zero, and the tube is operated thus for two hours or more.

A reception test or measurement of cathode current while all elements are supplied with normal operating voltages will show whether the rejuvenation process has improved the emission.

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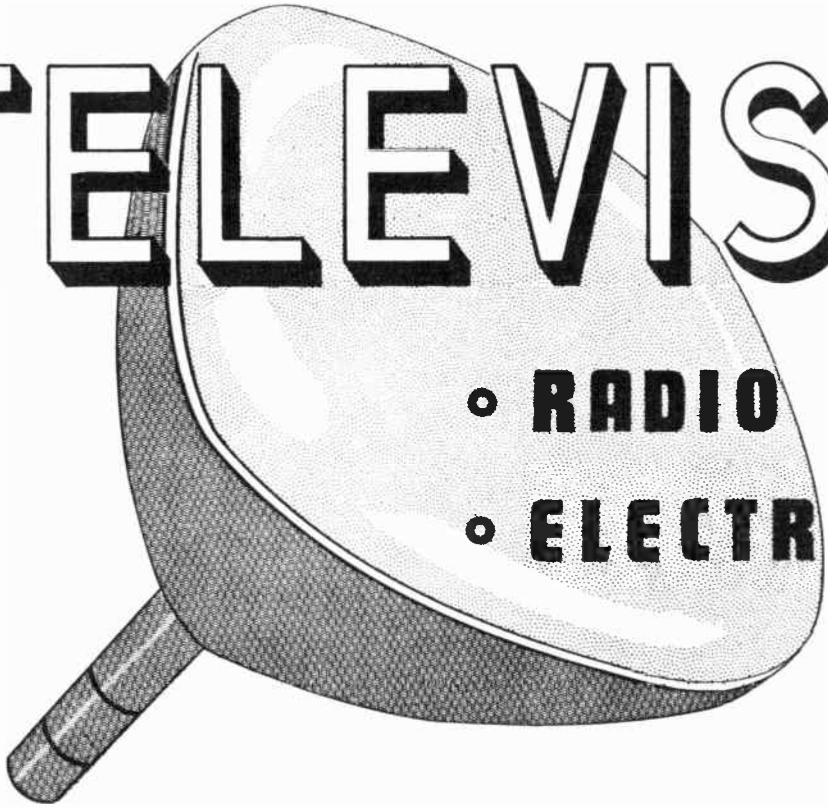
TELEVISION



• RADIO
• ELECTRONICS

LESSON 87 — TELEVISION SIGNAL TRACING

Coyne School

practical home training

Chicago, Illinois

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Lesson 87

TELEVISION SIGNAL TRACING

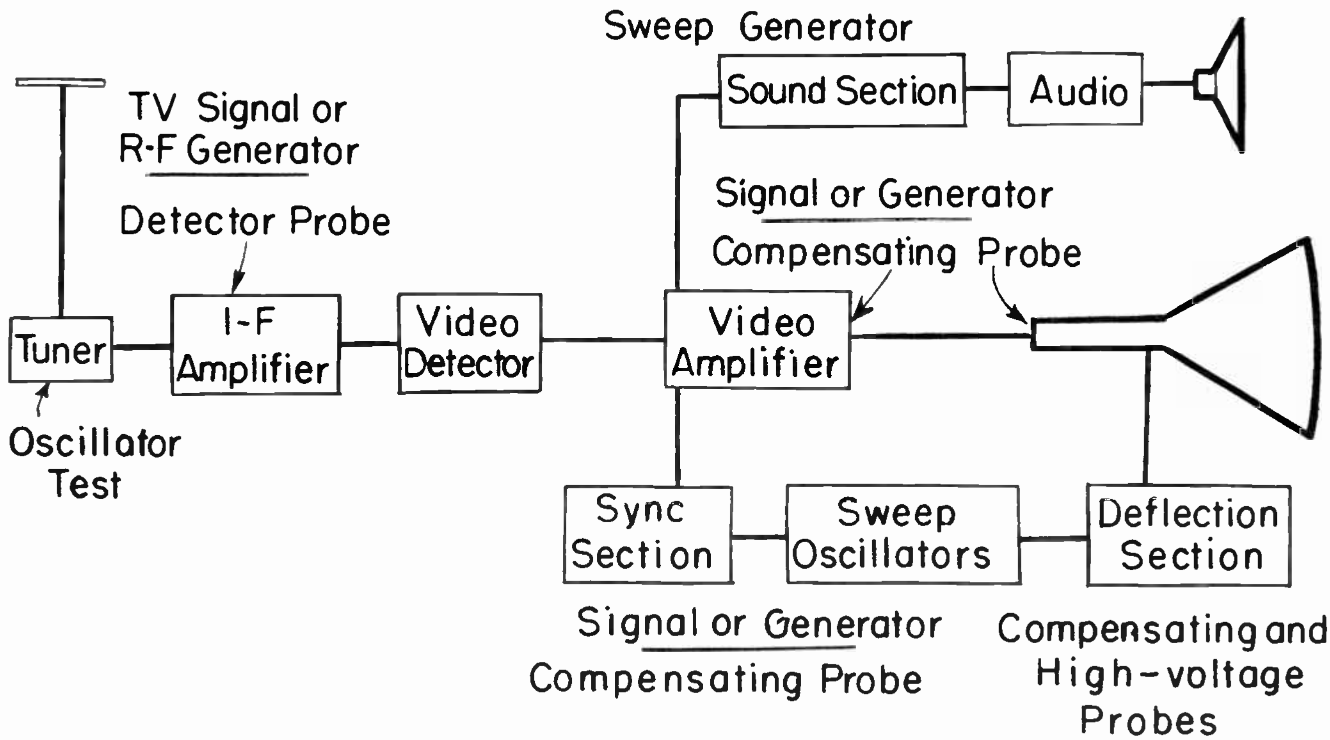

Fig. 1. Types of signals and test instruments used for signal tracing in a television receiver.

Were you endowed with such magical vision as to see a television signal before it reaches the picture tube you could watch the signal travel all the way from the antenna terminals, provided the receiver were in good condition. If, however, you could see the signal only as far as the input to a video amplifier stage, but not at the output or anywhere beyond the output of this stage, you would know beyond doubt that trouble exists somewhere between input and output.

Then it would be merely a matter of using the VOM or VTVM, and other common service equipment, for routine tests in that one amplifier stage. Thus you could pinpoint the trouble in some certain part or connection without wasting time in other sections of the receiver.

It actually is possible to watch signals pass through a receiver, all the way to the picture tube, by using an oscilloscope. This is signal tracing. So long as the scope shows a trace of proper waveform you know that no serious trouble exists ahead of the point then being checked. When the trace shows an unmistakably bad waveform, there must be trouble between the point then checked and the last point at which the signal still was good.

If transmitted TV signals are weak, or if it is not convenient to connect the receiver to an antenna, signal tracing may be carried with an r-f signal generator whose output is modulated. You can follow the modulation waveform just as though it were the waveform of a regular TV signal.

Signals at carrier and intermediate frequencies must be demodulated or detected in order to make them visible on the screen of the scope. Therefore, for all tests between antenna terminals and video detector input we must use a detector probe on the vertical input of the scope. The video detector of the receiver demodulates i-f signals, and makes

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a detector probe unnecessary at all points beyond. For all tests between video detector output and picture tube grid-cathode or deflection circuits we need only a plain prod on the vertical input of the scope, although a frequency-compensating probe will give more accurate reproduction of waveforms.

Fig. 1 shows the principal sections of a receiver, together with the kinds of signal sources and oscilloscope probes which may be used for tracing in each section.

It is difficult or impossible to follow signals from antenna terminals to mixer input in the tuner. This imposes no real difficulty, for if signals are satisfactory at the mixer output and beyond, we may safely assume that there are no serious faults in the tuner. If signals are bad at the mixer output, there is bound to be tuner trouble.

When tuner trouble is indicated, first try adjusting a fine tuning or continuous tuning control. Then check the oscillator by observing its d-c voltage with a VTVM. If there is oscillation the grid will be negative by two or more volts, while with no oscillation the grid will be only slightly negative with reference to the cathode or ground.

There are two obstacles in the way of tracing signals through the tuner itself. First, demodulation would be necessary to make waveforms visible on the scope, and carrier frequencies are too high for satisfactory demodulation with generally available detector probes. Second, even at the output of the r-f amplifier and input to the mixer, carrier signals still are too weak to produce a useful trace on most service oscilloscopes.

In the i-f amplifier, from the output of the mixer to the input of the video detector, either a TV signal or a modulated r-f generator signal should produce modulated voltages at the intermediate frequency. In this section of the receiver we pick up i-f signals with a detector probe, when employing any kind of signal source.

The vertical and horizontal sweep oscillators produce their own sawtooth voltages whether or not they are synchronized by applied signals. Consequently, at and beyond the outputs of these oscillators there will be scope traces without either a TV signal or a signal from a modulated generator. We should use the frequency-compensating probe on circuits operating up to about 400 volts, and a voltage-divider probe for all higher voltages. High-voltage probes and their uses are described in the lesson on "Tests And Measurements With Oscilloscopes".

When there are satisfactory signals at the inputs or grids of sweep amplifiers, but still there is faulty deflection at the picture tube, a high-voltage probe is needed for tests in amplifier plate circuits and beyond, for there we are almost certain to encounter potential differences in excess of 1,000 volts.

The sound section, from its takeoff through the sound demodulator, handles frequency modulated signal voltages. Our source of test voltage may be either a TV signal or a frequency-modulated generator. Your regular sweep generator is frequency modulated, and answers the purpose very well. If the sound section and demodulator are working, either a TV signal or the sweep generator will produce audio signals which may be heard from the speaker of the receiver.

The basis idea in all signal tracing is to locate one point at which there are satisfactory indications, and another point, as close as possible, at which there is no signal or an unsatisfactory signal voltage. The trouble must be between these two points. It is obvious that a satisfactory signal at both input and output of a stage or section means no trouble between input and output. Furthermore, if the signal is bad at both input and output, the trouble is not between the two points tested, but must be in some preceding stage or section.

OSCILLOSCOPE ADJUSTMENTS. The horizontal sweep of the oscilloscope must be adjusted to show traces of the modulation frequency. When working with TV signals, adjust the horizontal sweep of the scope to show either vertical or horizontal waveforms, as you desire, and bring two or three complete waveforms onto the screen.

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LESSON 87 – TELEVISION SIGNAL TRACING

When working with signals from a modulated r-f generator, adjust the horizontal sweep of the scope to bring two or three cycles of modulation onto the screen. This means using an internal sweep frequency of one-half or one-third the generator modulation frequency.

If the r-f generator is being externally modulated, tests may be somewhat easier if you use external synchronization for the scope. Take the external sync voltage from whatever source is modulating the r-f generator.

WORKING WITH TRANSMITTED TV SIGNALS. In any given locality, signals from some transmitters usually are stronger than from others. Tune the receiver to the channel providing strongest signals.

If the picture tube shows any picture at all, no matter how poor, or if there are any indications that a picture signal is present, adjust the fine tuning or continuous tuning for best possible reproduction. Do the same with the contrast or picture control. Adjust vertical and horizontal hold controls to keep pictures in sync, if possible. Should there be no picture of any kind, it may be possible to hear the sound program that accompanies pictures. Then adjust the fine tuning or continuous tuning for clearest sound.

Try all active channels to make sure you have the strongest signal. Thereafter do not change channels during the tests. A change might make it difficult to compare signals and signal strengths at successive test points.

After obtaining any kind of scope trace indicating a signal at any test point, try readjusting the fine tuning or continuous tuning for maximum height of trace. This is especially necessary after originally tuning for sound, when no picture could be seen.

Waveforms which show correct and incorrect action of various receiver sections when working with TV signals are shown in lessons which deal with the respective sections and with use of the oscilloscope.

For the i-f amplifier and traps, also for the video detector and amplifier, and for d-c restoration circuits, typical scope traces are in lessons of the following numbers: 35, 37, 42, 54, 58, and 78.

For the sync section, including vertical integrating filters, look for waveform traces in lessons 35, 54, and 65.

Performance of sweep oscillators of all types, also of automatic frequency control circuits for these oscillators, is shown by waveform traces in lessons 54, 66, and 67.

For sweep amplifiers, both vertical and horizontal, and for deflection coil circuits, there are typical traces in lessons 54, 66, 68, and 69.

Service manuals for particular receivers often illustrate a whole series of waveforms which indicate normal performance. Most often these waveforms are for circuits and sections which follow the video detector. One group may include the video amplifier section and other circuits extending to the grid-cathode input to the picture tube. Another group will apply to sync, sweep, and deflection circuits. Such information in service manuals often is under the heading of waveform analysis.

Illustrations of waveforms for a certain receiver usually show approximate peak-to-peak voltages. If you have the necessary equipment, measure voltages actually obtained during your tests and compare them with voltages given by the manufacturer. There may be variations up to twenty per cent, or somewhat more in a few cases, without indicating serious trouble other than the possibility of weak tubes. Peak-to-peak voltage measurements are explained in the lesson on "Tests And Measurements With Oscilloscopes".

MODULATED GENERATOR SIGNALS. The chief advantage in using a modulated r-f generator is that its output may be made strong enough to force a signal through receiver stages even when troubles are such as prevent recognizable results from a TV signal. Then it is possible to try correcting probable faults until modulation traces come through with less r-f output from the generator. The disadvantage is that modulation

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waveform from the generator cannot be exactly the same as that of a standard TV signal, and troubles or their causes may not be so clearly apparent as when reproducing a TV signal.

The generator may be of any type which will furnish r-f voltages in the television carrier range, and which allows either internal or external modulation of these voltages. When the horizontal sweep of the scope is adjusted to suit the modulation frequency of the generator, the modulation waveform will show on the scope in much the same manner as would the waveform of a TV signal.

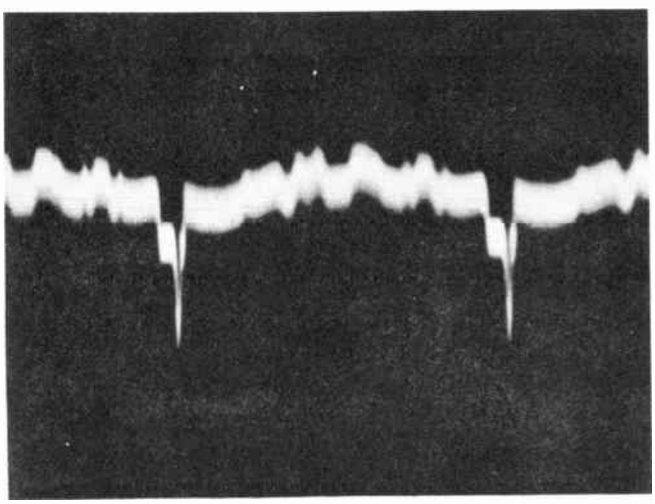

Fig. 2-A

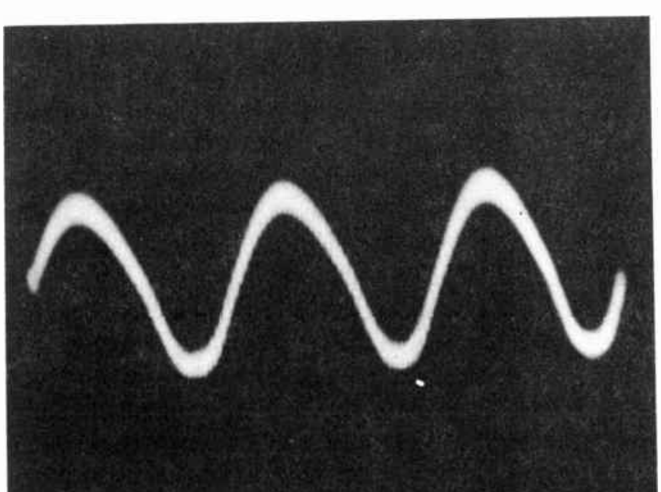

Fig. 2-B

Fig. 2. Traces of a TV signal and of sine-wave modulation as taken from an i-f amplifier.

Fig. 2 shows scope traces obtained from the second stage of an i-f amplifier through a detector probe. At A is the trace from a TV signal, showing vertical sync pulses and picture variations. At B is the trace from a generator signal with sine-wave modulation at 400 cycles.

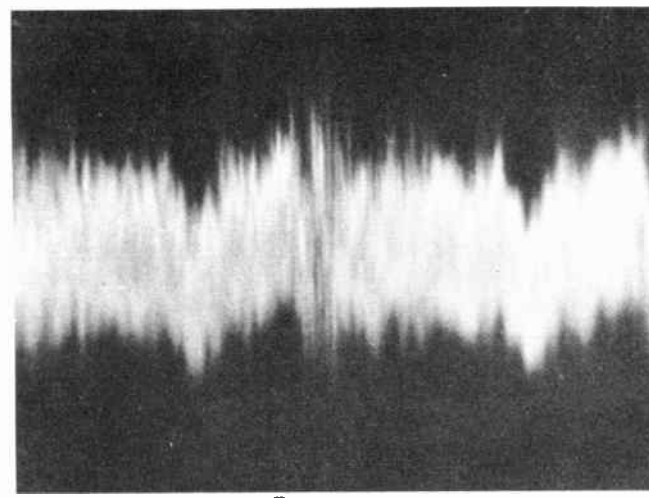

Fig. 3-A

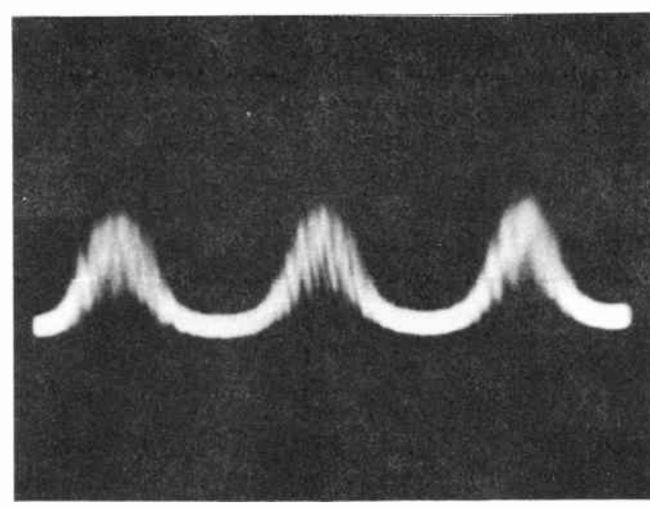

Fig. 3-B

Fig. 3. Effects of regeneration show clearly on any kind of signal waveform.

Fig. 3 shows effects of feedback and regeneration in the i-f stage preceding the point of takeoff. At A is the trace resulting from a TV signal, and at B is the trace from the 400-cycle modulation of the r-f generator.

MODULATED GENERATOR CONNECTIONS AND TUNING. A transmitted TV signal may be applied, of course, only at the antenna terminals of the receiver. The signal

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from a modulated r-f generator may be applied not only at the antenna terminals, but at the mixer grid or at the video detector load for testing only certain sections of the receiver.

When the generator is connected to the antenna terminals its modulation should travel all the way to the picture tube, provided no very serious trouble is present. Make a connection at antenna terminals with a shielded output cable on which is a pad or termination for matching receiver input impedance, usually 300 ohms.

Tune the generator for a radio frequency within the carrier frequency range of any channel which is not locally active or allocated. Low-band channels may allow easiest signal tracing. Tune the generator first near the middle of the channel range. After obtaining a scope trace of the modulation waveform, retune the generator and adjust a fine tuning or continuous tuning control of the receiver for maximum trace height with good waveform.

If your modulated signal generator will not tune to frequencies so high as television carriers it is entirely practicable to use the harmonic of a generator frequency. That means tuning the generator to a fundamental frequency whose second or third harmonic is a desired carrier frequency. Avoid tuning the generator to a fundamental within the i-f range of the receiver, or to any frequency of which a harmonic falls in the receiver i-f range.

Should you have good reason to believe that trouble is not in the tuner, connect the modulated r-f generator to the mixer grid or to the grid of the first i-f amplifier. Then modulation may be traced through the i-f amplifier section and through all following sections.

When applying the modulated r-f signal to the grid of any tube, make the connection through a ceramic or mica capacitor of 500 to 1,000 mmf capacitance. The connection may be made also to a metal sleeve or an ungrounded shield on the mixer tube, as during alignment, although it may be difficult to get a strong signal into the mixer with this method.

Tune the r-f generator to a frequency within the i-f range of the receiver. Readjust generator frequency for maximum height and best waveform of modulation trace with fairly low output from the generator. The receiver should be tuned to any inactive channel, and the regular antenna disconnected. Adjustments of fine tuning or continuous tuning will have no effect when the test signal is applied beyond the tuner. Adjustment of a contrast or picture control may help to obtain clear traces.

Should you wish to trace for trouble only in receiver sections following the video detector, connect the modulated r-f generator to the high side of the video detector load or to the grid of the first video amplifier. Make this connection through a ceramic or mica capacitor of about 1,000 mmf. The generator must have its r-f tuning adjusted for a frequency at least five or six times higher than the modulation frequency, but lower than four megacycles in order to fall within the video-frequency range.

MODULATING THE R-F GENERATOR. Practically any modulation frequency may be used, just so long as the horizontal sweep of the scope can be adjusted to show a trace of that frequency. R-f generators of service types most often provide internal modulation at 400 cycles per second, which is entirely satisfactory. With external modulation for the generator, frequencies such as 60 cycles, 120 cycles, 1,000 cycles, 15,750 cycles, or anything higher or lower may be used.

Internal modulation of r-f signal generators usually is of approximately sine-wave form. Sine-wave modulation is satisfactory for all signal tracing. If the signal generator permits external modulation, and if you have a square-wave generator, square-wave modulation of the r-f signal may have some advantages when tracing in sync and sweep sections. In these sections we are interested in sync pulses and their effects. Sync pulses consist of square-wave modulation on television carrier and i-f signals - hence the advantage of square-wave modulation for some tests.

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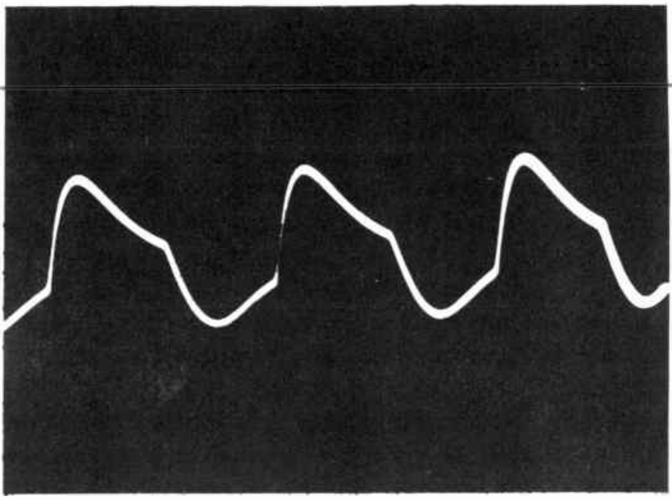

Fig. 4-A

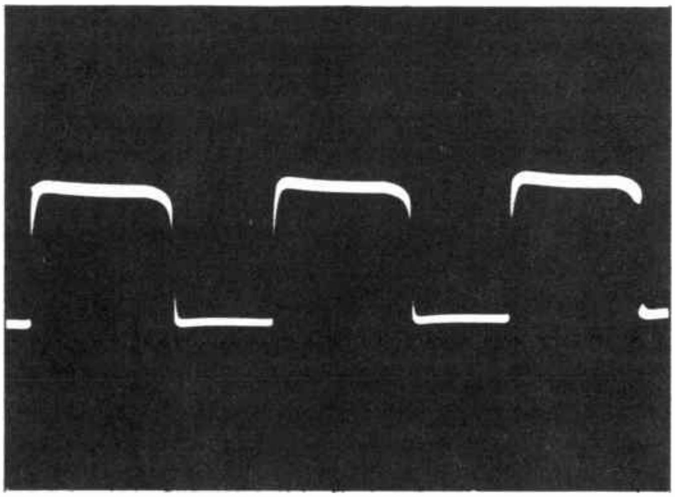

Fig. 4-B

Fig. 4. Traces of square-wave modulation as picked up in the i-f amplifier and in the following video amplifier section.

Fig. 4 shows scope traces resulting from square-wave modulation. At A is a trace picked up with a detector probe from the plate of an i-f amplifier. The trace at B was picked up with a frequency compensating probe at the plate of a video amplifier. In both instances the output of the modulated generator was applied at the antenna terminals of the receiver.

The trace picked up with the frequency-compensating probe is clearly of square-wave form. With pickup through the detector probe there is distortion. This distortion occurs because the detector probe is not frequency-compensated, also because the small capacitor inside the probe, through which signals reach the demodulating crystal, has high reactance and much attenuation at low frequencies in the square wave.

Wave distortion is due to the probe, not to trouble in the i-f amplifier. This is proven by the fact that we obtain a good square-wave trace farther along (at B of Fig. 4) although the signal at this latter point has come through the i-f amplifier before reaching the video amplifier.

Do not alter the frequency of either sine-wave or square-wave modulation between successive tests. This might change the trace waveform and cause you to suspect trouble where it doesn't exist. If you wish to change modulation frequency, do so while taking signals from the same point in the receiver. Then you can tell what portion of the waveform change is due to change of modulation frequency.

Be careful not to overmodulate the r-f signal when using variable internal modulation or when using external modulation. If increasing and decreasing strength of modulation causes the scope trace to become higher and lower with no change of form you are not overmodulating. If the waveform changes shape you are overmodulating. The general rule is to use an r-f signal strong enough to show a good trace of modulation while modulation strength itself is fairly low.

It is necessary also to keep the r-f signal strength low enough to avoid overloading any tubes through which the signal passes before being picked up for the scope. When the trace waveform becomes distorted upon increase of r-f signal strength there is overloading of receiver tubes. Try increasing and decreasing strength, and stay within the range which causes higher and lower traces without change of waveform.

At A of Fig. 5 is a trace from square-wave modulation at 15,750 cycles, picked up with a frequency-compensating probe at the output of a sync separator. At B is a trace from the same modulation picked up at the output of a sync amplifier. These two traces are an example of how modulation may be followed from stage to stage.

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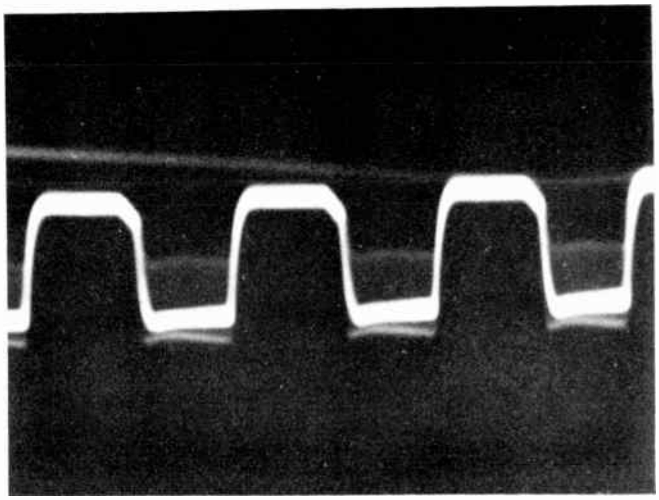

Fig. 5-A

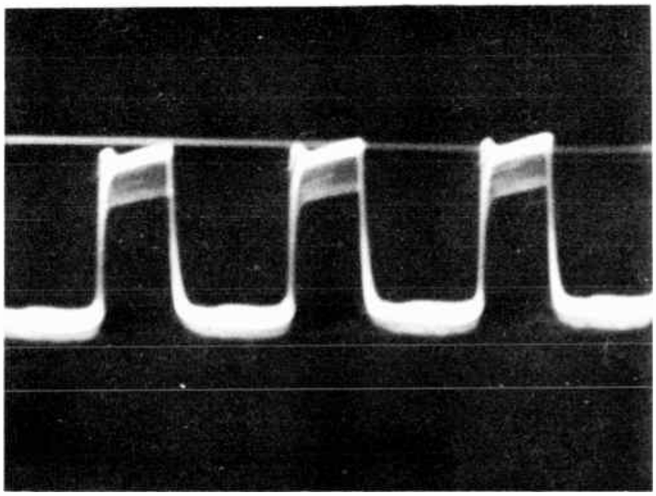

Fig. 5-B

Fig. 5. Square-wave modulation as picked up in successive stages of a sync section.

With any kind of modulation at the field frequency of 60 cycles per second there may be difficulties due to pickup of stray 60-cycle fields from building power lines. At a modulation frequency of 15,750 cycles per second, the horizontal line frequency, there may be pickup of horizontal sync and deflection fields from receiver circuits.

Shielded cables on generator and oscilloscope, with proper grounding of the receiver and all instruments, should reduce pickup of external field pulses below a point which causes spurious traces. If the scope shows any waveform which cannot be made higher or lower, and which cannot be made to disappear by adjustment of r-f or modulation voltages, that waveform is produced by external fields. Shielding and grounding must be improved to prevent such false traces.

TRACING WITH A MODULATED GENERATOR. To illustrate differences between TV signals and signals from a modulated r-f generator we shall follow both kinds through the circuits of Fig. 6. Commencing at the video amplifiers which follow a video detector (not shown) these circuits extend through a sync separator and sync amplifier or inverter to a vertical blocking oscillator. From the inverter other circuits lead through a horizontal afc system to a horizontal multivibrator oscillator. A third line to be followed extends from the first video amplifier through an agc keyer tube.

Three signal sources were used for testing: First, a transmitted TV signal. Second, an r-f signal generator with square-wave modulation. Third, an r-f signal generator with sine-wave modulation. The generators were connected to the antenna terminals of the receiver, with receiver and generators tuned for channel 6. As a consequence, before reaching the circuits of Fig. 6 all signals had to come through the tuner, the i-f amplifier, and the video detector. Points at which the scope probe was connected are numbered from 1 to 15 on the diagram. Following explanations are numbered to correspond with these points.

1. Plate of first video amplifier. With a TV signal, and the scope adjusted to show vertical intervals and sync pulses, the trace is shown at A of Fig. 7. With the scope adjusted for horizontal intervals and sync pulses the trace appears as at B. Signal modulation frequency, so far as sync pulses are concerned, is the regular 60-cycle field frequency for trace A and is the horizontal line frequency of 15,750 cycles per second for trace B. These traces show familiar waveforms.

With square-wave modulation on the signal generator the scope trace taken from the video amplifier plate appears as at A of Fig. 8, and with sine-wave modulation it appears as at B.

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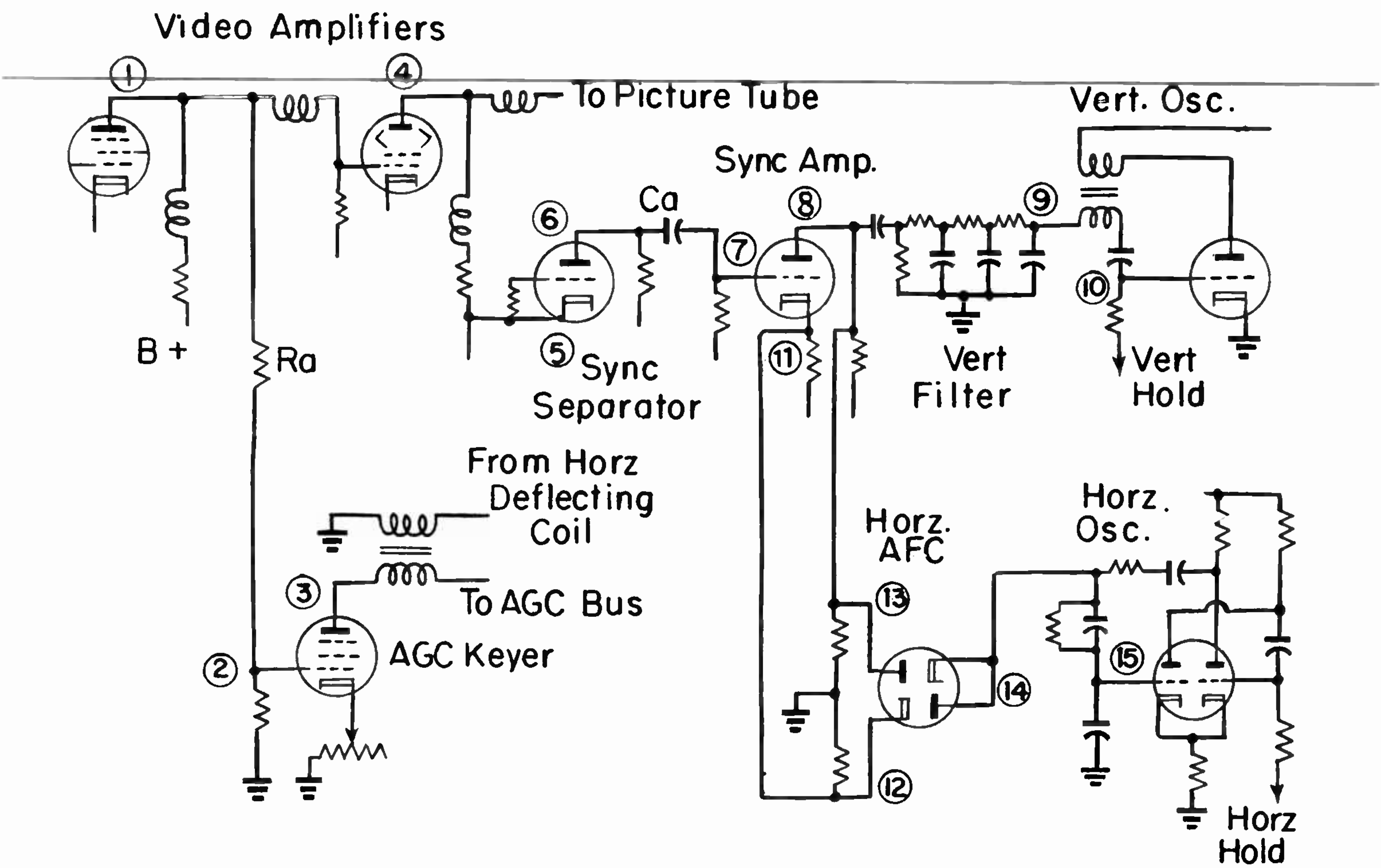

Fig 6. Circuits through which various kinds of modulation are traced, as shown by oscilloscope traces which follow.

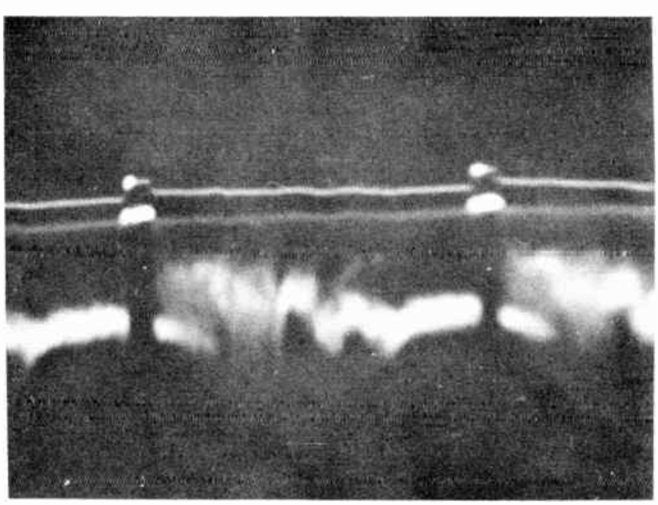

Fig. 7-A

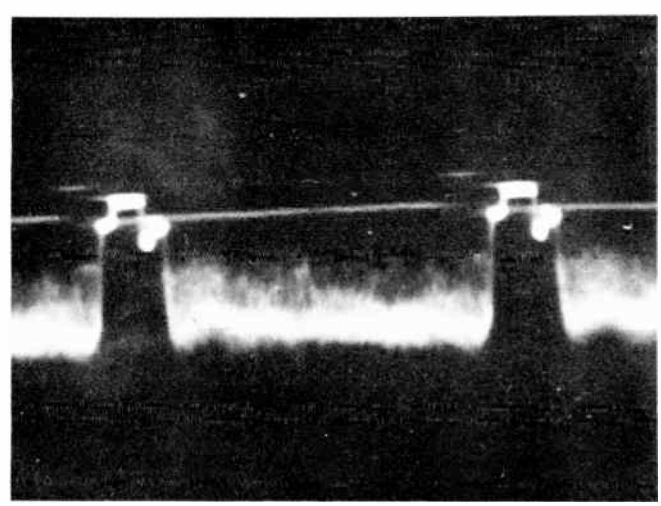

Fig. 7-B

Fig. 7. Television signals at the video amplifier.

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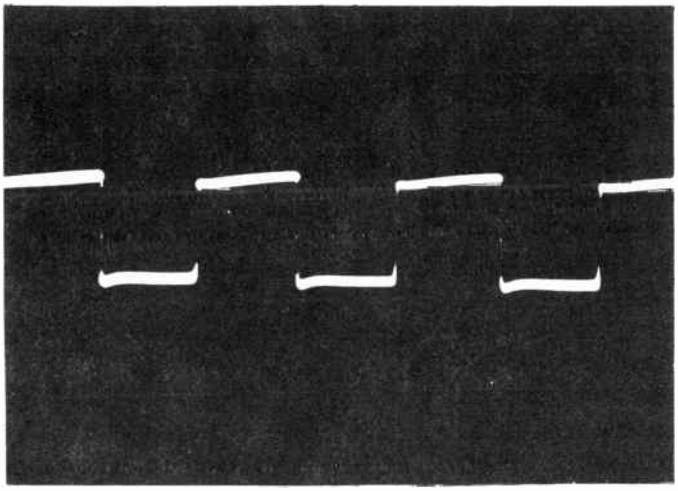

Fig. 8-A

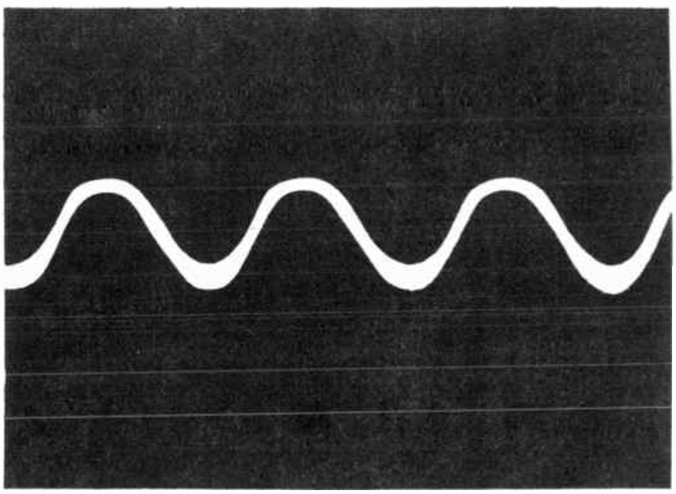

Fig. 8-B

Fig. 8. Square-wave and sine-wave modulations appearing at the video amplifier.

All voltage traces from the output of the video amplifier show, with little or no distortion, the waveforms originally applied as modulation on the carrier or r-f signals. This makes it evident that either a TV signal, a square-wave modulated r-f signal, or a sine-wave modulated r-f signal should be about equally useful for tracing all the way from a tuner through the picture tube grid-cathode circuit of a receiver. The fact that any of these modulations comes through without serious distortion indicates that no major trouble can exist between antenna terminals and the first video amplifier of the receiver used for these tests.

2. Grid of agc keyer tube. This grid is connected through resistor Ra to the plate of the first video amplifier, so the trace from this point should be of the same form as one of those in Figs. 7 or 8, provided no trouble exists between the two test points.

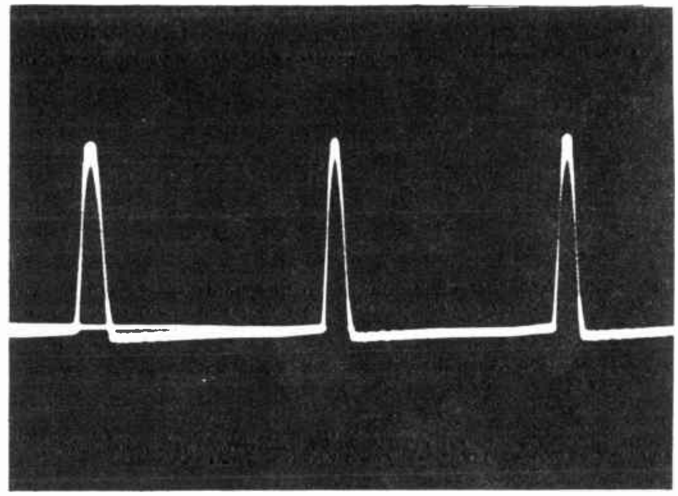

Fig. 9. Sharp positive pulses appear at the plate of the agc keyer tube.

3. Plate of agc keyer tube. At this point we obtain the trace shown by Fig. 9. The trace is the same with a TV signal and with any kind of generator modulation. In fact, this trace remains unchanged when disconnecting all signal sources from the receiver. Before reading further, can you tell from Fig. 6 why this is so?

The trace is unchanged because the voltage producing it comes from a horizontal deflecting coil circuit. Deflection voltages require no received signal to maintain them. They result from action of the horizontal sweep oscillator, which oscillates whether or not it is synchronized by a signal voltage.

4. Plate of second video amplifier. If there is no serious trouble between the plate of the first video amplifier and the plate of the second video amplifier, a trace of a TV signal or of generator modulation will be of the same form at point 4 as at point 1. The trace at 4 will be inverted and will be much higher if the second amplifier is doing its work. A satisfactory trace at 1 and a bad trace at 4 would indicate trouble between these two points.

5. Sync separator cathode. This cathode is connected through a plate load resistor and

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peaker to the plate of the second video amplifier. A trace taken from this point should be of the same form and same polarity as one from the plate of the video amplifier.

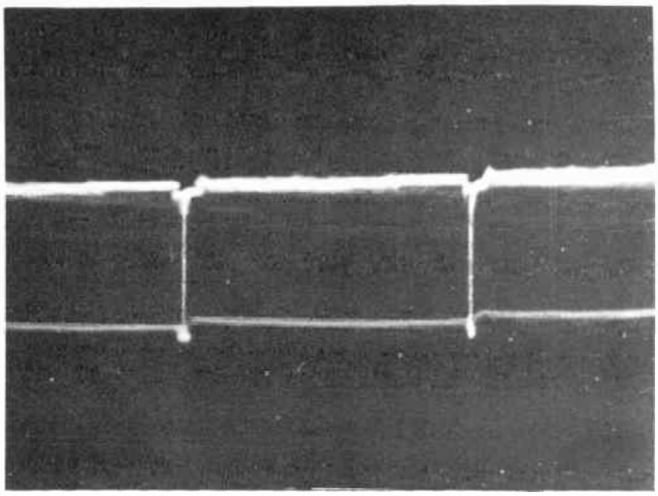

Fig. 10-A

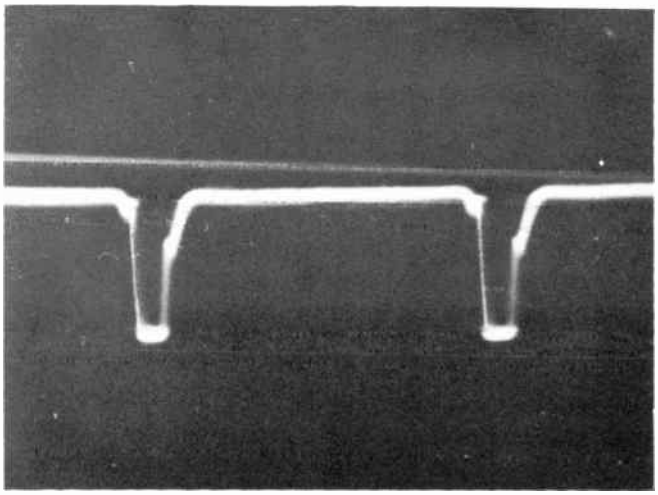

Fig. 10-B

Fig. 10. TV signal traces taken from the plate of the sync separator tube.

<u>6. Sync separator plate.</u> With the scope adjusted for vertical intervals and sync pulses, a TV signal causes the trace shown at <u>A</u> of Fig. 10. With the scope adjusted for horizontal intervals the trace is as at <u>B.</u> Effects of picture signal variations have practically disappeared, leaving only sync pulses. These pulses are inverted in relation to those at the cathode of the sync separator, because, with a signal applied to either gird or cathode of a triode there always is inversion at the plate.

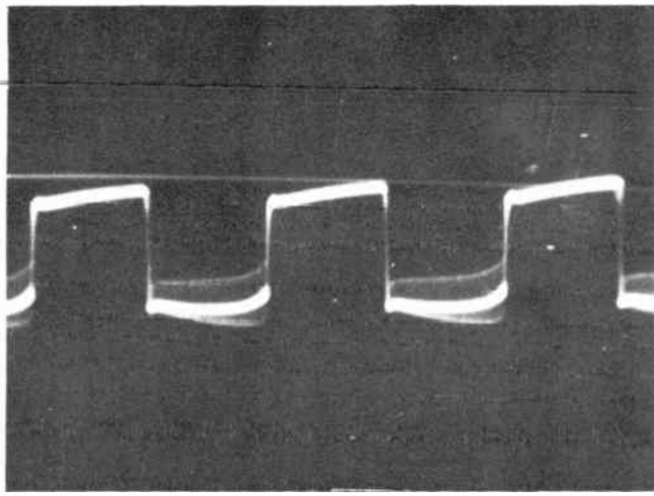

Fig. 11-A

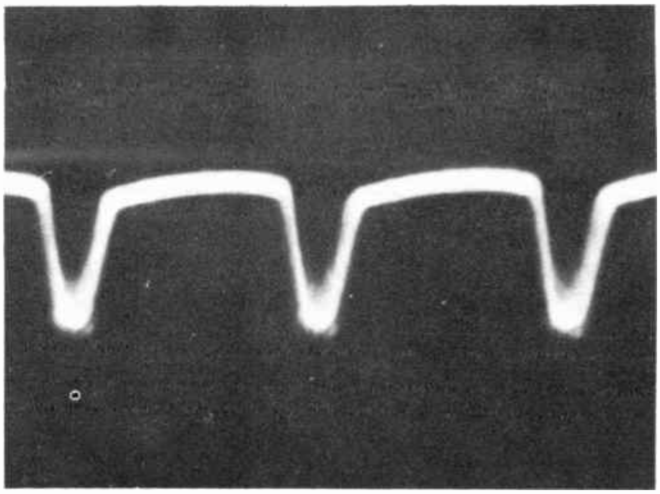

Fig. 11-B

Fig. 11. Traces of square-wave and of sine-wave modulation from the sync separator.

When using an r-f generator with square-wave modulation the trace from the sync separator plate is as at <u>A</u> of Fig. 11, and when using sine-wave modulation the trace is as at <u>B.</u> Either of these traces resulting from r-f generator modulation would be satisfactory for signal tracing, since both show that sync pulses would come through in recognizable form.

<u>7. Sync amplifier grid.</u> This grid is connected through capacitor <u>Ca</u> to the plate of the sync separator. Therefore, in the absence of trouble between these two points, a trace from this amplifier grid should be of the same form and polarity as those in Figs. 10 or 11, depending on the kind of signal source being used.

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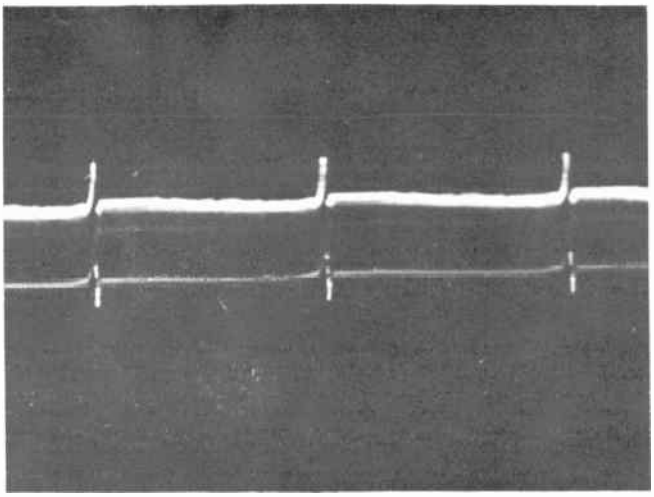

Fig. 12-A

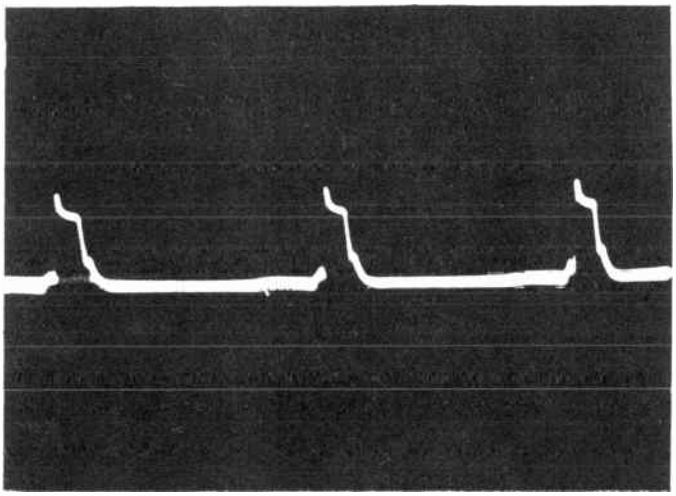

Fig. 12-B

Fig. 12. A TV signal causes these vertical and horizontal waveforms at the plate of the sync amplifier tube.

<u>8. Sync amplifier plate.</u> A TV signal, with the scope adjusted for vertical intervals, produced the trace at <u>A</u> of Fig. 12, and with the scope adjusted for horizontal intervals produced the trace at <u>B.</u> There is inversion between signal input at the grid of this tube (Fig. 10) and signal output at its plate.

When using an r-f generator with square-wave modulation the scope trace taken from the sync amplifier plate appears as at <u>A</u> of Fig. 13. With sine-wave modulation the trace is as at <u>B.</u> When sine-wave modulation frequency was changed to 15,750 cycles per second the trace changed from the form at <u>B</u> to that at <u>C.</u> This latter trace is of truer waveform than with a lower modulation frequency because we are using an actual sync

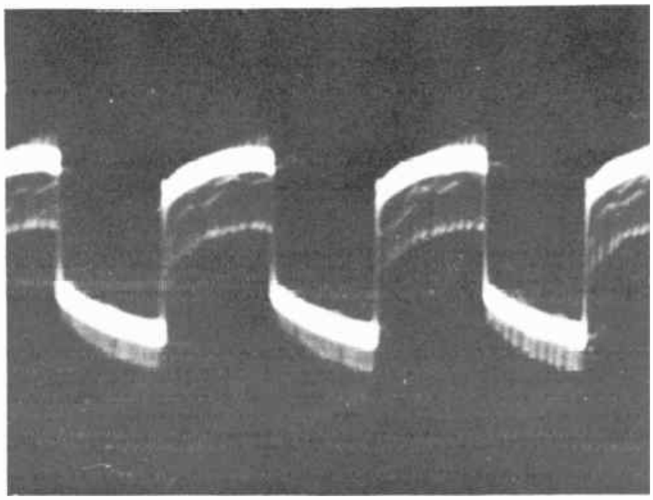

Fig. 13-A

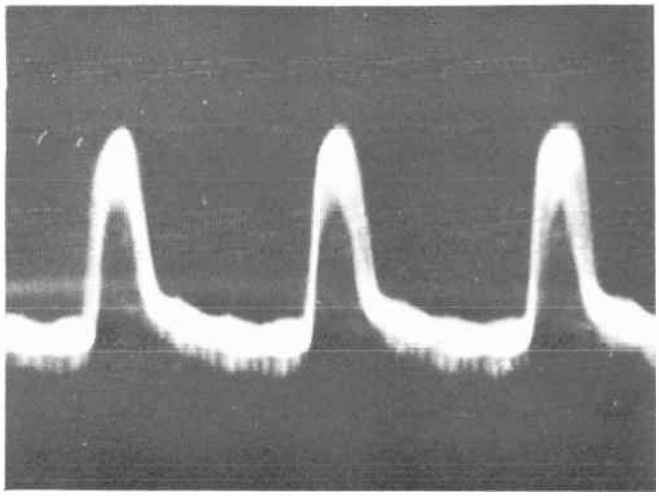

Fig. 13-B

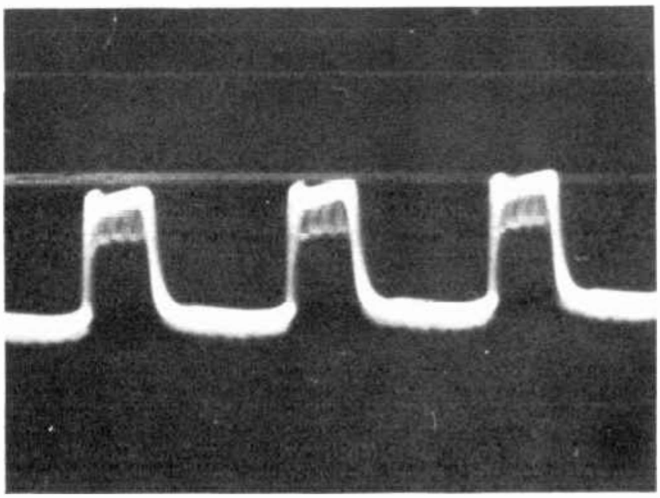

Fig. 13-C

Fig. 13. The sync amplifier plate yields these traces when using square-wave and sine-wave modulation.

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frequency for modulation. Although the trace originated from a sine wave, clipping and limiting in the sync section have flattened the top and bottom.

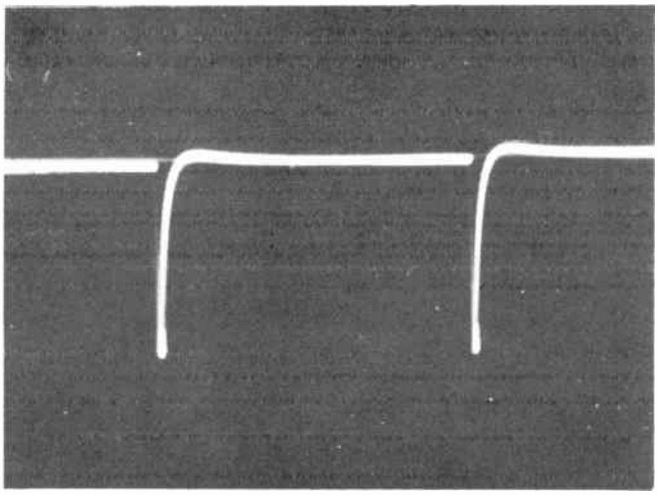

Fig. 14. The waveform at the output of the vertical integrating filter is not affected by a received or applied signal.

9. Output of vertical filter. A trace taken from this point is shown by Fig. 14. The scope was adjusted to show vertical intervals or sync pulses. This trace remains the same with and without any kind of signal being applied to the receiver. This is because the trace voltage comes back from the vertical oscillator, which operates in the same general range of frequencies whether or not it is synchronized.

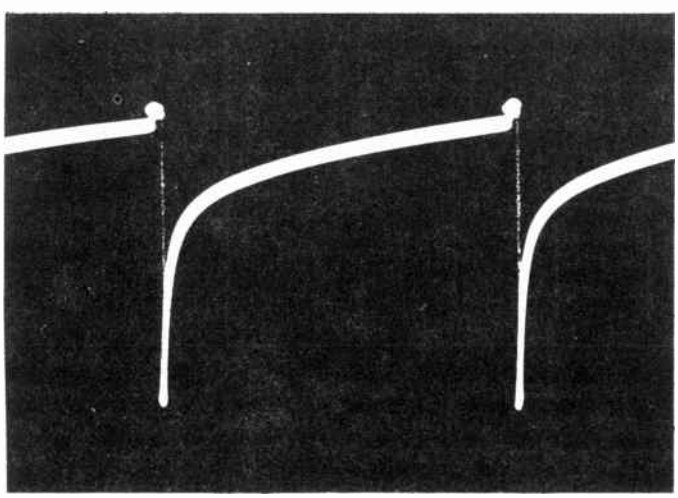

Fig. 15. This waveform is typical of those at all blocking oscillators.

10. Grid of vertical oscillator. The trace from this oscillator grid is shown by Fig. 15. This waveform is typical of all blocking oscillators. Since the oscillator operates in the same manner with and without synchronization, this trace remains the same with neither a TV signal nor a generator signal applied to the receiver.

11. Cathode of sync amplifier. Going back to the sync amplifier, which acts also as an inverter for the horizontal afc system, we find that a trace taken from the cathode is of the same form as a trace from the grid of this tube. The grid trace is shown by Figs. 10 and 11. Traces from cathode and grid are alike because there is no inversion between these two elements of a triode.

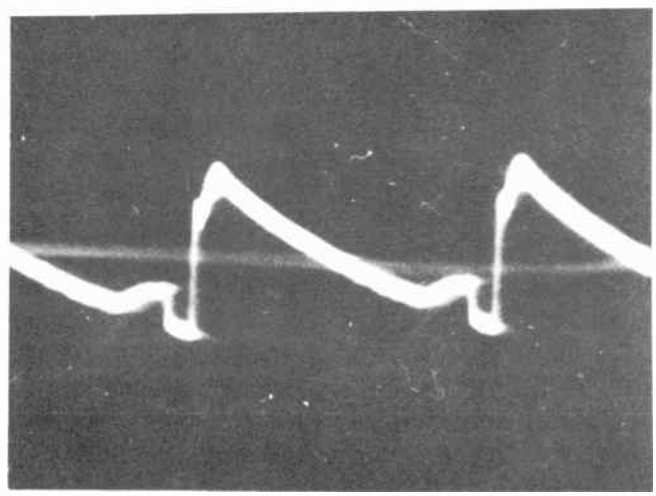

Fig. 16-A

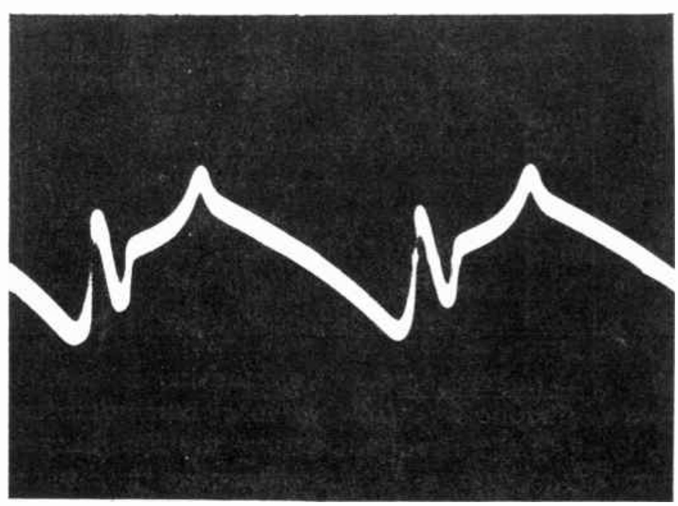

Fig. 16-B

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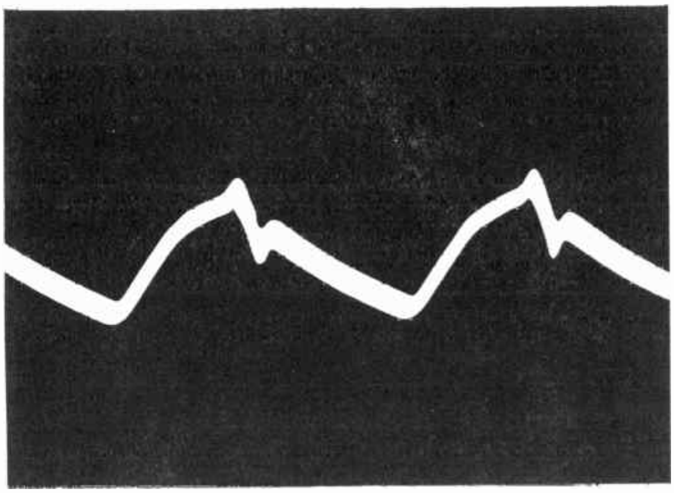

Fig. 16-C

Fig. 16. At the afc tube we find waveforms showing effects and action of frequency correction.

12. Input cathode of afc tube. A TV signal produces the trace shown at A of Fig. 16. The scope, of course, is adjusted for horiizontal intervals or to show horizontal sync pulses. Changing the adjustment of the horizontal hold control causes the dips on the waveform to move one way and the other as pictures go in and out of horizontal sync.

With square-wave modulation of an r-f generator the trace at the afc cathode appears as at B. Frequency control action still is clearly apparent when altering the horizontal hold control. Sine-wave modulation of the r-f generator produces the trace at C. Frequency control action cannot be seen quite so clearly as with a TV signal or with square-wave modulation. Note, however, that all three traces of Fig. 16 show a characteristic long downward slope, and any one of them would be useful when following signals through a receiver.

13. Input plate of afc tube. Traces obtained with a TV signal, with square-wave modulation, and with sine-wave modulation of an r-f generator are shown respectively at A, B, and C of Fig. 17. All three traces show a characteristic upward slope. The sine-wave trace at C appears fuzzy only because of intentional misadjustment of the horizontal hold control. The fuzzy trace cleared up and became sharper when readjusting the hold control, also when slightly readjusting the r-f generator tuning.

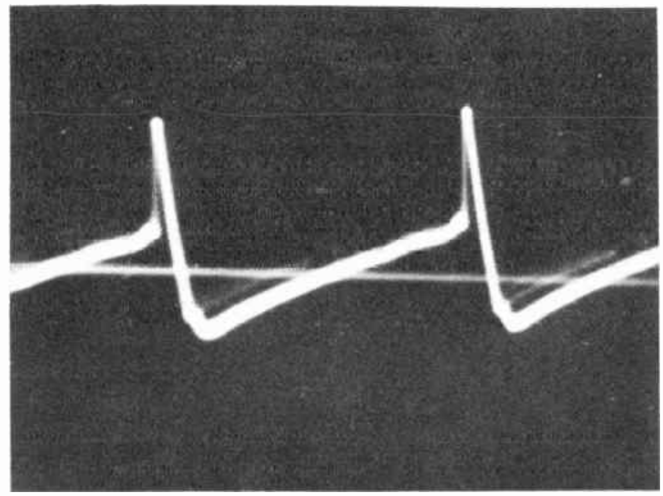

Fig. 17-A

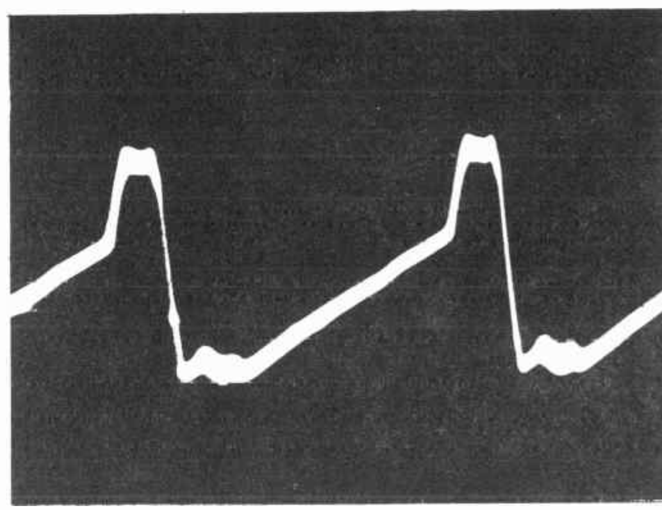

Fig. 17-B

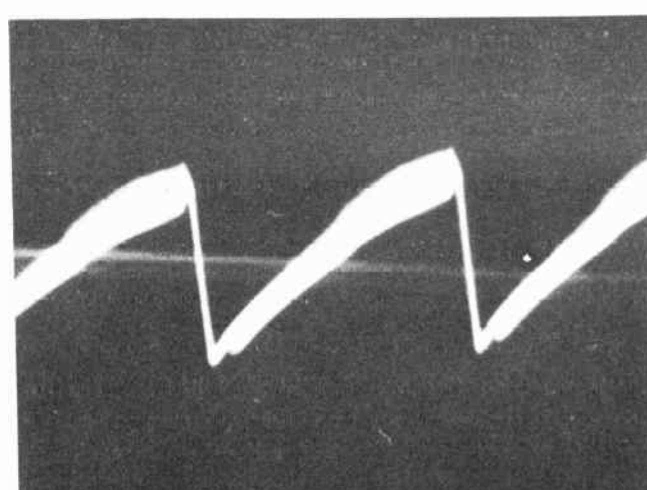

Fig. 17-C

Fig. 17. Afc waveforms are recognizable regardless of the kind of modulation from which they originate.

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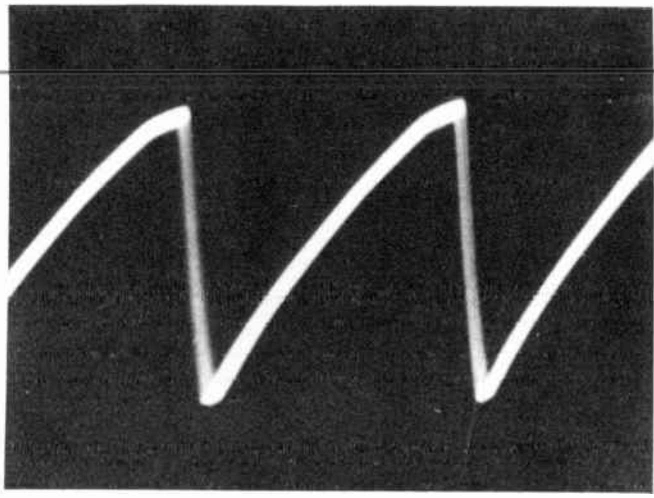

Fig. 18. This waveform at the afc tube is fed back from the output of the horizontal sweep oscillator, accordingly is of sawtooth form.

14. Feedback elements of afc tube. The remaining cathode and plate of the afc tube are connected together, and to them is applied the voltage waveform of Fig. 18. This voltage is being fed back to the afc tube from the second plate of the multivibrator oscillator. As a consequence, the trace taken from this point remains unchanged with and without a signal of any kind applied to the receiver.

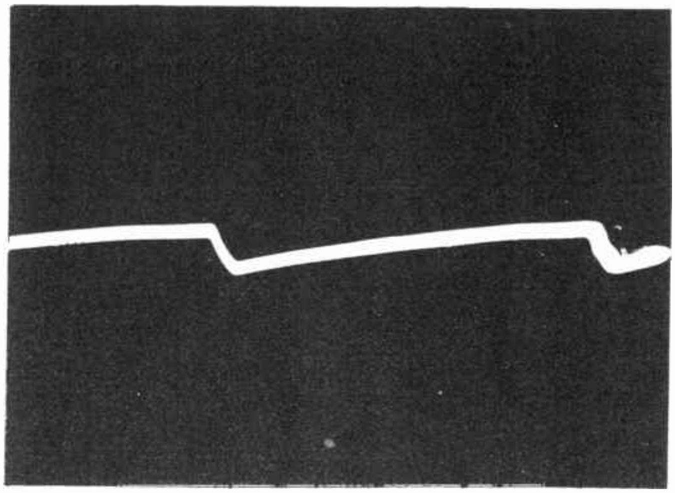

Fig. 19. This is the correction voltage applied at the input grid of the horizontal multivibrator.

15. Input grid of horizontal oscillator. Here we pick up the voltage waveform shown by Fig. 19, showing the frequency correction voltage applied to the oscillator from the afc circuit. This voltage wave will appear about the same whether or not a signal of any kind is applied to the receiver. That is, the afc system always tries to maintain a certain oscillator frequency.

We should appreciate the fact that signal tracing with a modulated r-f generator will not allow identifying so many kinds of trouble as tracing with TV signals. But the modulated generator method does show whether or not the effects of TV signals will pass from stage to stage and from section to section of a receiver. It is an easy method of narrowing the search for trouble to a very small portion of the complete receiver, after which this one portion may be checked with greater exactness.

While tracing signals through any section of a receiver it is a good idea to vary all operating and service controls which may affect performance of that section. When working in sync or sweep circuits try adjusting the vertical and horizontal hold controls, also any service adjustments for the horizontal afc system, and size controls for height and width.

If you are working on i-f amplifier, video detector, or video amplifier sections, or if the signal is coming through these sections before reaching the point of pickup, there are additional controls to be checked. These would include a fine tuning or continuous tuning control, any channel selector switch, the contrast or picture control, and any automatic gain control such as a threshold adjustment.

TRACING IN THE I-F AMPLIFIER SECTION. The first rule is to attempt no tests without a good detector probe for signal pickup. Other practices not quite so necessary, but still helpful, are as follows.

Override the automatic gain control voltage with $1\frac{1}{2}$ d-c volts from a dry cell. This is especially necessary when using signals from a modulated generator, which usually are strong enough to cause automatic limiting of gain.

Pick up signals from plates rather than from grids of amplifier tubes. In the low-

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impedance plate circuit the probe will have less detuning effect than in the higher impedance grid circuit.

When working with a TV signal adjust the scope for viewing vertical rather than horizontal waveforms. The vertical waveforms are much easier to recognize.

Sine-wave modulation of an r-f signal generator usually is easier to follow than is square-wave modulation. Sine waves at almost any modulation frequency tend to hold their forms better than do square-waves. Square waves are likely to acquire peaks and slopes which are confusing, but do not indicate receiver trouble.

Commencing at the mixer output and working through following i-f stages, the scope trace should become higher and higher if the amplifiers are operating properly and if automatic gain control and cathode biases are not unduly limiting the gain. As traces become higher, reduce them by decreasing the r-f output of a signal generator rather than by reducing the vertical gain of the scope. For TV signals it is necessary to reduce the gain of the scope.

Since all signal voltages are at intermediate frequencies it makes no great difference to what channel you tune the receiver, and an r-f generator if used. Tune to the channel giving strongest TV signals, or clearest generator modulation traces.

When using an r-f generator make sure that you are viewing the modulation, not the effect of some strong field pickup by the probe. The height of the trace should rise and fall when varying either the r-f or the modulation strength, and should disappear when either of these are reduced to zero or their minimum strength. The trace waveform should disappear also when the r-f generator is tuned to some decidedly different frequency, and when a channel selector is switched to some other channel. Otherwise you are picking up voltages from stray fields.

Should it prove impossible to pick up the modulation waveform of either a TV signal or an r-f generator it probably will be possible to trace frequency responses all the way from the mixer plate to the input of the video detector. The procedure is like that for observing frequency responses at the video detector load or beyond, except that a detector probe is needed for signal pickup.

Connect the sweep generator to the antenna terminals of the receiver through an impedance matching probe. Then apply the detector probe, on the vertical input of the scope, first at the plate or output circuit of the mixer, then to the plate of each following i-f amplifier. If response traces increase in height from stage to stage it is almost certain that the i-f amplifiers are operating correctly, although there might be misalignment.

DETECTOR PROBES. Success or failure in tracing signals through the i-f amplifier depends largely on whether or not your detector probe is suited to this kind of work. To obtain waveforms resembling the actual TV signal the probe must have rather high input impedance so that excessive detuning of receiver circuits may be avoided. But, with a high impedance probe, signal strength at the mixer output and possibly at the first or second i-f plate may not be great enough to produce good scope traces unless the scope is highly sensitive in its vertical amplifier.

In the case of weak signals or an insensitive oscilloscope it would be necessary to use a low-impedance detector probe to take off enough signal to produce useful traces. The low-impedance probe is more than likely to so detune the tested circuit that resulting traces do not look like television signals.

These difficulties are considerably reduced when obtaining test signals from a modulated r-f signal generator. The generator output may be made much stronger than any TV signal ordinarily available.

The detector probe and its cable leading to the vertical input of the scope must be shielded to prevent pickup of surrounding fields and to prevent ill effects of hand capacitance. The outside of the probe shield should be insulated to prevent its causing short circuits, and to protect you from shocks while working on sets in which B-

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minus is not chassis ground. Under no conditions use a long ground lead between scope and receiver chassis. Instead, the detector probe should be fitted with a short ground lead which may be clipped to points near the points of signal pickup.

Any detector probe must take some r-f current from the tested circuits in order to produce traces on the scope. In this respect the probe is equivalent to a voltmeter or high or low resistance in altering r-f voltages in circuits tested, and in altering their performance.

Capacitance of the probe sometimes changes the resonant frequency of a tested circuit to an extent that causes oscillation in the i-f amplifier. Such oscillation may be prevented by connecting in series with the probe tip a fixed carbon resistor of 200 to 300 ohms, or sometimes more resistance if necessary. This resistance will reduce the height of scope traces, so should be as small as stops oscillation.

Capacitances and inductances (of internal connections) in some detector probes are enough to form circuits resonant at high frequencies. This self-resonance would cause high peaks on scope traces. Fortunately, few if any commercial probes are self-resonant at frequencies so low as 50 to 60 mc, so should not cause resonant peaks when tracing in i-f amplifiers. Self-resonance is likely at the higher carrier frequencies, and could cause trouble when checking between r-f amplifier and mixer or r-f oscillator.

SIGNAL TRACING WITH SOUND BARS. While tracing the modulation of an r-f generator you will see sound bars on the screen of the picture tube if the picture tube remains in operation with contrast and brightness adjusted as for normal reception. These bars indicate that the generator modulation is getting through to the grid-cathode circuit of the picture tube.

It is quite possible, and is rather common practice, to trace signals with sound bars on the picture tube as an indicator, instead of traces on an oscilloscope. This method is limited to following signals from the mixer output to the picture tube signal input. Sound bars or their absence tell nothing very useful about what is happening in sync and sweep circuits.

Since the picture tube cannot be connected to various test points, as can an oscilloscope, the connection from the signal source must be moved from point to point. You may begin the tests with the signal source at the antenna terminals, then shift its connection successively through the i-f amplifier and video amplifier to the picture tube input. Otherwise you may begin with the source at the picture tube signal input and shift it in successive steps all the way back to the antenna terminals of the receiver. The signal source ordinarily is a modulated r-f generator.

If you trace from picture tube to antenna terminals, sound bars will appear so long as circuits are operating at all points between the picture tube and the connection of the signal source. When bars disappear, you have just passed the point of trouble.

If you trace from antenna terminals to picture tube there will be no sound bars until the signal source is applied to a point beyond the trouble. Then all circuits between the signal source connection and picture tube are operating.

When commencing at the antenna terminals, use an impedance matching probe on the generator output. Tune the generator and receiver to the same channel. Only moderate strength of r-f signal should be needed. Vary the generator tuning, the fine tuning or continuous tuning of the receiver, the receiver contrast control and it brightness control to obtain distinct bars on the picture tube, if possible.

The number of bars will depend on frequency of generator modulation. The bars may be held stationary by adjusting the vertical hold control, or by adjusting the modulation frequency if this is possible.

Check through the i-f amplifier section by connecting the generator output through a capacitor of about 1,000 mmf to the grids of successive tubes. Tune the r-f generator to a frequency within the i-f range of the re-

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ceiver, then readjust this tuning for clearest bars. R-f signal strength must be increased as you proceed toward the video detector, because there will be less and less amplification between the point of signal input and the picture tube. The signal must be applied to the i-f section only in the form of modulation on an intermediate frequency. Applying straight audio frequency voltages, not modulation voltages, in the i-f section will not produce sound bars at the picture tube.

A signal applied to the video detector load, to the grid of any video amplifier, or to the grid-cathode input of the picture tube may be either straight audio frequency or modulation of a video frequency. For straight audio frequency make the connection through a large capacitance. One microfarad is not too large. Otherwise the signal strength must be very great, possibly as much as two volts, when reaching the picture tube input.

If you use a modulated signal applied anywhere from the video detector load to the picture tube input the connection may be made through a capacitor of about 0.01 mf. Tune the signal generator to any radio frequency in the video range. When using a radio frequency lower than about two megacycles, sloping and shifting bars or lines will appear along with sound bars. These sloping bars are due to beat frequencies.

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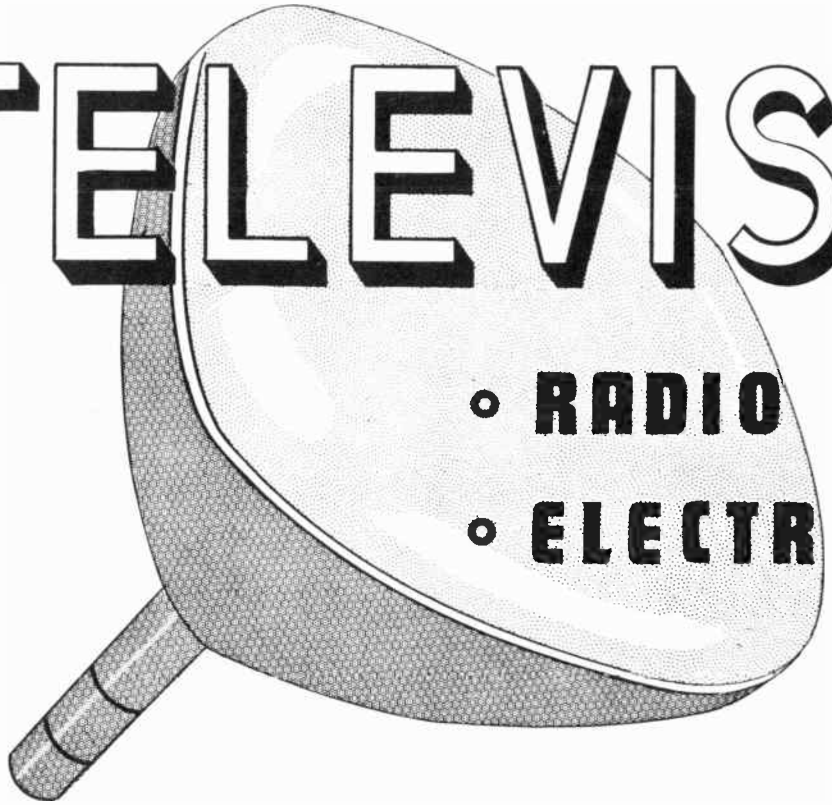
TELEVISION



• RADIO

• ELECTRONICS

LESSON 88 — TELEVISION RECEIVING ANTENNAS

Coyne School

practical home training

Chicago, Illinois

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Lesson 88

TELEVISION RECEIVING ANTENNAS

Fig. 1. This is a Yagi type of antenna designed for peak reception on channel 7.

A television receiving antenna may be outdoors, indoors, or built into the cabinet, but somewhere or other must be an antenna. In any of these positions we may use any of many basic types of antenna, and there are literally dozens of modifications of every type.

The best antenna for any installation depends on how far the receiver is from transmitters, on whether all transmitters within receiving range are in the same or different directions, on the position and size of buildings, bridges, and other obstructions near the receiver, and, of course, on receiver sensitivity.

In recent years the sensitivity of receivers has been so increased, and internal noise so reduced, that it would seem that receiving antennas must have become less important, just as they became less important when radio broadcast sets were improved many years ago. But this has not yet come to pass in television. Performance of even the best of receivers may be greatly improved by a good antenna. The right antenna will help overcome disadvantages of poor location, and provides the only means for avoiding some of the most bothersome kinds of interference.

In these antenna lessons will be explained the characteristics of antennas which are of importance when choosing the right kind for any given installation, also how antennas should be erected and connected to deliver the best possible signals to a receiver. Four important electrical characteristics of an antenna are as follows.

1. <u>Gain.</u> A measure of how much signal energy the antenna can pick up from carrier waves.

2. <u>Bandwidth.</u> The range of carrier frequencies, or channels, in which an antenna will pick up sufficient signal energy for satisfactory reception.

3. <u>Directional Properties.</u> Directions from which carrier waves must approach an antenna for strong signal pickup, for weak pickup, or for rejection of signal energy.

4. <u>Impedance.</u> We have impedance in antennas because every antenna possesses inductance, capacitance, and resistance. Impedance is important, because it is relations between impedances of antenna, transmission line, and receiver input that determine how successful will be this whole system in extracting useful signal energy from carrier waves reaching the antenna.

A television antenna may be nothing more than two straight rods of metal tubes,

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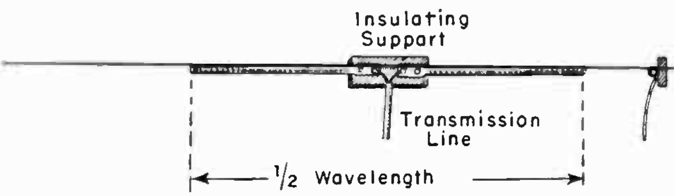

Fig. 2-A.

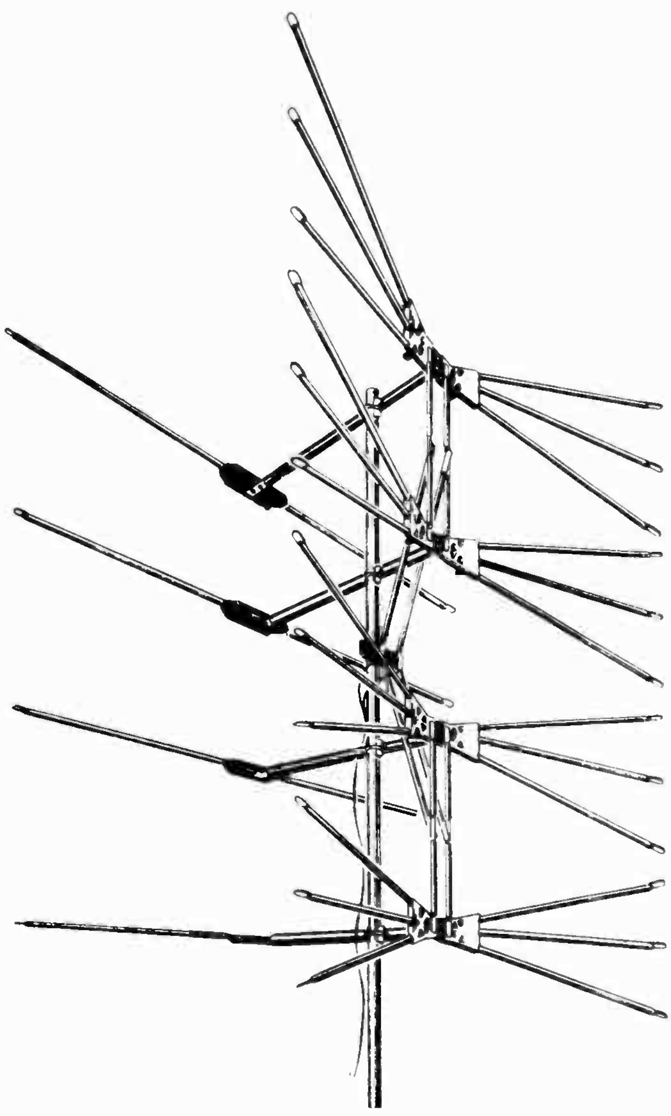

Fig. 2-B.

Fig. 2. The simplest television receiving antenna, and one of the more elaborate types.

as at A of Fig. 2. To the inner ends of these antenna elements is connected a two-conductor transmission line leading to the tuner of the receiver. On the other hand, an antenna may be quite elaborate, as at B. But no matter how elaborate the antenna, it consists of one set of rods or tubes extending to the left and of an exactly similar set extending to the right, with the two sides connected to a two-conductor transmission line going to the receiver.

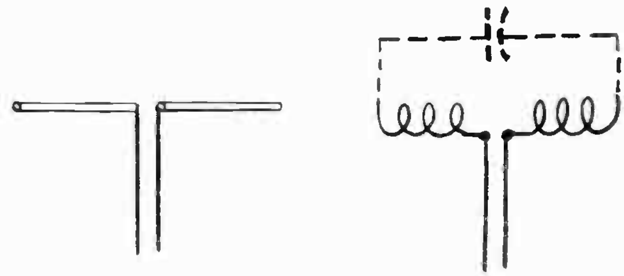

Fig. 3. Every antenna has many of the characteristics of a series resonant circuit.

All antennas, whether simple or elaborate, acts essentially like series resonant circuits. This is illustrated by Fig. 3. Inductance is proportional to overall width of the antenna, which means overall length of its conductors. Capacitance is proportional to conductor diameter, or to the number of conductors, and, in general, to whatever increases or decreases the effective area of the conductors. This series resonant circuit is mounted where its conductors are cut by lines of electric force in television carrier waves.

All television receiving antennas, at least all in common use, are half-wave dipoles. The word dipole means "two poles", in the sense of two magnetic poles or two electric poles. Every half-wave dipole antenna consists of conductors of such overall length that passing carrier waves cause simultaneous positive charges or poles at one end and negative charges or poles at the other end.

This occurs when overall length of the dipole equals one-half the length of a carrier wave, or when we have a half-wave dipole. As you can see in Fig. 4, when a carrier wave is cutting the antenna as at A, the left-hand end of the dipole is made positive and its right-hand end is made negative. When the moving wave comes into the relation at B the polarities at opposite ends of the dipole are reversed.

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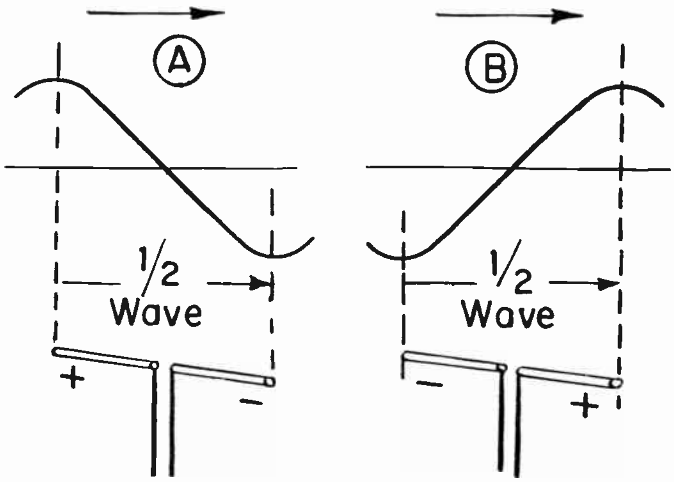

Fig. 4. The ends of a dipole which extends through a half-wavelength are at maximum positive and negative potentials of the carrier wave.

Right here we have the explanation of why antennas designed especially for high-frequency channels have conductors so much shorter than those designed for lower-frequency channels. Carrier waves are short at high frequencies, and relatively long at low frequencies. We must have short dipole conductor for the short waves, longer conductors for the longer waves.

Antenna conductors usually are tubular, with diameters of 1/4 to 1/2 inch or more, and most often made of aluminum alloys, but sometimes of stainless steel or other suitable metals. Center separation or gap between opposite sides of the dipole is only enough to allow an insulating support and terminal connections for the transmission line. Exact width of this gap is not important.

There are a few antennas in which the dipole is a continuous conductor with no center gap. This is a possible construction because, as you can see in Fig. 4, the center is at zero potential when the ends are at maximum positive and negative potentials. Still other designs have overall lengths greater than a half-wave, but connections of additional elements are such as to bring about the same action as in a half-wave dipole.

<u>RECEPTION DISTANCE AND ANTENNA HEIGHT.</u> It is a general rule that the higher an antenna above earth level the greater is the possible reception distance. But actual reception distances, in miles from transmitters, depend on other things as well. Distance varies with relative positions of the antenna and nearby objects, on how freely carrier waves reach this position, or on what obstructions are along the path of carrier wave travel.

Reception distance depends on the type of antenna and on how well or poorly it is installed and connected. Sensitive receivers, and those with low internal noise levels, perform well at greater distances than other kinds. The ratio of signal to noise in space around the antenna helps determine the maximum distance from which useful signals may be obtained.

So-called fringe areas are localities in which reception is difficult, and where everything possible must be done to increase pick-up of signal energy. Primary reception areas are localities in which a simple antenna will provide sufficient signal pickup for receivers of moderate sensitivity. A fringe area may be anywhere from 20 to 70 miles from transmitters, and a primary area may be within 8 to 10 miles, but in every case the actual reception distance depends not only on distance but also on all the factors mentioned in preceding paragraphs.

Frequency of television carrier waves is so high that they behave somewhat like light waves, and tend to follow only straight "lines of sight". In theory, maximum reception distance is limited to a line between transmitting and receiving antennas at such level that carrier waves just clear the curvature of the earth or the horizon, as in Fig. 5. Horizon distance for either transmitter or receiver, in miles, is equal to 1.41 times the square root of antenna height, in feet, about earth level. The sum of the two horizon distances is theoretical maximum reception distance.

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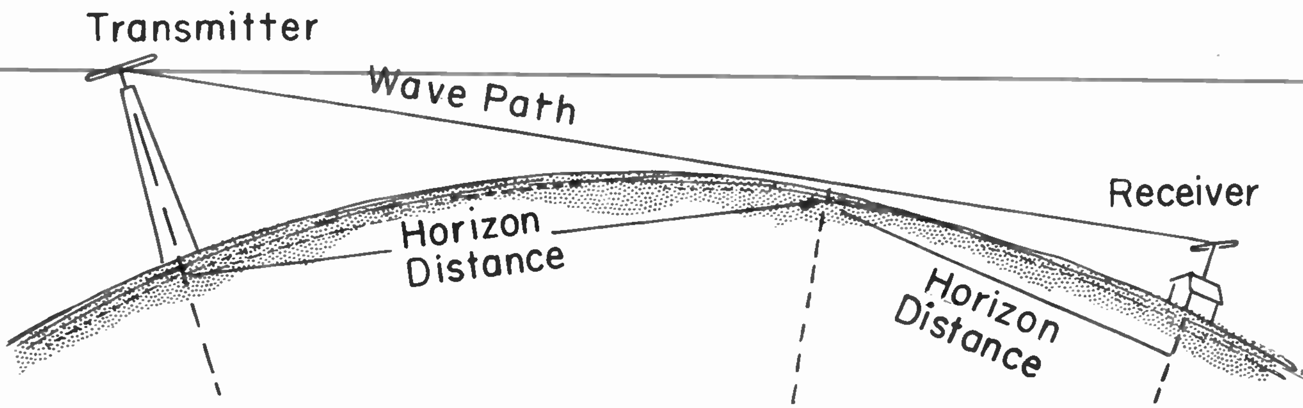

Fig. 5. Carrier waves from a transmitter must clear the curvature of the earth in order to reach a receiving antenna.

A little figuring will show that elevating a receiving antenna from 10 feet to 40 feet adds only four or five miles to theoretical reception distance. The real reason for getting the receiving antenna high is to place it above electrical noise, and above buildings or other obstructions close to the antenna.

We have been talking about distances within which dependable and continuous reception may be expected. You will read reports of reception at distances of hundreds of miles, but such reception is erratic except where transmitters are on mountains.

Occasional long distance reception may be due to diffraction, which means bending of carrier waves over the horizon and around obstructions, and to refraction, which means bending as the waves pass through boundaries of air masses whose dielectric constants are temporarily different. Long distance may be due also to some kinds of reflection, although it is generally believed that television carriers are not reflected from the ionosphere as are waves at standard and short wave broadcast frequencies.

ANTENNA POSITION. You should observe the following rules when picking a position for an outdoor antenna.

1. Mount the antenna as high as practicable above nearby objects. Try for 30 feet or more above earth level. This improves signal to noise ratio.

2. Stay as far as possible from building walls, poles, large trees, and so on.

3. Pick a spot where no nearby large buildings or trees are directly in line between receiver and transmitters.

4. Keep clear of all kinds of electrical machines, advertising signs, and other devices in which electric currents under go sudden variations.

5. Avoid streets which carry heavy motor traffic, also electric railways.

6. Select a position where the antenna supporting mast may be mounted with least difficulty, and where guy wires may be attached when the mast is high enough to require guying.

7. Try to pick an easily accessible position, in case of future trouble with connections, brackets, or guy wires.

8. Be sure to obtain permission from the owner of the building to erect an antenna on it. Persons who occupy leased or rented buildings may not have authority to grant this permission.

9. If the work is done in an incorporated city or village, check the local codes with reference to antennas. Check also with presently effective rules of the National Electrical Code, the fire underwriters rules, if you make antenna erection part of your business.

ORIENTING THE ANTENNA. To orient an antenna means to rotate the entire structure on or around its vertical support or mast

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until finding a position for maximum signal pickup, for maximum rejection of interference, or some acceptable compromise between the two.

First of all, the antenna conductors must be supported in a horizontal position or nearly so. This is because television signal waves are horizontally polarized, by which we mean that electric forces, as distinguished from magnetic forces, in the electromagnetic waves act along horizontal lines. These forces produce alternating opposite polarities in the half-wave dipole only when the dipole conductors are on an approximately horizontal line.

Standard and short-wave broadcast signals are vertically polarized, as are also the interference waves from most spark voltages or noise voltages. F-m broadcast signals are horizontally polarized, like television signals.

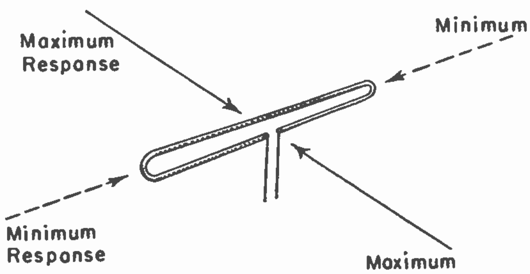

Fig. 6. Directions from which carrier waves must come to a simple antenna for maximum or minimum responses.

When a half-wave dipole is in the path of horizontally polarized signal waves, these waves must approach the antenna from a direction at right angles to the antenna conductors in order that there may be maximum response. This is shown by Fig. 6. The waves may approach from either side of the antenna illustrated, or from either side of a plain, straight dipole. You cannot change the wave direction, so you rotate or orient the antenna. Waves traveling in line with the antenna conductors produce minimum response.

As a simple antenna is rotated away from a direction of maximum response, signal pickup decreases rather gradually. We might illustrate this as in Fig. 7, where

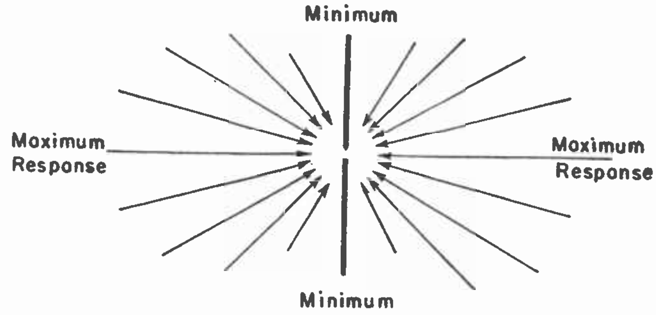

Fig. 7. Relative lengths of arrows are proportional to relative strengths of signal voltages obtained from carrier waves coming for the various directions

relative lengths of arrows are proportional to relative strengths of signal pickup for waves approaching from various angles. The same effect would be had upon rotating the antenna to various angles in relation to wave direction.

In localities where signal waves are strong the antenna may be rotated quite a ways from the position for maximum response before losing a great deal of signal pickup. However, when trying to reduce the pickup of an undesired signal by getting the antenna conductors in line with wave travel, you will find that minimum response is decidedly sharp. The antenna may be rotated only a little away from the exact minimum before the undesired signals become relatively strong.

Directional responses usually are shown by polar diagrams or polar patterns, of which Fig. 8 is an example. The outline marked A shows a response practically the same as that on either side of the antenna in Fig. 7, but instead of arrows there is only the outline which would pass through the outer ends of all the arrows.

Our polar diagram has circles for 25, 50, 75, and 100 per cent of maximum response. There might be circles for each 10 per cent change in response. The greatest dimension of the principal outline of any pattern always extends to the 100 per cent circle or to maximum response. At points where the outline crosses any other circle the response is the percentage of maximum corresponding to that circle, and is the response

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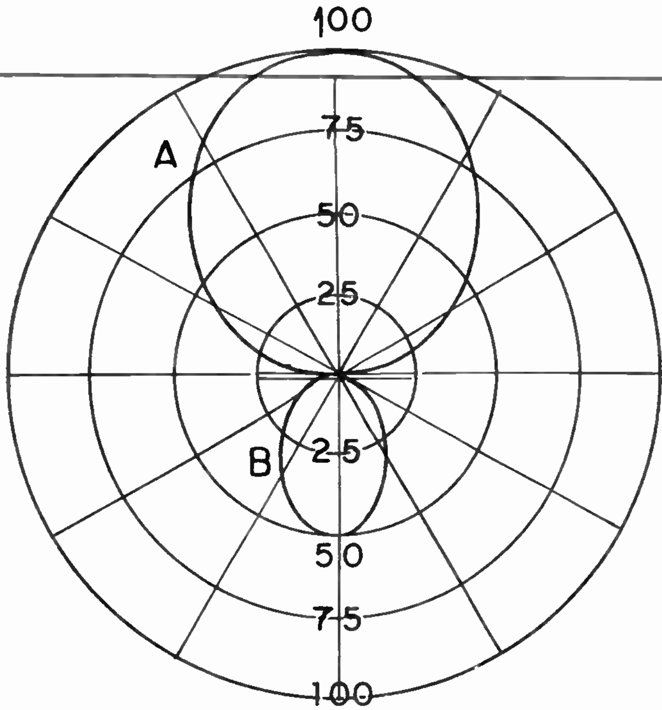

Fig. 8. A polar diagram showing the directional properties of a particular antenna.

to signal waves from the direction or angle shown by lines which radiate outward from the center of the diagram.

Were response to signal waves from the opposite direction only 50 per cent of maximum, the outline for this direction (marked B) would extend only to the 50 per cent circle. Thus it is possible to show relative strengths of response in any direction as percentages of maximum response. The outline for maximum response, no matter what its direction, is called the major lobe of the pattern. All lesser response outlines are minor lobes. On our polar diagram A is the major lobe and B is a minor lobe. With some types of antennas there may be many minor lobes extending in various directions. All the lobes together form the directional pattern.

You may orient an antenna by observing pictures at the set to indicate signal strength and directional response. This takes two persons, one to move the antenna while searching for the best position, the other to watch changes of picture strength at the receiver.

Communication between receiver and antenna locations might be by shouting, or with some code of tapping — two taps for better, one for worse, or something like that. It is more satisfactory to use telephone handsets, either self-powered or battery powered. The self-powered type derives all necessary power from voices fo persons speaking. When using either kind of phones, do not connect them through the television transmission line, use a separate two-wire cable.

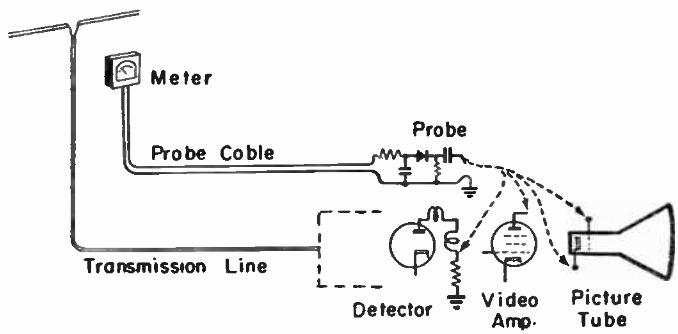

Fig. 9. How a meter and detector probe may be connected to the receiver while orienting an antenna.

One person can do the entire job of orienting with the method illustrated by Fig. 9. This requires a detector probe or equivalent crystal detector circuit which may be connected to the video detector load, to a video amplifier grid or plate, or to the signal input of the picture tube in the receiver. The detector output is connected through a long two-wire cable to a sensitive low-range d-c voltmeter carried to the proposed location for the antenna. Since only d-c voltage is to be measured, a lamp cord cable usually is satisfactory, although a shielded or coaxial cable may give better results.

If you use picture observation as the signal strength indicator, tune to the weakest channel, if it is known, and turn the contrast control so low that changes of signal strength will be clearly evident by brightening of pictures. If the indicator is a meter, set the contrast control as for normal reception. With either method it is highly desirable to override the agc voltage with about three volts from a battery. Otherwise it will be difficult or impossible to determine antenna position for peak signal strength. The ultimate object, of course, is to get the antenna

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into the position allowing best pictures or highest reading of the meter.

Mount the complete antenna on a mast four or five feet long, so that it may be carried about and rotated. Connect the antenna to the receiver through the regular transmission line, using a length of line approximately the same as probably will be needed for the final installation. Hold the antenna as far as possible from you.

Commence with the antenna rods or tubes horizontal and at right angles to the direction of the transmitter operating in the channel to which the television receiver is tuned. Hold the antenna high while rotating it very slowly one way and another. Move a few feet to another position and again rotate the antenna; a very little shift in position often makes great changes of signal strength.

When antenna position and orientation are best for the weakest channel, keep the antenna thus while tuning the receiver to different stations. If you are working alone, make the antenna position while going to the receiver for retuning. It may be necessary to make some compromise in position and direction to obtain good signals in all active channels. If the antenna is picking up interference, orientation may have to be in a direction for least interference without excessive drop in picture strength.

FIELD STRENGTH MEASUREMENTS. Still another method of positioning and orienting receiving antennas makes use of an instrument which measures and indicates carrier signal strengths in microvolts. Such an instrument, usually called a field strength meter, includes a television tuner followed by one or more stages of i-f amplification, a tube or crystal video detector, and sometimes a video amplifier stage. The output of this system goes to a d-c type or a rectifier type microammeter, or there may be a d-c or a-c VTVM circuit. Several ranges permit measurements from less than 50 to as much as 20,000 microvolts.

The instrument may be a-c operated, with power brought through a long cord from any accessible line receptacle. The d-c power supply rectifier may be a selenium type, with tube heaters in series on line voltage. Some field strength meters are powered by self-contained batteries. The instrument cabinet must be fully shielded.

Carrier field strengths may be measured in absolute or relative numbers of microvolts. Absolute field strength is the number of microvolts induced in a dipole one meter (39.37 inches) in overall length, which is correctly oriented for carrier wave direction. This gives a measure of microvolts per meter. If the test antenna is not exactly one meter long it is necessary to correct the number of indicated microvolts by dividing into it the actual meters of antenna length.

Relative field strength is the number of microvolts indicated by the meter without reference to length of the testing antenna. If the meter is connected to an antenna being used for the installation, the indicated number of signal microvolts will be directly proportional to length of antenna conductors, and will not be in microvolts per meter unless suitable corrections are made. Readings will show relative strengths of signal pickup in each channel tested.

Difficulty or confusion may arise because the field strength meter may not have the same sensitivity on each channel as the receiver with which the antenna is to be used. This would prevent accurate comparisons of performances to be expected on different channels. Nevertheless, the field strength meter allows accurate orientation of any antenna onany one channel or group of channels.

A field strength meter should be connected to the receiving antenna through the transmission line to be used for the installation. This line must not be coiled nor sharply twisted or bent. With two men working, one usually positions and orients the antenna while the other reads the meter which is at the far end of the extended transmission line. The remainder of the process is carried out in exactly the same manner as when using the receiver as a signal strength indicator.

Field strength in microvolts required for reception depends on receiver sensitivity, on the amount of internal noise compared to

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amplification, and on external noise and other interference where the antenna is located. The least input to the tuner which allows any useful reception seldom is less than 50 to 100 microvolts, but may be lower in some receivers. Good pictures may require 200 to 300 microvolts, while excellent reception surely should result with 500 or more microvolts. These are signal strengths at the tuner input, not microvolts per meter in space around the antenna.

MOUNTS FOR ANTENNAS. An antenna is supported on a tubular mast which may be of steel, with or without lengthwise seams, or of aluminum alloy, or the mast may be of thin-wall electrical conduit, standard conduit, or standard weight steel pipe. For total mast lengths up to about 25 feet the diameter of light-weight tubing usually is 1-1/4 or 1-1/2 inches. Heavier and stronger tubing or pipe may be as small as 1 inch in diameter for masts of this length. Greater heights require proportionately greater mast diameters.

Some antennas come with a single length of mast which is 4, 5, or 6 feet long. For others the mast must be purchased separately. Clamps for attaching the antenna structure to a mast are furnished with the antenna. Antennas are shipped or delivered with elements folded together or partially disassembled to save space. With each antenna you will find instructions for assembly or erection.

Tubing, conduit, or pipe for masts may be purchased in lengths up to 20 or more feet. A long or high mast may be made up by adding extensions 4 to 6 feet long to the short mast.

Extension clamps or brackets are available in wide variety from television supply houses. At A of Fig. 10 the lower end of the extension is held alongside the top of the original mast by two long U-bolts whose threaded ends pass through cross bars. At B the mast and extension are held end to end in a long split clamp. Other styles of clamps allow fastening an extension of one diameter to a mast of greater diameter. At C the lower end of the extension is swaged down to a diameter which allows slipping it into the top of the original mast.

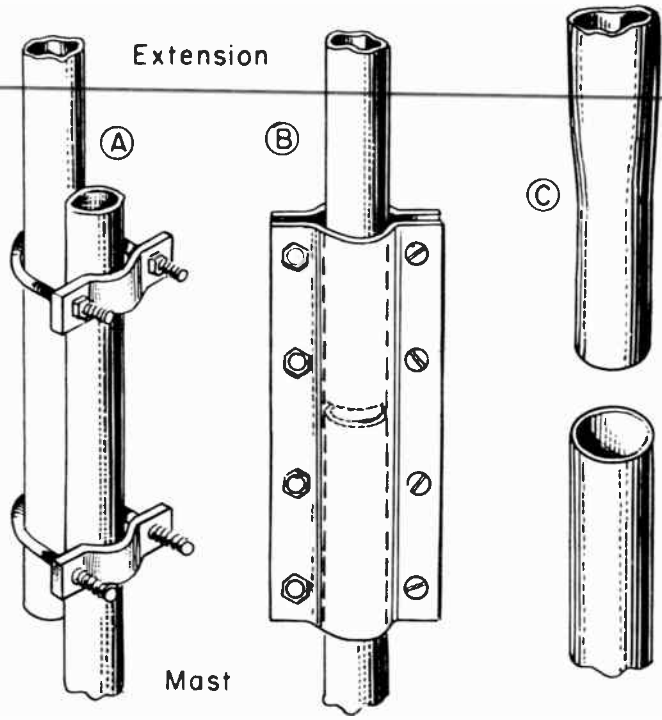

Fig. 10. Some methods of fastening an extension to an antenna mast.

The lower end of a mast is held by a bracket or brackets which allow secure attachment at whatever place on the building is to be used for support. Listed in catalogs of television supply houses you will find mast supports suitable for almost any imaginable kind of installation. We shall examine a few types designed for use on chimneys, plumbing vent pipes, roofs, and vertical walls.

A chimney mount is illustrated by Fig. 11. The mast is clamped in brackets that fit over one of the square corners of the chimney. The brackets may extend out diagonally, as shown, or may extend in line with one of the flat sides of the chimney. The mast must be held far enough from the main body of the chimney to clear a top cap or cornice.

An installation requires two brackets, separated vertically by at least a foot to provide rigid support. The brackets are held on the chimney by steel straps which are cut to approximate length, then tightened by draw bolts or turn buckles. If the chimney is in use, the antenna should be supported high

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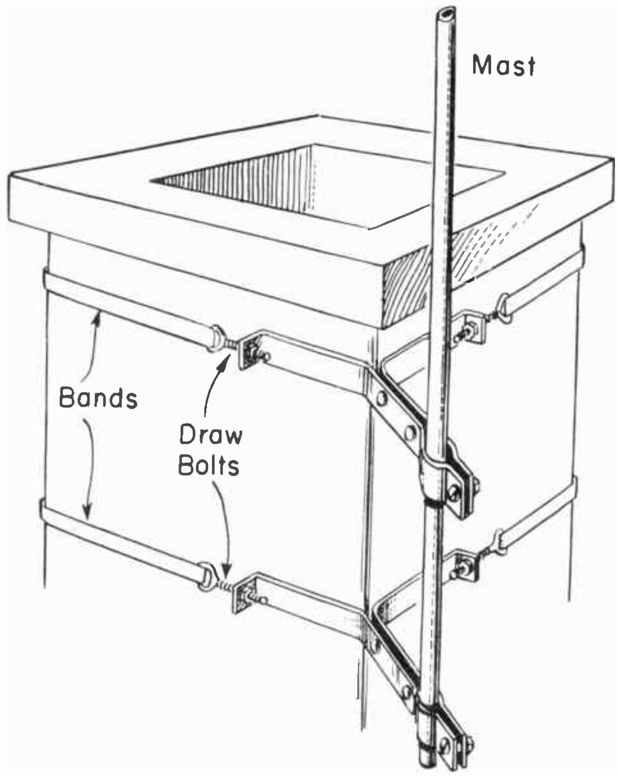

Fig. 11. A chimney mount for the antenna mast.

enough to be clear of smoke and fumes. This means clearance of at least 4 to 5 feet.

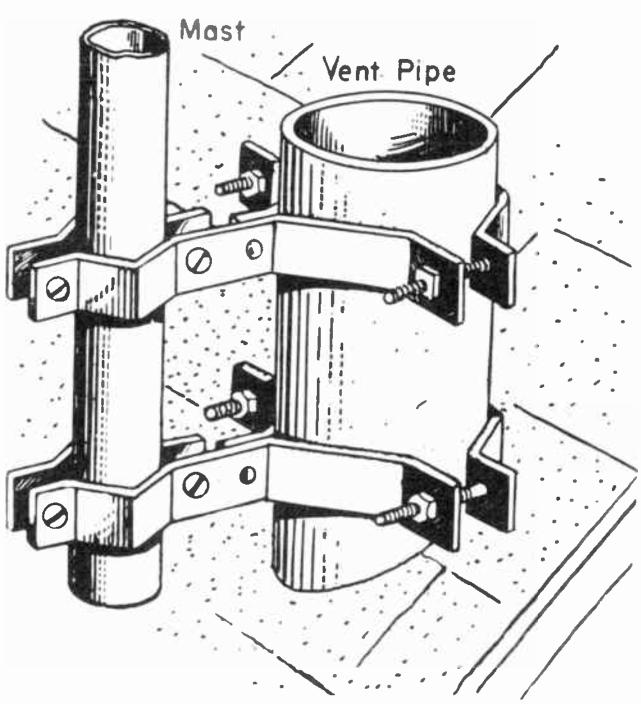

Fig. 12. Here the mast is mounted on a plumbing vent extending up through a roof.

Fig. 12 shows how an antenna mast may be mounted on a plumbing vent pipe that extends up through a roof. Again there are two brackets, which should be separated vertically as far as possible. Brackets are available for vents of various diameters, of which the most common are 2 inches and 4 inches.

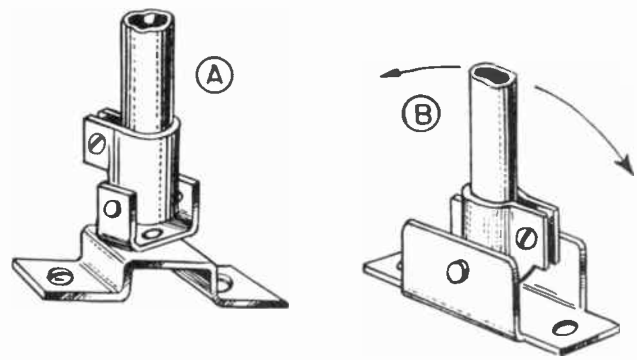

Fig. 13. Mast mounts suitable for supporting surfaces which are either flat or sloped.

In Fig. 13 are two mounts which may be used on flat roofs or on the slope of a peaked roof or on any other slanting support. The clamp for the bottom of the mast in the unit at A is attached by a pin to a swivel member which may be rotated to any position on the main mounting base. The mast and bracket may be tilted to compensate for the slope of a roof surface, and simultaneously rotated to make the mast vertical regardless of how the base is positioned. With the mount shown at B the mast and its clamp may be tilted in the supporting bracket to compensate for any slope of the supporting surface. Of course, any bracket which allows tilting may be used also on a roof or other surface which is flat or horizontal.

Brackets such as those of Fig. 13 often are placed directly on roofing material, but perferably are attached to a rather large flat board which then rests on and helps protect the roofing material. The board may be held in position by several wire nails which extend through the bottom no more than 3/16 inch, and will not go through ordinary roofing. The mast, of course, must be held erect with guy wires.

One style of mount for the ridge position on any roof with a peak is illustrated by Fig.

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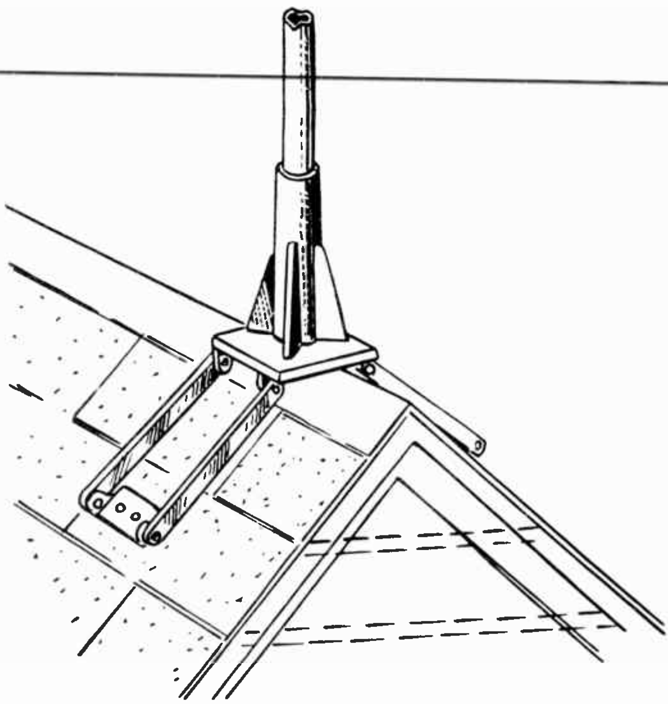

Fig. 14. A mount designed for the peak of a roof.

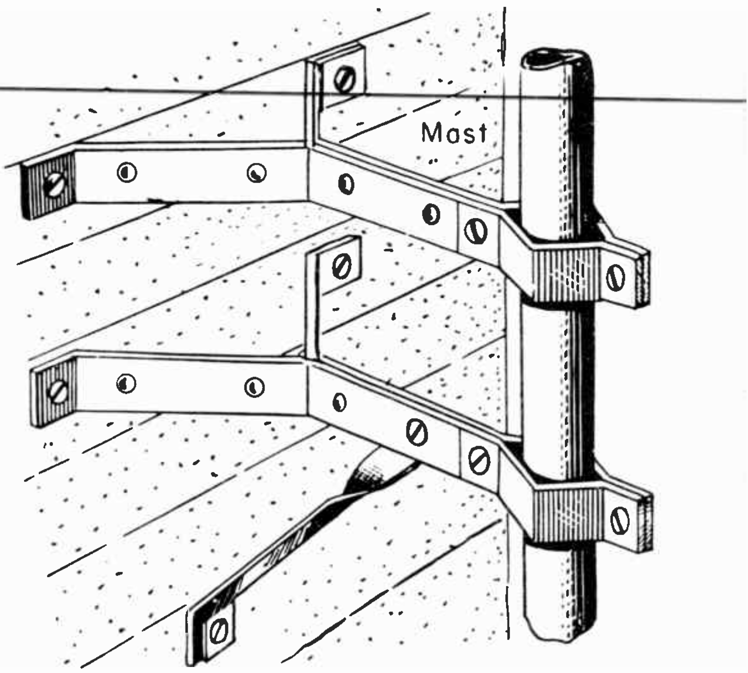

Fig. 15. Mounting brackets attached to a vertical wall surface.

14. As with practically all roof peak mounts, the side brackets are adjustable for any angle or degree of slope, and may be fitted to different slopes on opposite sides of the peak. Brackets of this general type require guying of the mast to keep it vertical.

When making any kind of roof mounting, avoid puncturing the roof surfacing if this is possible. If puncturing is unavoidable, be sure to close the openings with a liberal application of roofing compound or mastic. You may be held liable for damage resulting from leaks. Never attempt to support the antenna mast on tile, slate, or metal roofs; this is sure to cause damage.

One style of mounting for vertical walls is shown by Fig. 15. The open V-shaped ends of the brackets are fastened to the wall, with the mast held by brackets at the outer ends. The lower bracket is shown with an added brace extending downward at an angle. For light-weight antennas and short masts this bracket often is omitted.

The mast must be far enough out to clear eaves and other overhangs of roofs. Brackets such as illustrated are obtainable for clearances of 8 to 24 inches. Still greater clearances may be had with adjustable brackets which have mast clamps at the outer end of flat bars whose inner ends are supported by the wall brackets. A series of matching holes allows making various extensions.

There are mounting brackets designed for attachment to the corners of vertical walls. These are quite similar to the chimney brackets of Fig. 11, but are bolted or screwed to the walls instead of being held with bands. Still other brackets allow attaching the mast at the end of a gable or a peaked roof. These consist of flat or L-section bars which extend about as shown by broken lines in Fig. 14, with mast clamps at the center of each bar. Especially useful for apartment house installations are window brackets which fasten to sills or frames of windows.

All brackets and other hardware for outdoor mountings must be heavily galvanized, cadmium plated, or otherwise rust-proofed. This rule applies to screws, bolts, nuts, and washers as well as to the brackets themselves.

Brackets may be fastened to wooden (frame) walls and to roofs by means of lag screws or even with large wood screws.

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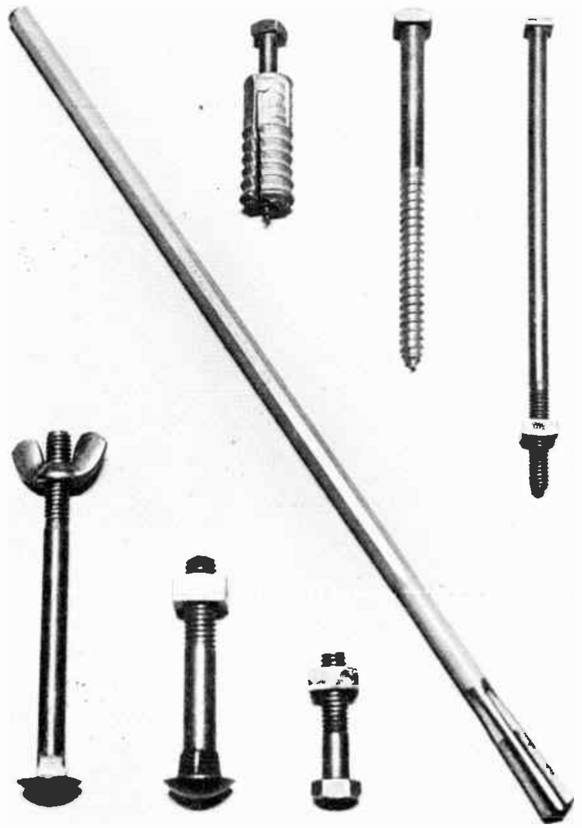

Fig. 16. Fastenings for mast mounts, and a star drill for making holes in masonry. At the top, near the drill, is an expansion screw.

When the inside of a wall can be reached it is possible to use square-head bolts or else carriage bolts with nuts and lock washers. Fig. 16 pictures several kinds of screws and bolts useful for antenna installation, also a star drill for making holes in all kinds of masonry. The fluted end of this drill is held where the opening is to be made while the outer end is struck repeatedly and sharply with a hammer while slowly rotating the drill around and around or first one way and then the other.

After drilling a hole in masonry it may be filled with a wooden plug and brackets held with screws turned into the plug. For any screw large enough for such work it doubtless will be necessary to drill a pilot opening in the plug. A more reliable fastening may be made with an expansion screw or bolt. The expansion sleeve fits snugly in the drilled hole, and is spread to make a very secure grip as the screw is turned into the sleeve. If there is any possibility that mortar joints or other masonry joints have been strained or opened, apply mastic or calking compound in and on the outside of the strained area.

Any mast as much as 6 feet long between the highest bracket or clamp and the bottom of the antenna structure should be supported with guy wires. If the vertical separation is as much as 20 feet there should be an additional set of guys, and for more than about 30 feet there should be a third set. This is necessary to care for such loading as caused by strong winds or by icing, also to prevent swaying which might affect pictures and sync.

Three guy wires are used for each set, spaced as evenly as possible around the mast. The lower ends of the wires should be far enough out so that their angle with the mast is no less than 30 degress. To provide adequate support the lower ends of the three guys should extend around considerably more than a half circle, with the mast as a center point.

Guy wire usually is of stranded galvanized steel with 6 or 7 strands of number 18 or 20 gage. Stranded bronze radio antenna wire is satisfactory, and will not rust no matter how old it gets. Solid steel bailing wire sometimes is used, but it is so soft that stretching is likely.

Some masts have openings through which may be passed the upper ends of guy wires. Otherwise it is common practice to use a floating guy ring. This is a metal ring which fits rather loosely around the mast and has three openings for the wires. The ring is supported at the desired height by a clamp fastened to the mast underneath the ring. At the bottom of Fig. 17 is a guy ring having three adjustable screws which are tightened against the mast and held so by lock nuts.

Fasten the lower ends of the guy wires to any solid building members with screw eyes, screw hooks, or screw bolts such as pictured in Fig. 17. The ends of the wires, both top and bottom, often are passed through the supporting openings and merely twisted.

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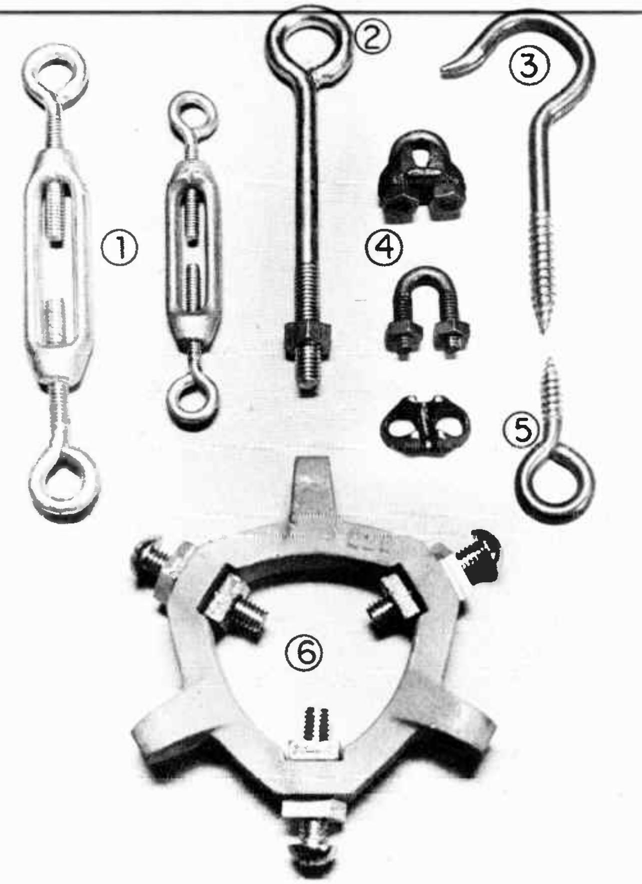

Fig. 17. 1- Adjustable turnbuckles. 2- Eye-bolt. 3- Screw hook. 4- Cable clamp 5- Screw eye. 6- Guy ring.

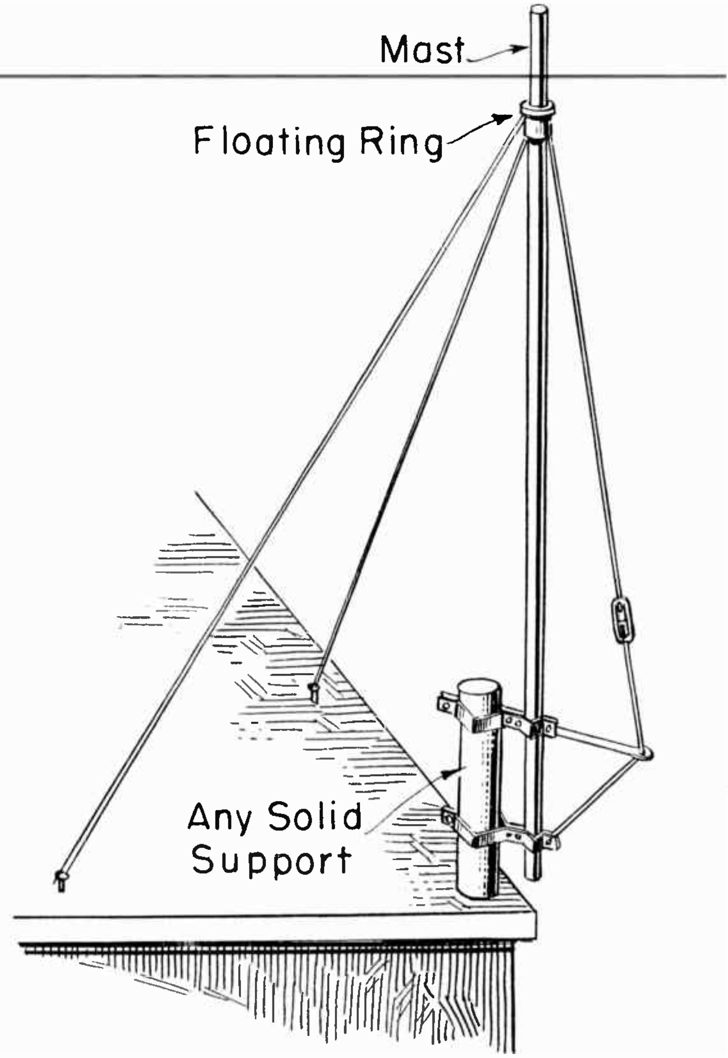

Fig. 18. A method of guying where no extended surface or support is available for a third wire.

It is much better practice to turn the ends back on themselves and fasten them with small cable clamps which consist of a U-bolt and clamp bar, as shown. It is also good practice to insert near the lower (accessible) end of each guy a turnbuckle which not only allows final tightening of the wires but also provides a convenient means for making the mast truly vertical.

Guy wires never should be so high on the mast that they are in the electrical fields around the antenna conductors, especially when the wires extend outward from the mast at a large angle, tending toward the horizontal. There have been cases in which signal reflections from guy wires cause ghost images so close to normal images as to blur the pictures. This is prevented by inserting a strain insulator, such as used for broadcast radio antennas, 4 to 5 feet down from the upper end of each wire.

In some cases it is desirable to mount an antenna mast where there is no space for three guy wires extending around even so much as a half circle with the mast as a center. Then it may be possible to use a bowsprit guy, rigged in some such fashion as shown by Fig. 18. The mounting may be on any solid support which is available.

Two guys attached in the usual manner may be spread by about 90 degrees. The third guy is securely fastened to a bracket which supports the mast and is attached to the solid support. To the upper bracket is attached a rod, a flat piece of steel, or anything which will reach out and carry the third guy wire. In this third guy it is advisable to use a turnbuckle, even though none are used in the other guys.

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GROUNDING. An antenna and its mast are just as much an attraction for lightning as any lightning rod or any other metal at high elevation. Consequently, every mast should be grounded as a safety measure. The ground connection should be made with copper or aluminum wire no smaller than number 8 gage, and preferably with number 6, unless local codes specify some other size. Aluminum wire is more often used.

The ground wire should be securely connected to a clean space near the bottom of the mast or on the mast bracket by some form of screw clamp. Regular ground clamps are inexpensive. The wire must run to something which is permanently and conductively connected without breaks into moist earth. The connection may be to any cold water pipe in a plumbing system, or to something like a hose bib. It is possible also to use a copper plated steel rod about 3/8 inch in diameter and 4 or more feet long, which is driven for nearly its full length into earth. The ground wire then is securely clamped to the top of the rod. These rods may be had from radio and television supply houses.

Do not connect the ground wire to a gas pipe, a hot water pipe, or an oil tank pipe. It is poor practice to make connection to any plumbing vent on a roof. Make the ground wire as short as is convenient. It need not be insulated at any point.

LIGHTNING ARRESTERS. To protect building occupants, also the receiver, every installation should include a lightning arrester of some type which carries the "UL" label signifying approval by the Underwriters Laboratories. A lightning arrester includes two metal points which are separated by small gaps in air or a vacuum from a conductor that is connected to ground. Sometimes there are resistors across the gaps, to allow dissipation of static charges which might cause slight shocks.

The two points on the ungrounded side of the gaps are connected to the two conductors of the transmission line, often by means of external screws and toothed washers which bite through the line insulation when the screws are tightened. Some arresters require that insulation be stripped from the two transmission line conductors. For television use only an arrester which has connections for both sides of the transmission line.

Some arresters are designed for attachment to the antenna mast, with the ground connection of the arrester making contact with the mast. Then a single ground wire serves for the mast and the lightning arrester or transmission line. Other arresters are designed for attachment to the building near the point at which the transmission line enters. A wire must be run from the arrester to an earth ground, but this wire does not ground the mast, unless through a branch connection or lead. There are also indoor lightning arresters for mounting on a cold water pipe which provides the ground connection, with provisions for attaching the transmission line to the arrester terminals.

GAIN OF ANTENNAS. The word gain, when it refers to characteristics of an antenna, has somewhat different meaning than when referring to performance of an amplifier. The gain of an amplifier is the number of times the input voltage or power is increased at the output. The gain of some particular antenna is a measure of how much greater is its signal output than that of a straight or folded half-wave dipole of standardized construction. Antenna gain is merely comparison with a standard; no antenna can increase signals above a strength corresponding to field strength in the space where the antenna is located.

The standardized half-wave dipole used for comparison is called a reference antenna. For each testing frequency there is a reference antenna whose overall length best suits the carrier wavelength corresponding to that frequency. To compare signal power outputs of the two antennas they are connected to suitable impedances. Voltages across the impedances will go up or down with stronger or weaker signals.

Signal outputs across the load impedances are measured in microvolts, but the greater signal strength from the tested antenna is stated in decibels of voltage. Output of the reference dipole is considered to be zero decibels, no matter what may be the actual output in microvolts. Output of the

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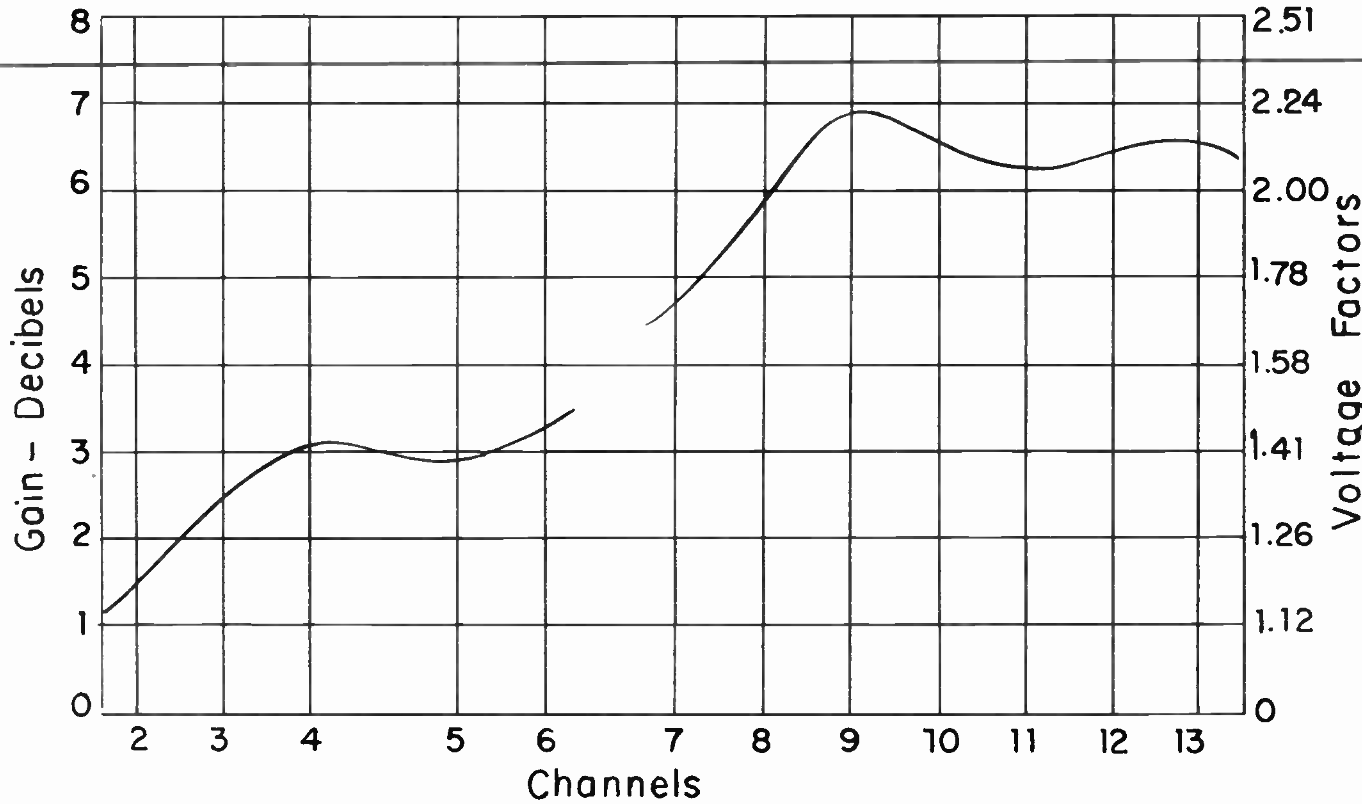

Fig. 19. Gain curves for a particular antenna.

tested antenna is taken as voltage gain in decibels above this zero. The antenna being measured for gain is used without alteration at all the frequencies on which it is designed to operate. But for each frequency there must be a reference dipole whose overall length suits the wavelength corresponding to that frequency.

Gain curves for a certain antenna might be as shown in Fig. 19. The gain on each channel is in relation to output from a reference dipole cut for the same channel. As an example, a gain of 3 db means that signal microvolts from this antenna would be about 1.41 times the signal microvolts from the reference dipole when both antennas are exposed to equal field strengths in space.

Gains in high-band channels are greater than in low-band channels. This does not necessarily mean that signal voltage input to a receiver will be greater on high-band channels. The reason is that antenna conductors are actually or effectively shorter for the high band than for the low band, and when both kinds of conductors are exposed to a given field strength, in microvolts per meter, the shorter high-band conductors cannot pick up as much signal as the longer low-band conductors.

To see how this works out assume that antenna conductors for the low band are cut (made of a length) for the middle of this band, which is at a frequency slightly higher and a wavelength slightly shorter than at the center of channel 4. These low-band conductors will be about 82 inches long. Assume that conductors for the high band are cut for the middle of this band, the center of channel 10. Their length will be about 29 inches.

For any given field strength in microvolts per meter the actual microvolts of signal pickup will be proportional to length of antenna conductors, and the relative pickups will be proportional to the ratio of conductor lengths. That is, the 29-inch conductors can pickup only 29/82 as many microvolts as the 82-inch conductors.

Supposing the low-band conductors were to pick up 100 microvolts. Then the high-

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band conductors could pick up only 29/82 of 100, which would be about 35 microvolts. The 100-microvolts pickup on the low-band will be multiplied by 1.41, the voltage gain of Fig. 19 at the center of this band. The result is 141 microvolts output from the antenna. The 35-microvolt pickup will be multiplied by 2.14, the voltage gain at the center of the high band, to give about 75 microvolts output. In spite of greater gain we have less signal output in the high band.

This explains why antenna gains should be so much greater for high band than for low-band channels. It also explains, at least in part, why many service men are puzzled by the evidently weaker high-band signals, where the antenna has so much greater gain than in the low band.

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TELEVISION

• RADIO
• ELECTRONICS

LESSON 89 — TELEVISION TRANSMISSION LINES

Coyne School

practical home training

Chicago, Illinois

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Lesson 89

TELEVISION TRANSMISSION LINES

Of the four characteristics that determine suitability of antennas for various installations we have talked only about the one called gain. Still to be examined are impedance, bandwidth, and directional properties.

Impedance, as you know, is opposition to flow of alternating or varying currents when this opposition results from a combination of inductive reactance, capacitive reactance, and resistance. There is inductive reactance in the antenna because of inductance in its rods or conductors. There is capacitive reactance because of capacitance between the rods themselves, also between the entire antenna and nearby conductors of all kinds.

Resistance which contributes to antenna impedance is chiefly the kind called radiation resistance. Radiation resistance is the number of ohms which, in series with antenna signal currents, would dissipate the same amount of power that actually leaves the antenna through radiation into space. You might wonder why a receiving antenna should have radiation resistance, since its purpose is not to radiate signal power.

The explanation depends on the fact that a receiving antenna can deliver into the transmission line which goes to the receiver no more than half the total signal energy picked up from carrier waves. The remaining signal energy is immediately re-radiated into space around the antenna. Therefore, a receiving antenna of any given type has, theoretically, the same radiation resistance as a transmitting antenna of the same type.

Antenna conductors have ohmic resistance, whish is the kind of resistance affecting both direct and alternating currents. But this ohmic resistance is so exceedingly small as to be a negligible factor in impedance. There is also some high-frequency resistance which, as doubtless you remember, is the amount of resistance which would cause the same loss of energy that actually results from many kinds of losses occurring at high frequencies. But high-frequency resistance accounts for very little of the antenna impedance.

A dipole antenna is resonant at a carrier frequency whose corresponding wavelength is twice the overall electrical length of the antenna. That is, there is resonance at the frequency for which antenna length equals a half-wavelength. At resonance the inductive and capacitive reactances are equal, and cancel, as in any other resonant circuit. This leaves impedance at resonance as equal, for all practical purposes, to the radiation resistance.

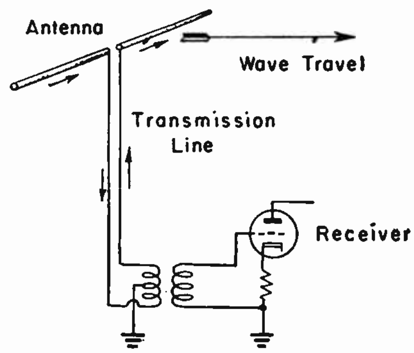

Fig. 1. Signal current in a half-wave dipole antenna and the receiver input.

Fig. 1 shows a simplified antenna circuit. Signal current induced in the antenna during a carrier wave half-cycle flows from one dipole conductor downward through one transmission line conductor, thence through the antenna coupling inductor in the receiver, upward through the other line conductor, and to the second dipole conductor. Signal current reverses on opposite half-cycles of the carrier wave.

Antenna current really consists of electrons surging back and forth in time with carrier wave frequency. No electrons enter the antenna at one end of its conductors, nor do any electrons leave the other open end. Electrons pile up or concentrate at the end or pole toward which they flow, and there become a negative charge. The resulting

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electron deficiency at the other pole is a positive charge. The negative and positive charges shift back and forth.

Now that we know something about antenna impedance let's inquire why it is so important. So far as the receiving installation is concerned, the antenna is a source of signal power for the input circuit of the receiver. The two-conductor transmission line forms the link through which signal energy is transferred from antenna to receiver. The antenna sees the transmission line as a load for the antenna, and the receiver sees the line as a source of signal power.

In any system of sources and loads there can be maximum transfer of power only when input impedance of each load is equal to output impedance of the source connected to that load. To have maximum transfer of signal power, impedance of the receiver would have to match impedance of the line, and impedance of the line would have to match that of the antenna.

Nearly all modern television receivers are designed to have impedances of 300 ohms at the tuner input or at the antenna terminals of the tuner. In many receivers it is possible to make input connections to provide input impedance of 75 ohms in the circuit which normally provides 300 ohms.

Types of transmission line most widely used have impedance of 300 ohms. There are other types having impedances either greater or smaller, which suits them for other special applications. In various ways, which we shall examine, it is possible to change antenna impedance to a value which matches almost any transmission line impedance. Sometimes we use between antenna and line a kind of transformer whose impedance on the antenna side is the same as antenna impedance, and on the other side is the same as transmission line impedance.

When discussing impedances of transmission lines we must keep in mind that any line consists of two conductors separated by insulation. The line has impedance because it possesses inductance, capacitance, and resistance. There is inductance and inductive reactance in the line conductors. There is capacitance and capacitive reactance because the conductors and insulating dielectric are the equivalent of a capacitor. There is high-frequency resistance as well as some leakage resistance in the whole structure.

The particular kind of impedance possessed by a transmission line may be given any of the following names: Characteristic impedance, because it is a characteristic or a property of the line. Surge impedance, because this kind of impedance is opposition presented to surges or pulses of current, or to rapidly moving charges. Image impedance, because it is impedance that would prevent charges from being turned back at the ends of the conductors in the manner that images are turned back or reflected at a mirror. Iterative impedance, because this kind of impedance repeats over and over again in every unit of line length; iterative means repeating.

There are two rather strange things about transmission line impedance. First, it is entirely independent of line length, remaining the same for any length of the same type of line. Second, this impedance is independent of frequency, it remains the same no matter what carrier frequencies are being received.

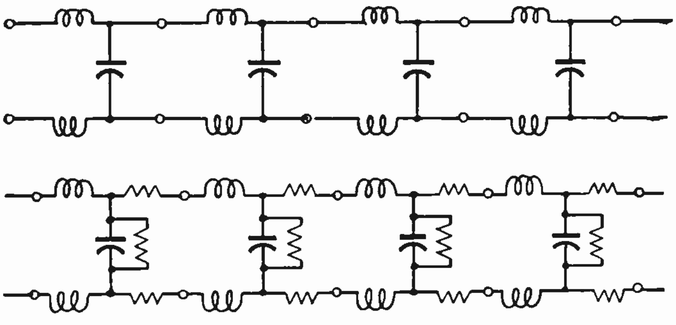

Fig. 2. A transmission line may be considered to consist of any number of unit lengths, with equal inductances, capacitances, and resistances in each unit.

Why transmission line impedance does not vary with frequency is shown by Fig. 2. Imagine that the line is cut into any number of equal short lengths, as represented between pairs of small circles on the diagram. Obviously, each short length will have the same inductance and same capacitance as each other length. These inductances and

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capacitances are represented by their symbols in the upper diagram. The lower diagram shows also the series ohmic resistances that exist in line conductors, and the shunt resistances which represent leakage between conductors.

Now we must use a little arithmetic. Characteristic impedance is equal to the square root of the quotient of dividing inductance by capacitance, like this,

$$\text{Impedance, ohms} = \sqrt{\frac{\text{inductance, microhenrys}}{\text{capacitance, microfarads}}}$$

Assume that in a one-foot length of a certain type of transmission line the inductance is 1.8 microhenrys and capacitance is 0.00002 microfarads. Dividing 1.8 (or 1.80000) by 0.00002 gives 90,000. The square root of 90,000 is 300. So we find that characteristic impedance of one foot of this line is 300 ohms.

Now take 10 feet of the same kind of line. There will be 10 times the former inductance, or 18 microhenrys. There will be 10 times the former capacitance, or 0.00002 microfarad. Dividing 18 (or 18.0000) by 0.00002 gives 90,000. The square root of 90,000 is 300. Se we find that 10 feet of this line has impedance of 300 ohms. Any other length of the same kind of line will have 300 ohms characteristic impedance.

By working with opposite changes of inductive and capacitive reactances which occur with variations of frequency we could demonstrate that frequency has no effect on line impedance. However, the fact is evident because frequency does not appear in our formula for characteristic impedance.

To obtain any desired characteristic impedance it is necessary only to change the unit inductance, the unit capacitance, or both. Both inductance and capacitance are altered by using conductors of different diameter, by altering the center-to-center spacing between the conductors, or by doing both these things. Impedance is increased by smaller conductor diameter and by greater spacing between conductors. Impedance is decreased by greater conductor diameter and by less spacing.

EFFECTS OF IMPEDANCE MISMATCHING. Although characteristic impedance of a transmission is not altered by variations of frequency, this is not true of antenna impedance. Antenna impedance does vary with frequency. There is large variation of impedance with changes of frequency in antennas designed for best performance on only one or two channels. Variation of impedance with frequency is much less in wide band antennas, designed to perform quite uniformly on many channels. When there is any considerable variation of antenna impedance with frequency, it is not possible to have an exact match between impedances of antenna and line for all received frequencies.

Mismatch of impedances in antenna and transmission line prevents some of the antenna signal power from getting into the transmission line, and going to the receiver. The greater the mismatch the weaker will be pictures, and the greater will be trouble from noise and other interference reaching the antenna. A mismatch of 2-to-1, meaning that either impedance is twice the other impedance, causes loss of about 10 per cent of signal energy. Mismatch of $2\frac{1}{2}$-to-1 loses about 20 per cent of signal power, while mismatch as great as 6-to-1 loses half of the antenna signal energy that would go into the line with perfect matching.

When there is mismatching of impedance between line and receiver we have the same losses that occur with mismatch at the antenna end of the line. In addition there are reflection losses. Reflection loss occurs when pulses of signal current try to get through a place where impedances differ. Part of the signal current or power gets through into the receiver, but the remainder is reflected and goes back up the line into the antenna.

Pulses coming down the line and those reflected back travel at the same speed, but separations between pulses in either direction depend on signal frequency at any instant considered. At certain frequencies the separations between pulses become such that maximum amplitudes of pulses or waves traveling opposite directions always meet at the same points along the line. At these

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fixed points the amplitudes of opposite waves combine, and the result is "standing waves".

Line reflections and standing waves cause ghose images on the picture tube screen. Because line length is short compared to distances traveled by carrier waves reflected in space, the ghost images are so close to regular signal images on the picture tube screen as to cause poor definition or slight smearing instead of complete separate ghosts.

If you install a transmission line whose impedance is the same as the rated impedance of the receiver or tuner there is little more you can do in avoiding mismatch at the receiver. It is possible to add short pieces of transmission line, called matching stubs, at the receiver terminals. A stub makes an improvement on only a single channel, and may cause trouble on other channels. The scheme does not work out well as a practical service operation.

Receivers in which the antenna input circuit or r-f amplifier grid circuit is tuned for each channel should provide good impedance matching for all received frequencies. Where the receiver input is differently tuned only for high and low bands, matching will be less satisfactory. With no input tuning there usually is quite a bit of mismatch unless the tuner input is arranged as a pure resistance of 300 ohms, or of other rated input impedance.

Wave reflections may occur not only at receiver or tuner input terminals, but also at joints in the line between antenna and receiver. Any connection of appreciable resistance will cause reflections. There will be reflections also at points where the line conductors come closer together or farther apart than on the remainder of the line. These are reasons for using a continuous unbroken transmission line. The continuous line should not be sharply bent or twisted at any point, because this may cause standing waves at certain frequencies.

TYPES OF TRANSMISSION LINE. By far the most commonly used transmission line is a flat or ribbon style having its two conductors supported and insulated in polyethylene. At the top of Fig. 3 is such a line having 300 ohms impedance. Next below is one having impedance of 150 ohms, and at the bottom is a piece of 75-ohm line. Differences are in separations of the two conductors and in overall width of the line. Overall widths are about 3/8-inch for 300 ohms, 3/16-inch for 150 ohms, and 1/8-inch for 75 ohms. Thickness of all these lines is about 1/16 inch.

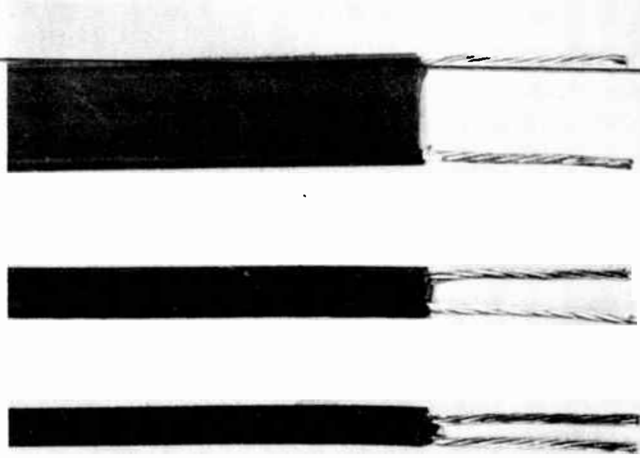

Fig. 3. Flat or ribbon types of transmission line with conductors molded in flexible insulations.

Transmission line of 300-ohm impedance is used for receivers having this value of input impedance. The 150-ohm line is used chiefly for making impedance matching transformers. The 75-ohm type may be used for receivers having 75-ohm input impedance, but most often is used for making matching transformers and for experimenting.

Fig. 4. Tubular transmission line, with conductors molded in opposite sides of insulating tubing.

Fig. 4 shows a piece of tubular two-conductor 300-ohm transmission line. The insulating support is a tube of polyethylene about 3/8-inch in outside diameter, with the

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two conductors embedded along opposite sides of the tubing. Compared with flat line, the tubular style has greater surface area of insulating dielectric between the conductors. This lengthens the leakage path on which accumulate soot, rain, snow, and moisture films. When this line is correctly installed and sealed there is, of course, no leakage through the body of air enclosed within the tubing. Tubular line often is used for ultra-high frequency reception as well as for the very-high frequency channels.

Minimum possible loss of signal energy occurs in open wire transmission line, which consists of bare conductors supported and separated by polystyrene spacers. Impedance of open transmission line depends on diameter of conductors and on their spacing or separation. The conductors must be large enough to support weight of the line between fastenings, but suitable spacings will provide any desired impedance.

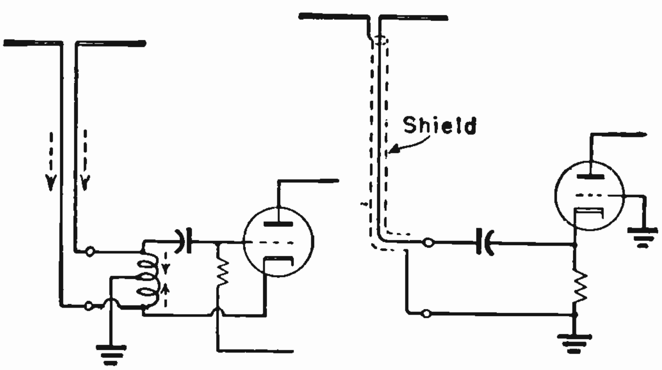

Fig. 5. Flow of interference currents in unshielded line (left), and connections for a shielded coaxial line (right).

Signal currents in any line having two similar conductors flow, as in Fig. 1, down one conductor and up the other conductor. But should fields radiated from noise sources or other sources of interferences reach the line, these fields affect both conductors equally and in the same manner. Currents induced by interference fields flow simultaneously the same direction in both sides of the line, as at the left in Fig. 5. Two simultaneous downward pulses, represented by broken-line arrows, flow opposite directions in the two halves of the antenna input inductor in the receiver, thence to ground. During intervening half-cycles of interference both induced currents flow upward.

The opposite induction effects balance in the receiver input inductor, and the interference effects cancel. This, at least, is the theory. In practice and interference currents do not always balance, and hardly ever balance when interference is strong.

To prevent strong interference picked on the transmission line from entering receiver circuits it is customary to use shielded line. One method is shown in principle at the right in Fig. 5. One line conductor is a flexible tubing of braided metal which is grounded to form an effective shield. Within the tubular shield, and separated from it by insulation, is the second line conductor.

Transmission line having two similar side-by-side conductors, as at the left in Fig. 5, may be called a balanced line, because the two sides are balanced with reference to ground. The type having a central insulated conductor within a shield which forms the second conductor may be called an unbalanced line.

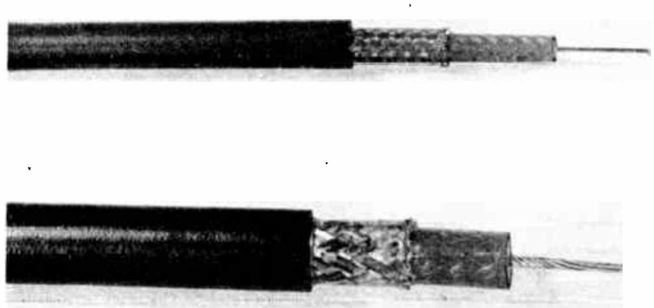

Fig. 6. Two types of coaxial cable which may be used as shielded transmission lines.

For unbalanced shielded lines we use coaxial cable, of which two sizes are pictured by Fig. 6. Outside diameter of the upper cable is slightly less than 1/4 inch; its characteristic impedance is 73 ohms. This is the style often used for television receiver lines. The cable at the bottom is about 4/10 inch in outside diameter, and has impedance

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of 75 ohms. Other coaxial cables which may be used for transmission line have outside diameters ranging from less than 3/16 inch up to 5/8 inch, and have characteristic impedances ranging from 50 to 125 ohms.

Coaxial cables such as used for television receiver transmission line are constructed with a central conductor which may be either solid or stranded. Between this conductor and the braided shield is polyethylene insulation. Around the outside of the braid is a protective covering of flexible plastic.

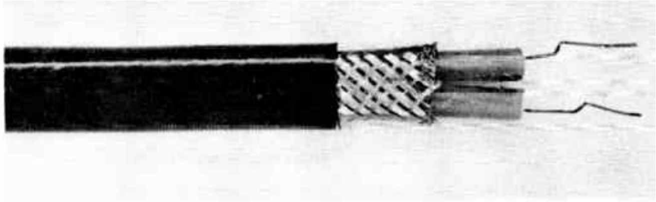

Fig. 7. A shielded twin-conductor transmission line.

Fig. 7 shows construction of a two-conductor balanced transmission line which is shielded. Each conductor is a small solid wire carried within a polyethylene tube, wherein it is held approximately centered by regularly spaced offsets along the wire. The side-by-side tubes are enclosed with a copper braid, which is the shield. Outside the braid is a tough protective covering of flexible plastic. Impedance is 300 ohms.

ATTENUATION IN TRANSMISSION LINES. Even were a transmission line perfectly matched for impedance at both antenna and receiver, there still would be some loss of signal energy in the line. This loss results chiefly from those dissipations of energy which we classify as high-frequency resistance. The loss, called attenuation, usually is specified in decibels per 100 feet of line.

Fig. 8 shows attenuations of several types of transmission line. The lettered curves apply to lines of following types.

A. Coaxial cable of 73-ohm impedance. Outside diameter slightly less than 1/4 inch.

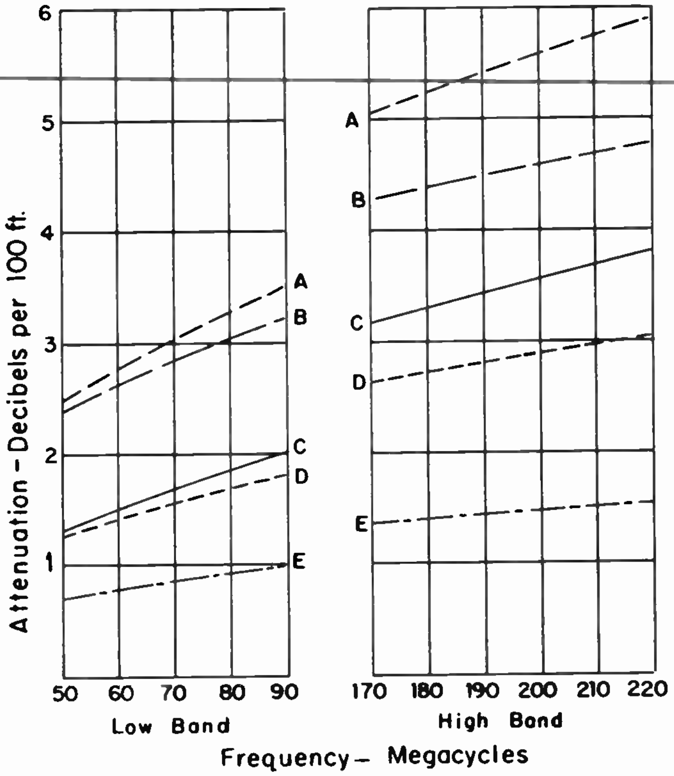

Fig. 8. Attenuations of various types of transmission lines operating at frequencies in the low and high bands of the vhf television range.

B. Shielded two-conductor lines having 300-ohm impedance.

C. Flat or ribbon unshielded line having 300-ohm impedance; the style most commonly used.

D. Coaxial cable of 75-ohm impedance. Outside diameter about 4/10 inch.

E. Open type air-insulated line with conductors supported by polystyrene spacers.

Attenuation is directly proportional to length of line. If a line is 50 feet long its attenuation in decibels will be half that shown by the appropriate curve in Fig. 8, and if only 20 feet long the attenuation will be only one-fifth as much.

Attenuation always increases with frequency, chiefly because dielectric losses increase with frequency. The increase is not directly proportional to frequency. Doubling the frequency may raise the attenuation by

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something like 40 to 50 per cent, depending somewhat on the type of line.

In lines of similar construction, but with different conductor spacings and impedances, attenuation is greater in those of lower impedance. For example, at 80 mc the attenuation of a 150-ohm line might be 25 per cent greater than of a 300-ohm line otherwise similar. Attenuation of a 75-ohm line might be about 2-1/3 times greater than that of a 300-ohm line.

Published values of attenuation are for lines whose impedance is perfectly matched, both at the antenna and at the receiver. When not so "terminated" there will be additional line losses due to the mismatching.

CHOOSING THE TYPE OF LINE. The most important factors in choosing the type of transmission line for a particular installation are as follows.

1. Receiver impedance. Line impedance should match receiver input impedance when this is practicable. Twin-conductor 300-ohm. lines are available either unshielded or shielded. Coaxial cable is not available with 300-ohm impedance, so types having impedance of 72 to 75 ohms are used. When the tuner input inductor is center tapped to ground, as in Figs. 1 and 6, and provides 300-ohm impedance between its outer ends, impedance is 75 ohms between either end and the center tap. The center conductor of a coaxial cable may be connected to either end of the receiver input inductor, and the coaxial shield connected to ground and the center tap.

2. Antenna impedance. Line impedance should match the nominal impedance of the antenna when practicable. When line impedance is chosen to match that of the receiver, and antenna impedance is widely different, a matching transformer may be used between antenna and line. Such transformers are described in pages which follow in this lesson.

3. Length of line. Although there is no fixed rule, it is well to favor a line of relatively small attenuation when the line is more than 50 feet in total length. A long line is likely to run through areas of strong interference, so a shielded line may be worth while.

4. Interference reaching line. There is probability of interference pickup on the line in apartment houses and in apartment-house districts, also in or near any commercial buildings, near hotels, near factories, and in any locality closely built up.

If signals are strong, any kind of shielded line should be satisfactory.

If signals are weak, a shielded line of lowest possible attenuation should be used. Even though a shielded line has greater attenuation than an unshielded type, it may reduce noise more than signal, and thus improve the signal-to-noise ratio.

Interference acting on the antenna itself is not lessened by any kind of transmission line. However, a low-attenuation line may help preserve signal strength.

5. Atmospheric conditions. The outer covering of shielded lines helps protect conductors and dielectric insulation from fumes, corrosive vapors, salt air near oceans, soot, smoke, and dirt films in general. Anything close to and in the field space of unshielded conductors increases energy loss and also alters the line impedance.

6. Cost of line. Flat or ribbon type 2-conductor line is least costly, while shielded line with two separately insulated conductors costs more than most other types ordinarily used. In general, shielded line costs more than unshielded line, except that open line on spreaders may cost more than some coaxial lines.

INSTALLING TRANSMISSION LINES. The following instructions apply to installation of all kinds of transmission lines. Precautions and special methods applying to unshielded lines and to shielded lines are in later sections of this lesson.

Lay out the route of the line so that it will be as short as possible. Support the line with regular standoff insulators, not with tape, staples, bent nails, and other substi-

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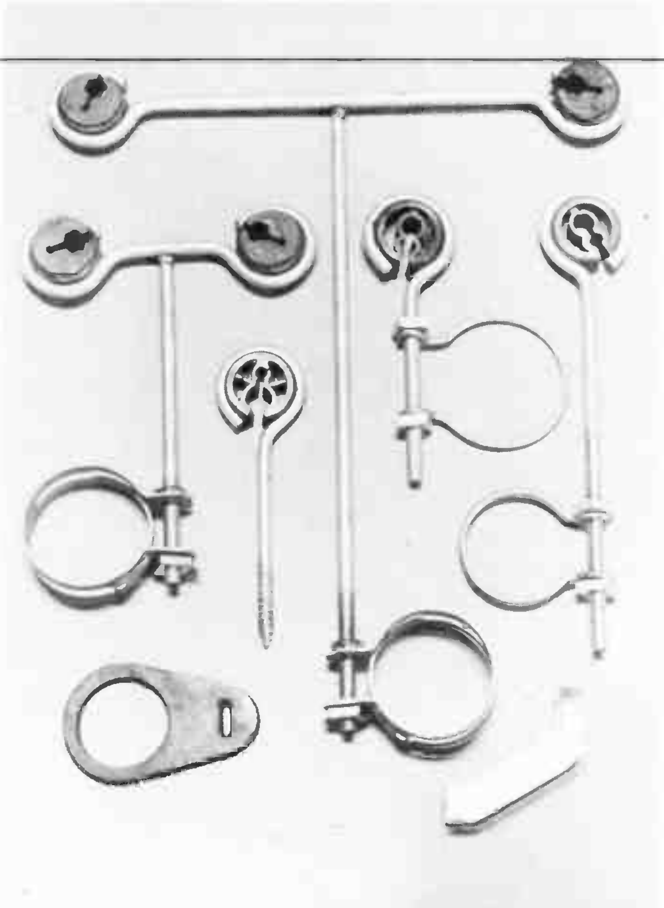

Fig. 9. Standoff insulators for television transmission lines.

tutes. A number of standoffs are pictured by Fig. 9. The insulating discs have slots which take ribbon type line, and round openings for tubular, coaxial, and other lines of generally cylindrical section. The disc is rotated until its edge opening is in line with a gap in the metal supporting ring, the line is inserted, and the disc turned to a position such that the line cannot escape. The ring is of steel soft enough to be spread or squeezed quite easily.

Standoffs having circular clamps tightened by nuts are designed for mounting on antenna masts. Those with screw ends are for mounting in wood. Types not shown have the ring and insulating disc on drive nails which may be hammered into mortar joints in masonry. For mounting on solid masonry a hole may be made with a star drill, the hole plugged with wood, and the standoff screwed into the wood.

It is rather common, but is poor practice, to simply bare the ends of line conductors and twist them around terminals on the antenna conductors. A more permanent connection is made by soldering eye-type lugs to the ends of the line conductors. It is still better to solder the line conductors to the antenna terminals and coat the joints with lacquer.

Leave a little slack at the antenna end of the line, so nothing will break in case the antenna mast does a little swaying. The line should be supported about every 6 to 8 feet, although longer runs sometimes are necessary. Try to get long runs into such positions that the line will not chafe against any solid objects. Avoid sharp bends, which are likely to cause reflections in the line.

Make sure that vertical or near vertical runs of line cannot slip downward through the supports. With standoffs such as shown by Fig. 9, get the line in its final position, then use pliers to squeeze the rings securely to the insulators so that they compress onto the line.

Bring the line into the building through a hole that slopes downward from the indoor to the outdoor end, as in Fig. 10. On the outdoor part of the line, close to the entrance point, form a drip loop to prevent rain and melted or condensed moisture from running into the building. In addition, the outer end of the hole should be sealed with putty, mastic, calking compound, or something of this nature. A winding of tape may be used on the line just where it enters the building, to avoid possibility of the line being pulled farther into the building.

UNSHIELDED LINE INSTALLATION. When using unshielded transmission line it is a good idea to bring the line away from the antenna mast at the first standoff, maintaining a separation of at least 6 inches for any remaining run down the mast, or better still running the line away from the mast at an angle of about 30 degrees. Flat or ribbon line often is twisted about one turn per foot or two of length, as also shown by Fig. 10. The theory is that this lessens pickup of interference on the line.

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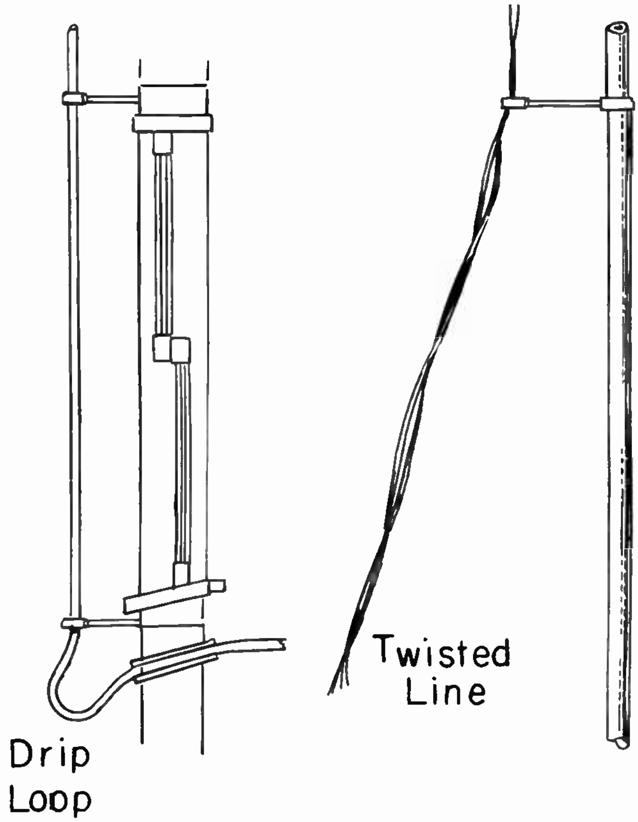

Fig. 10. A drip loop at the building entrance (left). Flat or ribbon line may be twisted to help avoid interference pickup (right).

Keep unshielded line at least two feet from metal objects such as gutters, downspouts, metal roofs, and any kinds of pipe or conduit, especially when the line must run parallel to any of these things. Crossing a piece of metal, such as a gutter, at approximately right angles will do no harm if clearance is at least three inches. Never run unshielded line inside of metal conduit or pipe of any kind. Stay as far as possible from all power or telephone wires. Use standoffs to keep the line from contacting any building surfaces, even though the surfaces are non-conductors. This applies where the line passes over the edges of roofs or other structures.

Avoid, so far as possible, runs that are horizontal or nearly so unless they are underneath some kind of weather protection, such as eaves or a porch. Otherwise rain, snow, or ice may collect on such runs of line and change its electrical characteristics. If the line must run horizontally in the open, support it above any probable level of snow.

Moisture may be prevented from collecting as a film on the line by applying a coating of silicone in grease or other carrier. These preparations may be had from supply houses. A fair substitute is automobile polishing wax. Such substances cause moisture to collect in drops, which more easily run off the line. Do not paint unshielded transmission line, especially not with paints having a metal base, as lead or aluminum.

The interior of tubular two-conductor line should be kept free from moisture. Try to do all cutting of this line indoors, or outdoors when the weather is dry, then seal the ends. Sealing may be done by squeezing the insulation closed and melting it together with a hot soldering iron. It is much easier to use small polyethylene plugs made and sold for this express purpose. If this type of line cannot be well sealed, make a small opening at the bottom of a drip loop and at any other point where there may be a sag in the line.

Unshielded line should be brought into the building through a tube of porcelain or other insulating material large enough that the line conductors won't be squeezed together. Never run ribbon line over a window sill, with the sash closing down on the line to make sharp bends and possibly break the insulation. Do not connect the line to radio type lead-in strips designed to go over window sills.

The line may enter the building through a wall, but usually more easily through the frame of a window or door in the room where the receiver is located. Otherwise, as in Fig. 11, the line may be brought into the basement, then carried by standoffs across a ceiling or open joists, and up through a floor to the receiver. Keep the line as far as possible from all metal, whether exposed or concealed in walls or floors. This applies to heating pipes or ducts, radiators, water or gas pipes, electrical conduit or cable, and all similar things.

In living rooms the line may be carried close to wood or other insulation materials for distances of a few feet. There are unobtrusive plastic standoffs for indoor use. Single-pointed brads with brass heads and insulation under the heads may be driven

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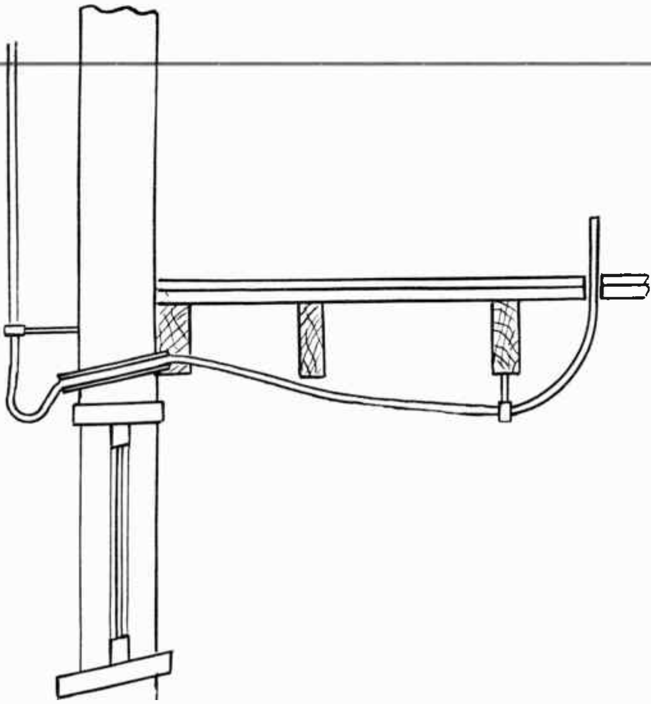

Fig. 11. The line may be brought into a basement and up through a floor.

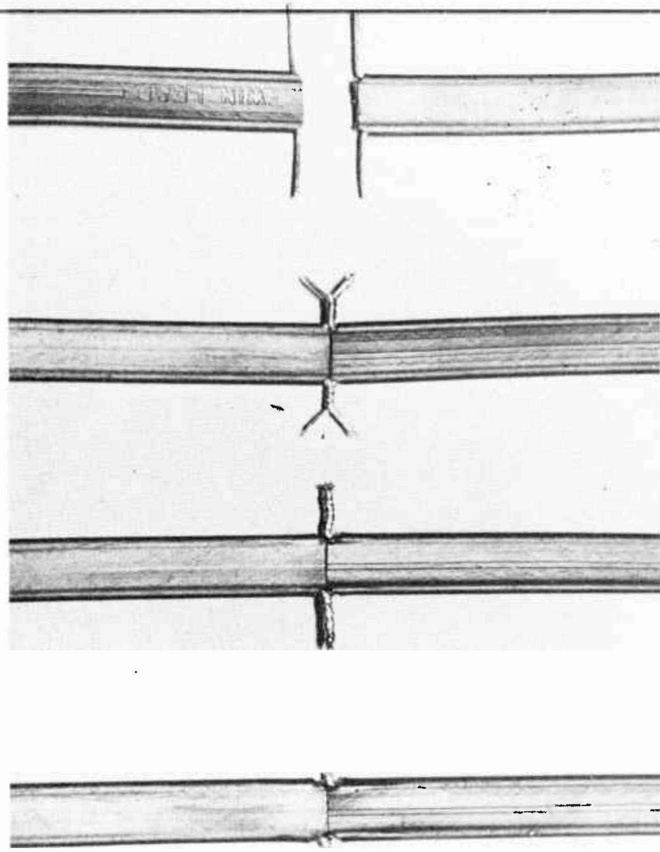

Fig. 12. Splicing a flat two-conductor transmission line.

through the center of two-conductor line into any supporting surface. Never use stapled or double-headed tacks. The line may be tucked back of moldings for short distances, but never should be run under carpets or rugs.

At the receiver end of the transmission line leave only enough extra length to permit moving the receiver for cleaning. Do not coil any excess length, cut it off. Although unshielded line may be spliced when more length is needed indoors, outdoor splices should be avoided. Indoor splices may be made with twin lead splicers designed for the purpose. These are small blocks of polystyrene with holes into which are slipped the bared ends of conductors on the pieces of line to be joined. The conductors are held together and in the block by small set screws.

Splices for joints either indoors or out may be made as shown by Fig. 12. Strip and remove the insulation to expose about a half inch of each conductor. Twist the conductors together until the cut ends of the insulation butt together. Solder the twisted ends with a hot iron, and do this quickly to avoid melting the insulation. Cut off the excess of conductor which extends out from the insulation. The splice should be wound with cellophane tape, and if to be outdoors it should be coated with polystyrene cement. Stress must be removed from outdoor splices by clamping the line securely in standoffs on both sides of the splice.

<u>SHIELDED LINE INSTALLATION.</u> Shielded transmission line may be run practically anywhere that is convenient. Such line may be close to or fastened to the antenna mast, to any kind of pipe, to gutters, downspouts, ducts, plumbing vents, and so on. Shielded line may be run inside the antenna mast, also in steel pipe or electrical conduit, but not in the same conduit with wires for light and power. The line may be run through wall spaces, as from floor to floor of a building, but avoid areas which may become hot, as near radiators, furnaces, and heating pipes.

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Shielded line should be clamped or otherwise securely fastened to its supports at suitable intervals. If there is possibility that a fastening may deform or cut the outer covering of the line, use windings of tape for protection at such points.

The central conductor of coaxial cable may be connected to either side of the gap between antenna conductors, with the braided shielding connected to the opposite side of the gap. The two conductors of shielded two-conductor line are connected to opposite sides of the antenna gap, like any other line having two similar conductors. The shield is not connected to the antenna conductor terminals, but should be connected to the mast, and the mast grounded.

If any kind of shielded transmission line is more than about 30 feet long, its shield should be connected to an additional ground wire at a point about half way along the total length of line. This is important when interference picked up on the line is to be reduced to a minimum.

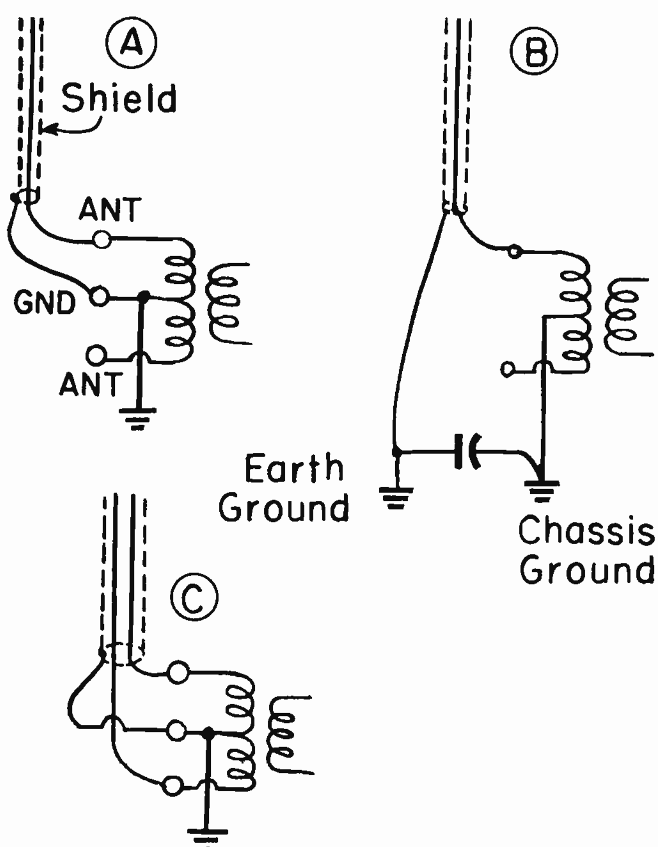

Fig. 13. Connections of shielded transmission lines at receiver terminals.

Receivers designed for 73-ohm or 75-ohm coaxial transmission line may have a regular coaxial connector, which is just the same as the microphone connector described in the lesson on "Television Alignment", where also is explained the method of joining the coaxial cable to such a connector. Otherwise connect the central conductor of the line cable to the receiver terminal marked "Antenna" and connect the cable braid to chassis ground. This is shown at A of Fig. 13.

With a hot chassis, the shield braid of the line would have to go to a separate earth ground, with connection from shield to chassis ground through a capacitor of 0.01 mf or greater capacitance. The capacitor should be of mica or ceramic type. This arrangement grounds the cable shield and one side of the antenna to the chassis for signal frequencies, but not for line power. Such connections are shown at B.

When using 300-ohm shielded two-conductor transmission line the receiver connections are made as in diagram C. The two line conductors which come through insulating tubes are connected to the two antenna terminals, just as with unshielded twin-conductor line. Connect the line shield directly to chassis ground if the chassis is cold. For a hot chassis make the ground connections as at B.

For maximum reduction of interference which may be picked on a transmission line the shield of the line should be connected through a large wire to an earth ground at the receiver end as well as at the antenna or mast, and possibly in between. A shield not well grounded may do more harm than good, since it then does not carry interference currents to ground.

Fig. 14 shows a method of making terminal connections on coaxial cable. First remove two inches or more of the protective outer covering. At the free end of the cable loosen the braid and push it back. With a pointed tool such as an awl spread the braid, without breaking its strands, to make an opening close to the end of the remaining outer covering. Bend the polyethylene insulation and central conductor at the point where the braid has been spread apart, push

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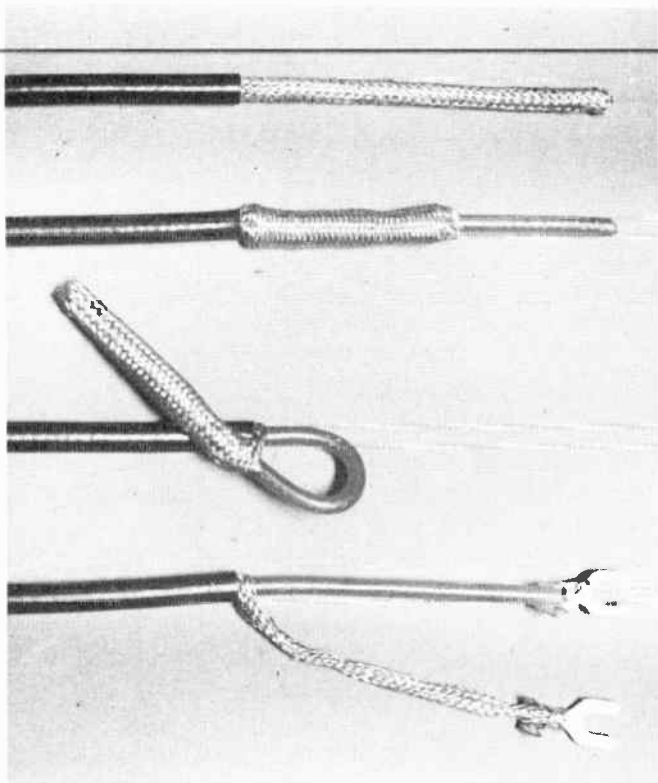

Fig. 14. Attaching terminals to the conductors of coaxial cable.

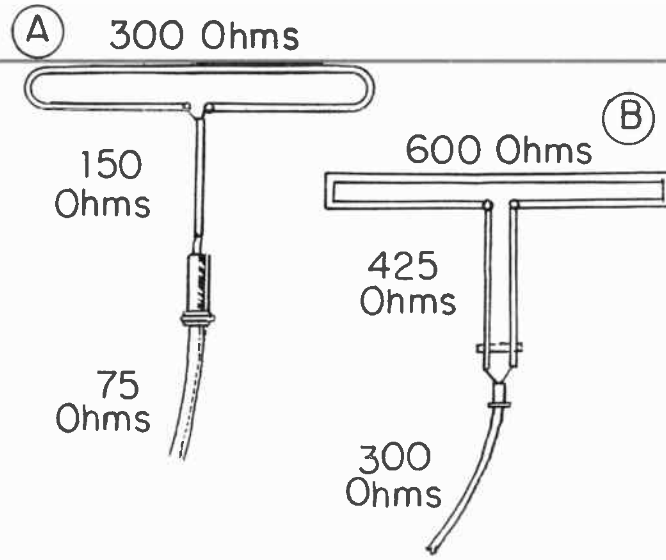

Fig. 15. Matching unlike impedances by means of quarter-wave transformers.

the bend through the braid, then work the rest of the insulation and central conductor through the opening to free the end. Solder spade terminals or eyelet terminals to the central conductor and to the end of the braid. The braid may be tightly twisted and filled with solder to stiffen it.

MATCHING UNLIKE IMPEDANCES. When making anything more than the most ordinary antenna installations there will be numerous cases in which it is necessary to match different impedances of antenna and line. This may be done by inserting between the antenna and transmission line a quarter-wave matching transformer.

A quarter-wave matching transformer consists of nothing more than a length of transmission line or a pair of spaced conductors whose impedance is something in between those of antenna and transmission line. The electrical length of the matching section is made equal to a quarter-wavelength at the middle frequency of the reception band.

Typical problems and their solutions are illustrated by Fig. 15. At A we have a 300-ohm antenna matched to a 75-ohm transmission line with a quarter-wave section of transmission line whose impedance is 150 ohms. At B a 600-ohm antenna is matched to 300-ohm transmission line by two wires of number 8 gage spaced 2-1/4 inches apart. Characteristic impedance of these spaced wires is about 425 ohms.

Impedance required in any quarter-wave matching section is equal to the square root of the product of impedances of antenna and transmission line, thus.

$$\text{Impedance of matching section} = \sqrt{\text{antenna impedance} \times \text{line impedance}}$$

Consider the problem at A of Fig. 15. The product of 300 (antenna impedance) and 75 (line impedance) is 22,500. The square root of 22,500 is 150. So we use a piece of 150-ohm transmission line for the matching section.

Since length of the matching section is to be a quarter-wavelength, and the overall width of antenna conductors in a half-wave dipole is a half-wave or approximately so, we may cut the matching section half as long as the antenna is wide for fairly acceptable results.

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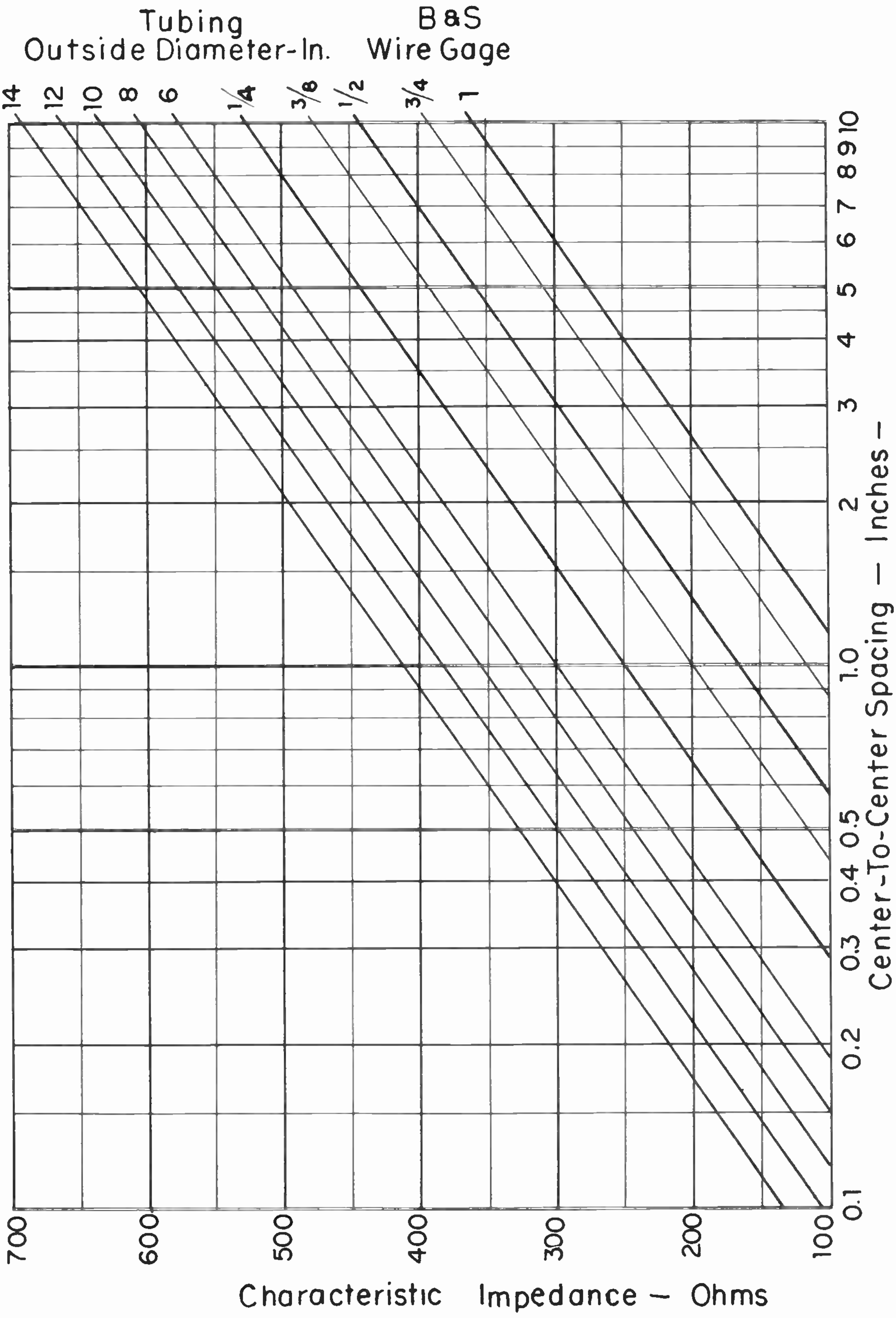

Fig. 16. Characteristic impedances of side by side spaced conductors in air.

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For more accurate computation of matching section length we should take into account the length of a half-wave in space for frequency at the center of the reception band, then make a correction for velocity constant in the type of line used for matching.

A quarter-wavelength of a space wave, in inches, is equal to 2950 divided by frequency in mc. Were our antenna designed to operate on all the vhf channels, the lowest frequency would be 54 mc at the bottom of channel 2. The highest frequency would be 216 mc at the top of channel 13. The middle frequency would be 135 mc. To determine the length of a quarter-wave at this mid-frequency we divide 2950 by 135 to find that the length is close to 21.8 inches.

Velocity constant, sometimes called propagation velocity, means the speed of radio waves in anything through which they pass. This speed or velocity is maximum in free space, is practically the same in air, but is less in and around metals when separated by, surrounded by, or in any way supported by dielectric materials other than air. Here are fractions of space velocity, or velocity constants, for some kinds of transmission line.

Open wire, on spacers	0.97
Metal tubing, spaced, in air	.95
Flat ribbon line, 300-ohm	.82
Flat ribbon line, 150-ohm	.77
Flat ribbon line, 75-ohm	.69
Coaxial cable, common types	.66

When using flat ribbon line of 150-ohm impedance for the matching section we should multiply the computed length in free space (21.8 inches) by the velocity constant of such line, which is 0.77. This gives approximately 16.8 inches as the correct length.

Now consider the problem illustrated at B of Fig. 15. Antenna impedance is 600 ohms and transmission line impedance is 300 ohms. The square root of the product of these numbers is close to 424 ohms, or about 425 ohms. There is no readily available transmission line having this impedance, so we shall make our own with the help of Fig. 16.

This graph has a scale of characteristic impedances at the left, and across the bottom a scale of center-to-center spacings, in inches, for conductors which are supported in air. Diagonal lines in the upper group apply to solid wires of various gage sizes or numbers. Diagonal lines in the lower group apply to hollow metal tubing of various outside diameters.

When using number 8 solid wire to obtain impedance of 425 ohms we follow across from 425 ohms on the impedance scale to the diagonal line for number 8 wire, thence down to the bottom scale which shows that center-to-center spacing should be about 2-1/4 inches.

The next step is to make a correction for length, by using the velocity constant for open wire on spacers. This constant is 0.97. Multiplying 21.8 inches, the computed length of a quarter-wave in space, by the constant 0.97 gives about 21.1 or 21.2 inches as the correct length of our 425-ohm matching section made with number 8 wire. Any other required impedance might be obtained by using spaced wires or tubing and by making similar computations.

An impedance matching transformer might be used between transmission line and receiver as well as between antenna and line. However, the length of matching sections, the fact that such a section should remain in a nearly straight line, and the difficulty of using spaced wires or tubing at the receiver, makes this method rather difficult to employ in practice.

If reception in one channel is much weaker than in other channels it may be possible to improve results on that particular channel with a resonant "stub" connected as in Fig. 17 either to the receiver terminals or the antenna terminals, without altering connections of the regular transmission at either place.

The stud is conveniently made of flat 300-ohm two-conductor transmission line. Commence with a length equal to somewhat more than a half-wavelength at the mid-frequency of the channel for which correction is to be made. Connect the bared conductors

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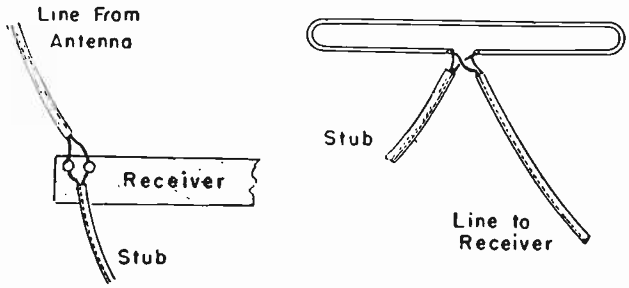

Fig. 17. Connections of matching stubs at a receiver or at an antenna.

at one end of the stub to the receiver or antenna. Turn on the receiver and tune it to the weak channel, making adjustments for the best possible pictures.

With wire cutters snip off the other end of the stub, about 1/4 inch at a time, until obtaining strongest possible pictures. If you cut off so much that picture strength decreases after maximum improvement, cut and connect another stub of the length which gave best performance.

This method corrects the receiver impedance by effectively adding inductance or capacitance, whichever is lacking, to bring about resonance at the received frequency.

The stub with conductors open at the free end acts like a circuit with series inductance and capacitance. When the stub length is between a half- and a quarter-wavelength it acts like inductance. At exactly a quarter-wavelength the stub becomes series resonant and shorts out the signals. At less than a quarter-wavelength the stub acts like capacitance. What you are doing, in effect, is adding inductance or capacitance to obtain cancellation of reactances and leave the necessary value of impedance for matching.

Similar results may be had with much less total length in the piece of line by using what is called a shorted stub. Instead of cutting off successive lengths and leaving the two conductors open, you try shorting the conductors at various points. This may be done with a razor blade that cuts through the insulation to contact both conductors, or with a pair of connected needle points, or in any other way which seems convenient. After determining the corrent position for the short, the excess line is cut off and the conductors soldered together. When length of the shorted stub is greater than a quarter-wavelength it acts like excess capacitance, and when less than a quarter-wavelength it acts like excess inductance.

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TELEVISION

• RADIO
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LESSON 90 — SUITING ANTENNAS TO CONDITIONS OF RECEPTION

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Lesson 90

SUITING ANTENNAS TO CONDITIONS OF RECEPTION

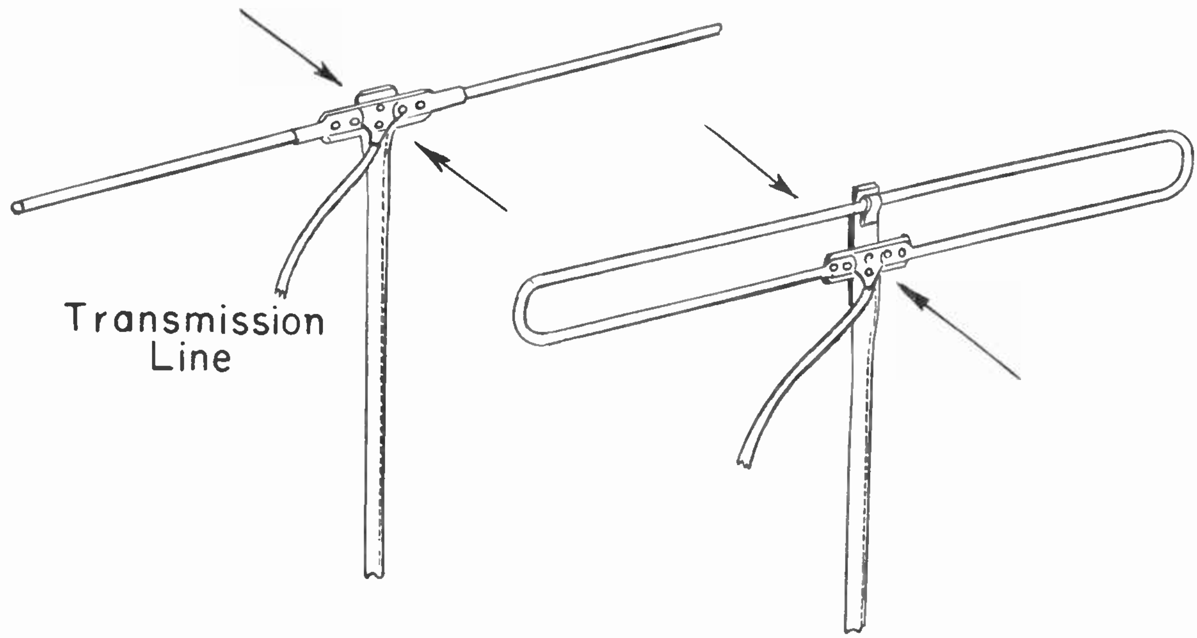

Fig. 1. The earliest types of receiving antennas, a straight half-wave dipole and a folded half-wave dipole.

The original and basic television receiving antenna is a plain, straight half-wave dipole, as at the left in Fig. 1. With the straight dipole cut for the wavelength or frequency at the middle of a channel to be received, this antenna delivers good signal strength on the single channel even where the transmitter is at a considerable distance. Close to transmitters, where field strength is high, the straight dipole serves quite well for all channels in either the high band or the low band. Impedance at resonance is, theoretically, close to 73 ohms.

In localities reached by signals from two or more transmitters in the same band, with stations at considerable distances, a wider frequency response or greater bandwidth becomes highly desirable. The earliest "wide band" antenna was the folded dipole, shown at the right in Fig. 1. This type has fairly uniform response throughout either the low-band or high-band vhf channels, depending on the band for which conductor length is suited.

The folded dipole consists of a continuous length of tubing, bent so that free ends of the tubing come almost together, with the sides parallel and one above the other. Spacing between sides of the bent conductor usually is $2\frac{1}{2}$ to $3\frac{1}{2}$ inches for a low-band antenna and 2 inches or less for a high-band type. Transmission line conductors are connected to the ends of the antenna tubing at the center gap.

Signal voltage in a folded dipole remains zero at the center of the continuous side, opposite the gap, so this antenna may be supported there by a clamp which grounds through the mast. Since the folded dipole is a variety of half-wave dipole, overall electrical length between the outer bends is made equal to a half-wavelength at the middle of the frequency band in which reception is desired. Impedance at resonance is approximately 300 ohms.

LENGTHS OF ANTENNA CONDUCTORS. It is common to speak of a half-wave dipole as having conductors long enough to extend across half of a wavelength at the carrier frequency for which the antenna is designed or "cut". What we actually want is a con-

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ductor of such overall length that charges can reflect back and forth between the ends in half the time required for a carrier wave to travel from end to end of the conductor. This is what we mean by the term electrical length of the conductor.

Reflected charges travel more slowly in the antenna conductors than carrier waves travel through space around the conductors. Consequently, antenna conductors must be somewhat shorter than a half-wavelength in space in order that charges may move from end to end during the time of a half wave.

You may determine the length in inches of a half-wave in space, very closely, by dividing the number of megacycles of frequency into the number 5905. As an example, to determine the length of a half-wave in space at a frequency of 71 mc we divide 71 into 5905, which gives the half-wavelength in space as 83.17 inches.

To determine correct length of antenna conductors we must allow for the fact that charges in the conductors travel more slowly than carrier waves in space. This allowance is made by dividing the number of megacycles into 5690 instead of 5905. To find overall length of conductors in a half-wave antenna designed for 71 mc we divide 71 into 5690, which gives the correct length as about 81.29 inches.

The number 5690 into which we divide megacycles of frequency gives conductor lengths suited for average reception conditions with antennas of simple construction. Some designs require slightly less overall length of conductors. Others may require somewhat greater lengths. Based on dividing megacycles of frequency into 5690, overall lengths of half-wave antennas cut for middle frequencies of channels and bands are given to the nearest 1/32 inch in the accompanying table.

REFLECTORS AND DIRECTORS. Both the straight dipole and the folded dipole of Fig. 1 respond equally well to signals from either of two opposite directions, which are at right angles to the line along which the antenna conductors extend.

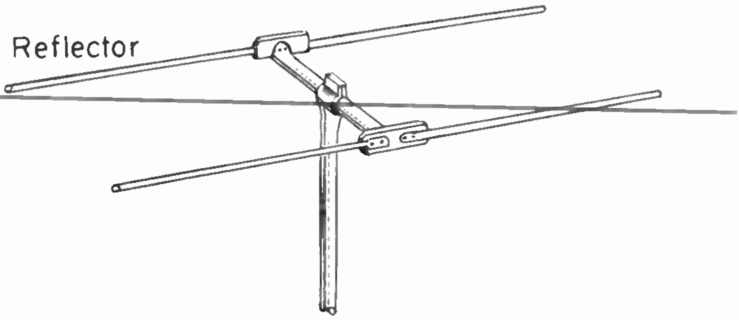

Fig. 2. A reflector mounted back of a straight dipole.

Quite commonly we find that all transmitters whose signals may be received lie in one general direction from the receiver rather than in opposite directions. Satisfactory reception could be had from weaker carrier signals were it possible to concentrate greater pickup ability in that one direction. This may be accomplished, as in Fig. 2, by mounting what is called a reflector element back of and parallel to the dipole element. When we say back of, we mean on

LENGTHS OF HALF-WAVE ANTENNAS, INCHES

Channel Or Band	Middle Frequency	Overall Length, inches
2	57 mc	99-27/32
3	63 mc	90-5/16
4	69 mc	82-15/32
Mid-band	71 mc	81-9/32
5	79 mc	72-1/32
6	85 mc	66-15/16
Mid-range	135 mc	43-23/32
7	177	32-5/32
8	183	31-3/32
9	189	30-3/32
10	195	29-3/16
Mid-band	195	29-3/16
11	201	28-5/16
12	207	27-1/2
13	213	26-23/32

the side of the dipole opposite to that from which maximum pickup is wanted. The reflector is electrically a continuous conductor from end to end. It may be a continuous

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piece of tubing, or two lengths held end to end by a mounting bracket.

Currents or alternating electric charges are induced in the reflector by carrier waves which have passed the dipole. Part of the signal energy picked up in the reflector is re-radiated back to the dipole, and reinforces signal currents induced in the dipole by carrier waves. At the same time, part of the signal energy re-radiated from the dipole acts on the reflector, adding to energy picked up from carrier waves by the reflector, and increasing re-radiation from the reflector.

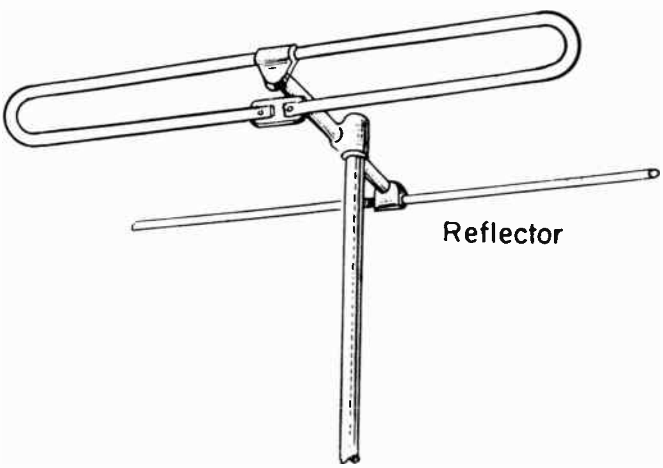

Fig. 3. A reflector on a folded dipole antenna.

A reflector mounted back of a folded dipole is shown by Fig. 3. A reflector may be similarly mounted behind any other form of dipole. In every case the result is a decided increase in total pickup of signal waves which reach the dipole before reaching the reflector. This increase of "front response" has the effect of decreasing relative response to carrier waves coming from the opposite direction, thus lessening the "back response".

We may go still further in increasing front response and decreasing back response of any kind of dipole by mounting a third element called a director in front of the dipole, as in Fig. 4. Part of the carrier wave energy picked up by the director is re-radiated to the dipole, and increases signal energy delivered from the dipole to the receiver. Whether an added element acts as a reflector or as a director is chiefly a matter of spacing between these elements and the dipole.

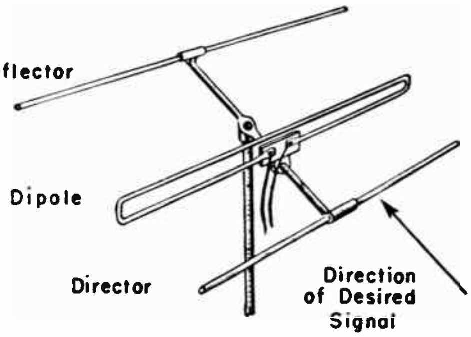

Fig. 4. A director is mounted in front of a dipole, in the direction from which maximum signal pickup is desired.

Our principal reason for taking a preliminary look at reflectors and directors just now is to allow discussing their effects on antenna impedance, and on matching of antenna impedance to transmission line impedance. Either a reflector or a director may be called a parasitic element. Addition of any parasitic element to an antenna system decreases resonant impedance at the transmission line takeoff.

Mounting a reflector back of a straight dipole may drop the resonant impedance from a normal 73 ohms to as little as 25 ohms. Adding a director to the combination may bring impedance even lower, possibly around 8 to 10 ohms. Only a reflector on a folded dipole may drop impedance from 300 to as little as 100 ohms, and with a director added the impedances comes down even lower.

Practically all antennas include reflectors, and many popular types have one or more directors. To retain the advantages of these parasitic elements to the fullest extent we must do something which prevents excessive lowering of antenna impedance, in order to have matching for common types of transmission line. Antenna impedance may be increased, or prevented from decreasing, by making various modifications in construction of the dipole element.

Before talking about methods of altering the impedances in an antenna system we should understand that we are dealing not with values such as exactly 72 ohms, 73 ohms, and 300 ohms, but with impedances which are approximately of these values.

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With an antenna of any given construction, actual impedance will vary with the distance of the antenna above earth, with how close it is to other conductors, which may be other antennas, and with proximity to non-conductors which act as dielectrics to divert electric fields and alter capacitances.

There is one more thing which should be explained at this point; it is our many references to behavior of straight dipoles and of folded dipoles. It is most unlikely that you will install any antennas of these simple types, they have long been outmoded by more elaborate and more efficient types. But if you look closely at the elaborate antennas, it is apparent that nearly all consist of, or at least include, one or more straight or folded dipoles. Understanding the behavior of these elementary types will make it much easier to forecast the probable behavior of any kind of antenna structure operating with any combination of reception conditions.

Now back to the matter of antenna impedances and how they are altered. Already we have examined one method of raising impedance. We have raised the impedance of 73 ohms in a straight dipole to around 300 ohms by using two side-by-side conductors as a folded dipole.

When there are two or more side-by-side conductors of equal diameters, impedance is related to that of a straight dipole as the square of the number of conductors. For example, the simple folded dipole has two conductors. The square of 2 is 4, so impedance of the folded dipole is 4 times 73, which comes to 292 ohms or approximately 300 ohms.

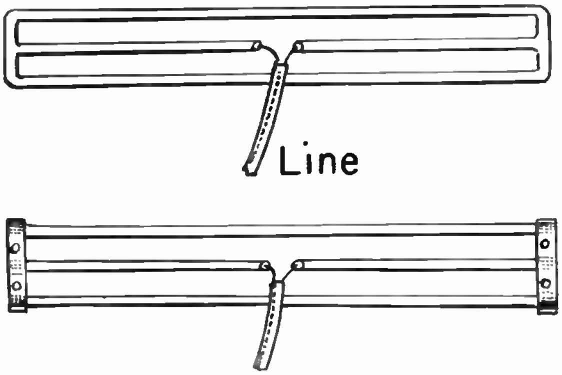

Fig. 5. Folded dipoles with three conductors.

In some antenna structures you will find three-conductor folded dipoles, made as in Fig. 5 with ends soldered, braced, or joined with metal clamps. To determine impedance of the three-conductor folded dipole we take the square of 3, which is 9. Then 9 times 73 equals 657. Impedance usually is spoken of as 600 ohms.

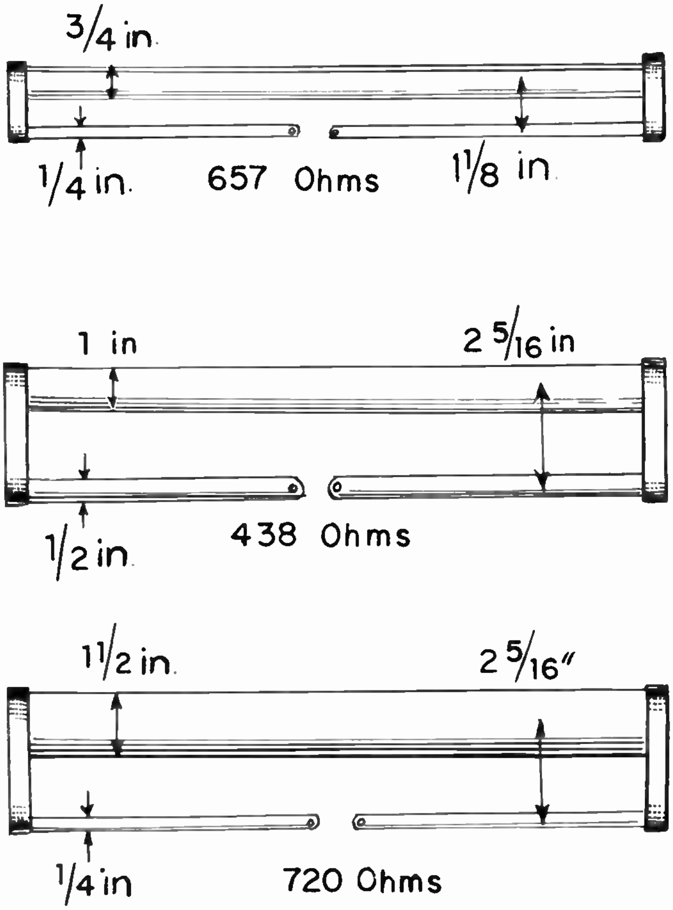

Fig. 6. Impedance of a folded dipole is increased by making one of its conductors of larger diameter than the other conductor

Another way of increasing the resonant impedance of a folded dipole is to make the continuous side of greater diameter than the side containing the gap at which the transmission line is connected. Some examples are illustrated by Fig. 6. Increasing the ratio of the larger to the smaller diameter increases the impedance at resonance when center-to-center spacing remains unchanged. Increasing the center-to-center spacing decreases the impedance when the ratio of diameters remains unchanged.

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Now we have learned that addition of parasitic elements tends to lower the impedance of an antenna at resonance. Using folded dipole elements with two or more conductors, or with conductors of different diameters, tends to increase the impedance. By suitably combining these factors the designer may make the resonant impedance of his antenna match the impedance of whatever transmission line is to be used.

BANDWIDTH. Reflectors and directors affect not only the resonant impedance of an antenna system, but determine also how the impedance will change at carrier frequencies below and above response. Fig. 7 is an impedance curve for a particular antenna cut for approximately the middle of the low band, at about 70 mc. Any antenna is resonant (reactances cancel out) at a frequency for which electrical length of the dipole equals a half-wavelength. Here we have the curve for an antenna of such electrical length as to be resonant at 70 mc.

At all lower and higher frequencies the impedance increases, because reactances do not balance, and do not cancel. At frequencies below resonance there remains an excess of capacitive reactance, while at frequencies above resonant there is an excess of inductive reactance - exactly as in a series resonant circuit made with a wound inductor and a capacitor.

At frequencies below resonance the dipole conductors are, in effect, too short - because for lower frequencies we should have a longer antenna. At frequencies above resonance the dipole is too long - we should have a shorter one for these higher frequencies.

Only at the frequencies of resonance can electric charges reflected back and forth between opposite ends of a dipole conductor keep perfect time with carrier waves. At all lower and higher frequencies these charges get more or less out of time or out of phase with carrier waves. Then the charges cannot build up to maximum possible strength, and less signal energy is picked up from carrier waves.

There is further loss of signal strength delivered to the receiver because of mismatch between impedances of antenna and transmission line at frequencies off resonance. Supposing, as an example, we were to use with the antenna whose impedance char-

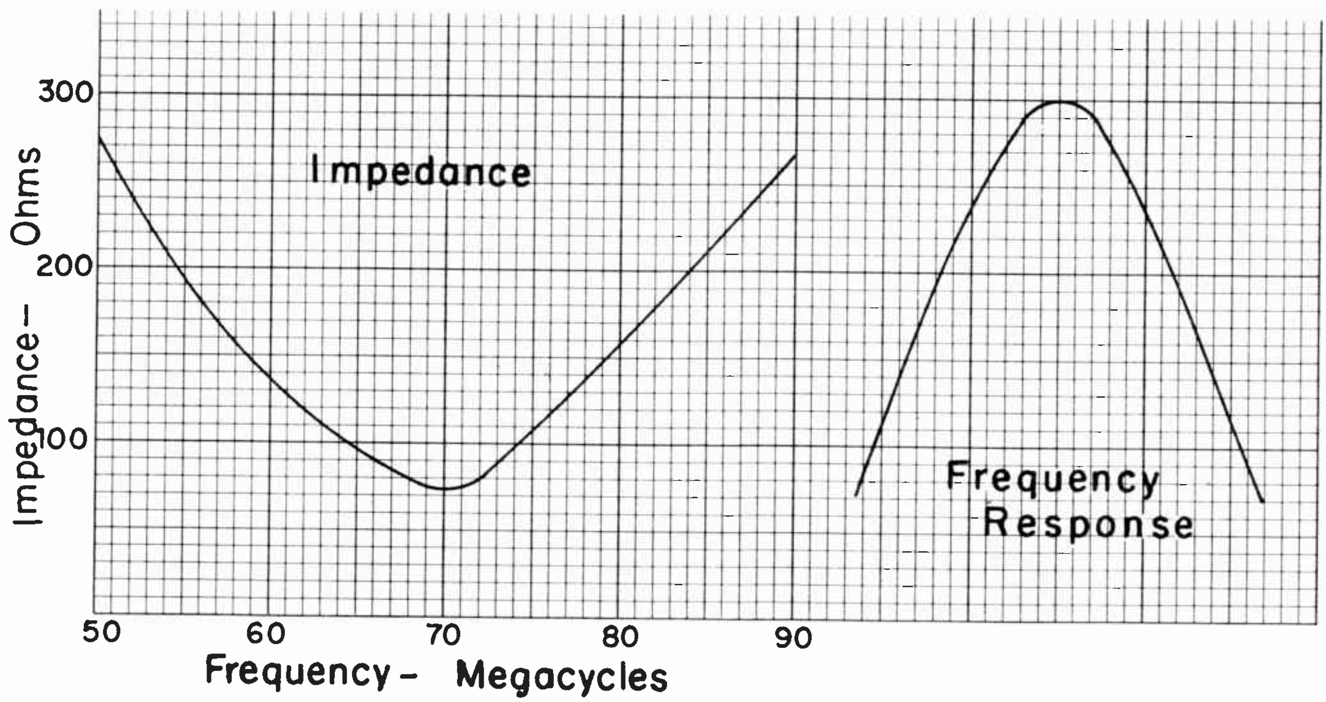

Fig. 7. How impedance of an antenna varies when carrier frequencies are below or above the frequency of resonance.

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acteristic is shown by Fig. 7 a transmission line having characteristic impedance of 72 ohms. There would be almost perfect matching, and maximum energy transfer, at resonance and at frequencies a little below and above.

But at the middle of channel 2, or at 57 mc, antenna impedance has risen to about 170 ohms. For the 72-ohm transmission line this means mismatch of almost 2.4 to 1. At the middle of channel 6, where frequency is 85 mc, antenna impedance is about 210 ohms. This means mismatch of nearly 3 to 1. Such mismatches of antenna and line impedances reduce transfer of signal energy by 15 to 25 per cent. This loss is in addition to that resulting from less effective pickup of carrier wave energy at these off-resonance frequencies.

Combined effects of impedance mismatch and reduced energy pickup at frequencies off resonance may cause frequency response of a straight dipole, so far as the receiver is concerned, to be somewhat like that at the right in Fig. 7. With a response so sharply peaked, gain will be high on the tuned channel but performance outside the one channel will be poor. In other words, we have a narrow-band antenna.

Relatively broad frequency response results from impedance which increases more slowly at frequencies each side of resonance. This improves the match to a transmission line and at the same time means smaller excesses of inductive and capacitive reactances, and more uniform signal pickup, at frequencies off resonance.

The basic principle of increased bandwidth is reduction of antenna Q-factor. Most often this is accomplished by increasing the capacitance in relation to inductance required at resonance. Capacitance is increased by using antenna conductors of greater diameter, or by using more conductors in the dipole section. As in any tuned circuit, a smaller Q-factor decreases maximum gain at resonance, but allows gain to be fairly uniform throughout a greater range of frequencies.

The greater the ratio of highest to lowest received frequencies the more difficult is the problem of maintaining satisfactory gain throughout an entire band. Uniform gain the vhf low band (frequency ratio about 1.5 to 1) is more difficult than in the high band (ratio of 1.2 to 1). Covering the entire vhf range, with frequency ratio of 4 to 1, presents a real problem. The uhf band is less difficult, because the frequency ratio is somewhat less than 1.9 to 1.

REFLECTORS. Now we may make a more complete examination of reflectors, which have major effects on resonant impedance, which determine to a great extent the directional properties, and also affect bandwidth.

The reflector usually is made from the same kind and size of tubing as the dipole element, being either straight for any style of antenna or else of the same form as the dipole when the dipole is other than straight tubing. The reflector may or may not be insulated from its support, but in no case is it connected by wire or cable to anything else. Incidentally, the fore and aft bar or other support that carries all the antenna elements and is itself attached to the mast, may be called the boom.

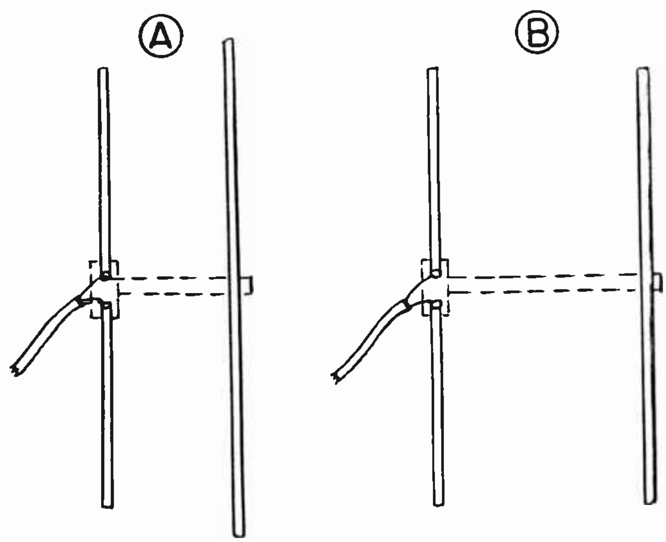

Fig. 8. Moving a reflector farther from its dipole lessens the change of impedance with variations of carrier frequency.

For maximum possible gain, which may be four to five decibels, the reflector would be spaced from the dipole about as shown at A of Fig. 8, and the reflector would be longer

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than the dipole. With this rather close spacing, impedance at the takeoff for the transmission line would be only about one-third of that with no reflector. For instance, impedance of a folded dipole would drop from 300 to about 100 ohms.

To avoid such great drop of impedance we may move the reflector farther from the dipole, as at B. Here the spacing is a quarter-wavelength at the resonant frequency of the dipole. By shortening the reflector to make it the same length as the dipole, gain is dropped only about one decibel due to increased spacing. The principal advantage of greater spacing is less change of impedance. Impedance of a folded dipole here would drop only to about 250 ohms.

With the reflector spaced a quarter-wavelength from the dipole, the reflector will be correctly "tuned" for best possible gain at this spacing when it is of the same length as the dipole. To maintain best possible gain when moving the reflector closer to the dipole it is necessary to tune the reflector to a lower frequency, by lengthening it. As the reflector is moved farther away, best possible gain for any spacing is maintained by tuning the reflector to a high frequency, by shortening it.

Mounting the reflector rather close to the dipole, say less than a quarter-wavelength, reduces the bandwidth of the antenna system. Moving the reflector farther away increases bandwidth. By comparing these statements about bandwidth with earlier statements relating to gain you will find that reflector spacings which reduce bandwidth will increase gain, while spacings which broaden the band will decrease the gain. Gain and bandwidth or frequency response always are opposed, when one increases the other decreases.

If a reflector is cut and spaced for maximum gain, the directional pattern of the antenna will be about as shown at A of Fig. 9. Front response will be stronger than back response, but there will not be enough difference to greatly affect reproduction of signals from opposite directions. Were the reflector longer than the dipole, and spaced for least possible back response, the directional pattern would be about as shown at B. Back response has been dropped to little more than 10 per cent of front response. •

When comparing the two patterns of Fig. 9, or any other directional patterns, remember that the outermost circle represents merely the point or direction of maximum gain for a particular antenna. It does

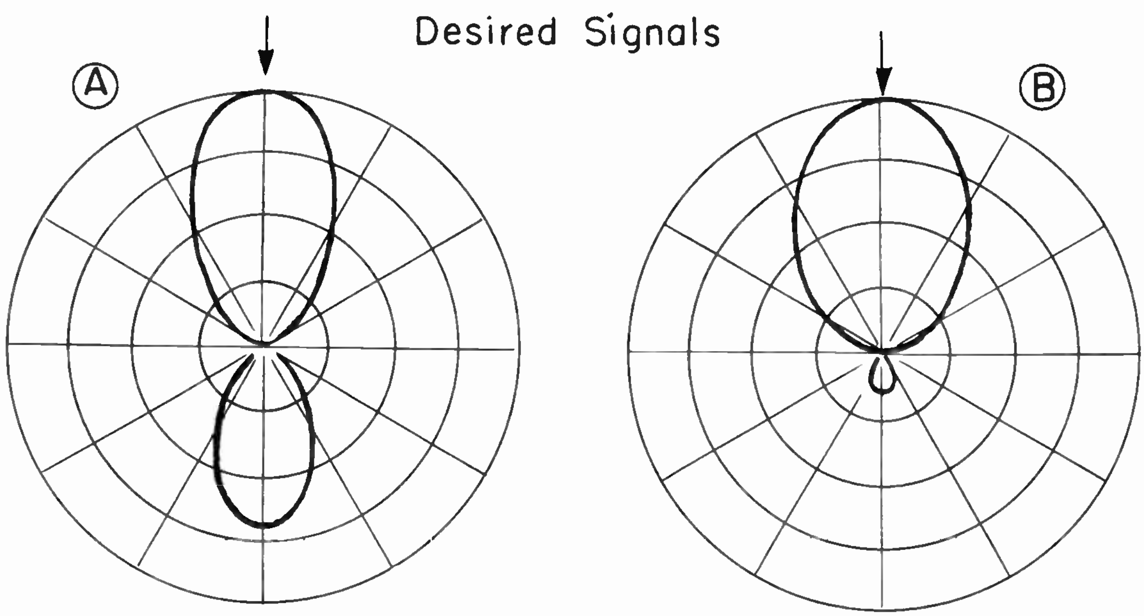

Fig. 9. A reflector cut and spaced for maximum gain (A) allows greater back response than when arranged solely for minimum back response (B).

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not represent any particular number of decibels. Decibels of gain for the pattern at B would be less than for the pattern at A, but in each case the response on the outer circle is maximum or is 100 per cent for the one particular antenna.

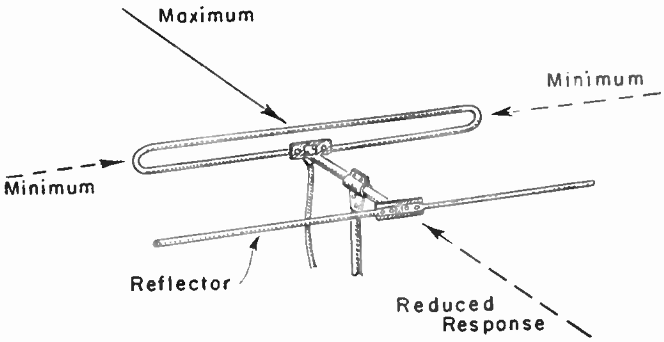

Fig. 10. Minimum pickup always is from directions in line with the dipole conductors.

Back response never is reduced to zero, nor can it be made so small as response in directions which are in line with the dipole conductors. This is illustrated by Fig. 10. Minimum response still is for signals coming toward the ends of the dipole.

DIRECTORS. It would be rare indeed to find an antenna structure with a director as the only parasitic element. Where there is to be only one such element, greater advantage nearly always results from making that element a reflector. Therefore, when talking about directors, we are referring to the addition of one or more directors to an antenna provided also with a reflector. It might be mentioned that more than one reflector seldom is used; the slight added advantage rarely would be worth the added cost and bulk.

A director drops resonant impedance of an antenna more than does a reflector. This, however, is only because an element which is to act as a director is placed closer to the dipole than is an element which is to act as a reflector. Were both kinds of parasitic elements spaced equally from the dipole, their effects on impedance would be almost alike.

When properly cut and spaced, a director adds still more to the gain which already has been raised by a reflector. The greater gain

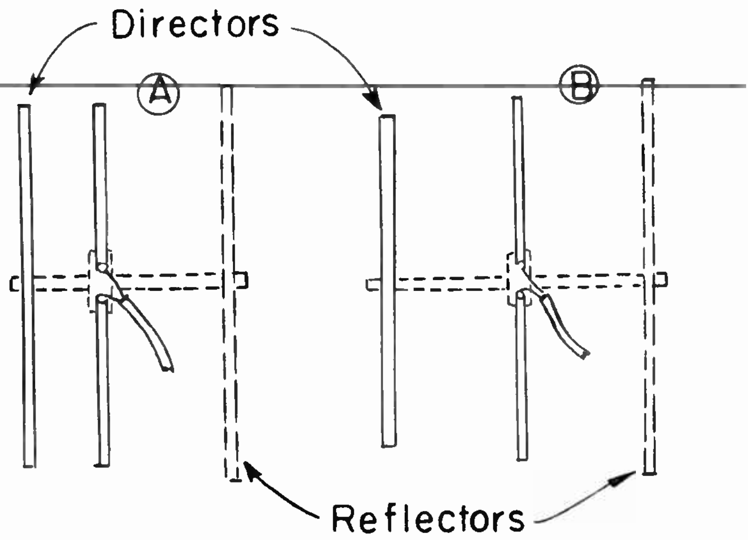

Fig. 11. A director spaced and cut for maximum gain (A) and for somewhat less gain but less decrease of antenna impedance (B).

is accompanied, as always, by narrower bandwidth. For maximum possible gain a director is spaced only about 1/10 wavelength from the dipole, as at A of Fig. 11, and is cut to the same length as the dipole. This spacing of the director drops resonant impedance of the antenna system to somewhat less than 20 per cent of the impedance with no director. For example, 250-ohm impedance of a folded dipole with reflector would go down around 50 ohms.

If the director is moved farther from the dipole, as at B, there is less gain but also less drop of antenna impedance. With the spacing shown, impedance of the antenna would drop to only about half its value with no parasitic elements, while signal response would be improved only about one-fifth as much as with the closer spacing at A.

To maintain best possible gain with a director moved farther from the dipole, the director must be shortened. Were the director moved even closer to the dipole than at A, the director would have to be lengthened to maintain best possible gain at this closer spacing.

It is apparent that the differences between a parasitic element acting as a reflector and another acting as a director are in spacing from the dipole and in length of

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the parasitic element. In most cases the reflector is farther from the dipole than is the director. The reflector is somewhat longer than the dipole, and the director or directors are somewhat shorter.

Directors always narrow the bandwidth of an antenna. As a director is moved closer to the dipole, for increase of gain as at A of Fig. 11, the bandwidth becomes narrower. Greater spacing of the director decreases gain, but at the same time widens the frequency response or bandwidth.

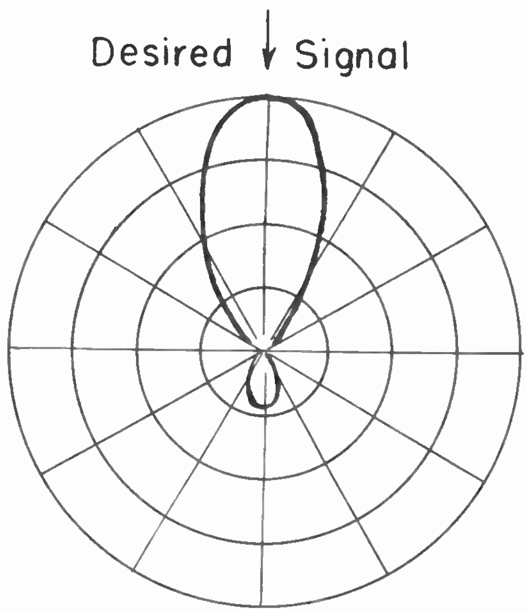

Fig. 12. Directional pattern of an antenna with reflector and director.

With a reflector and one director spaced as at A of Fig. 11, and with both cut to lengths giving greatest gain for these spacings, the directional pattern of the antenna will be about as shown by Fig. 12. The front lobe is somewhat narrower or is more sharply directional than with only a reflector, while the back lobe has shrunk to only about 20 per cent of the front lobe.

YAGI ANTENNAS. A Yagi antenna, as the name ordinarily is used, means any antenna having a single reflector and two or more directors. The name is that of the Japanese physicist who originally developed such an antenna of certain dimensions and element spacings. Although practically any number of directors might be used, many popular styles consist of three directors, of

Fig. 13. A five-element Yagi antenna.

one dipole element, and of one reflector. An antenna of this kind is illustrated by Fig. 13.

Characteristics of the Yagi include high gain, often as much as 10 decibels in the forward direction, small back response, and directional pattern with narrow forward lobe. As always, the high gain is accompanied by narrow bandwidth. Bandwidth of these antennas having a straight dipole is sufficient for fully satisfactory reception in only a single channel. A folded dipole allows good reception in two adjacent channels. Many of the more recent designs provide satisfactory response over several channels without sacrificing much of the gain, or unduly widening the angle of reception.

Frequency response or bandwidth of a Yagi antenna may be further broadened by making the directors slightly shorter and the reflector slightly longer than for best possible gain at any given spacings, also by increasing the spacings between the several directors and between these elements and the dipole.

Some Yagi antennas provide bandwidth great enough for the entire high band or the entire low band in the vhf range, or great enough for at least most of the low band channels. The dipole may be cut for one channel, the reflector for a lower channel, and the directors cut for higher channels in the band. Another method is to use two or three folded dipoles cut for frequencies at various points in the band to be covered, and all feeding into the one transmission line.

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Some designs include two dipoles of the three-conductor type.

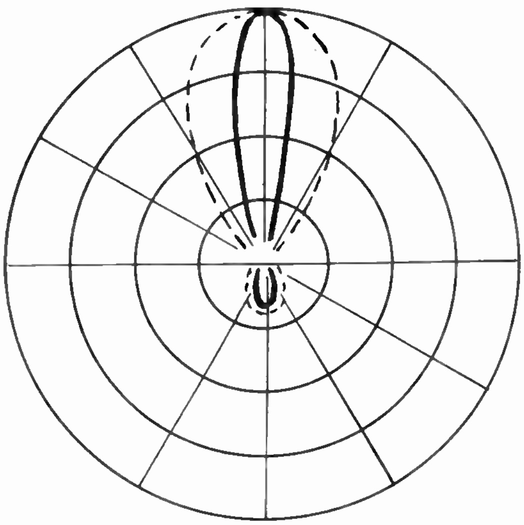

Fig. 14. Directional patterns of a single-channel and a multi-channel Yagi antenna.

A single channel multi-director Yagi may have a directional pattern about as shown by full lines in Fig. 14. A type designed to cover an entire band, either high or low, may have a pattern about as shown by broken lines.

The many directors of a Yagi antenna tend to bring resonant impedance of an ordinary folded dipole element from the normal 300 ohms down below 50 ohms. Impedance may be raised, or rather prevented from dropping, by any of the methods explained earlier. These methods include use of a three-conductor folded dipole, or making the continuous conductor of a folded dipole larger in diameter than the divided element to which connects the transmission line. It is possible also to match low impedance of a Yagi antenna to higher impedance of a transmission line by means of a quarter-wave-length matching transformer.

GHOSTS AND SIGNAL REFLECTIONS. An antenna with reflector, or with reflector and one or more directors, may be the only means for preventing what we call ghosts, reflections images, or multi-path images on pictures. Such trouble often originates in the manner illustrated by Fig. 15. A transmitter is located at point T, your receiving antenna

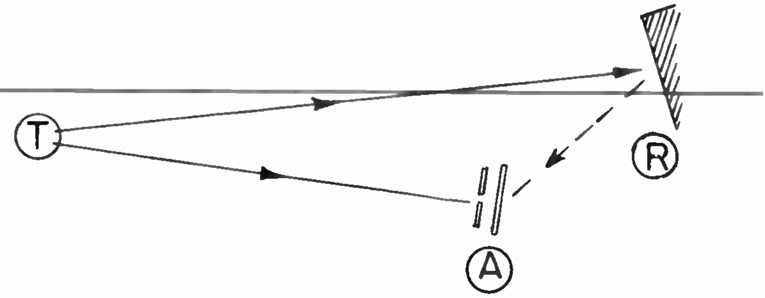

Fig. 15. A reflector may prevent reflected signals from causing trouble.

is at A, and at R is any surface capable of reflecting carrier waves.

Carrier waves traveling from the transmitter directly to the receiving antenna cause regular picture images. At the same time, waves reflected to the back of the receiving antenna cause ghost images unless the antenna has small back response.

The reflected signal travels a greater total distance than the direct signal in reaching the receiving antenna, and arrives a little later than the direct signal. Consequently, the ghost appears on the picture tube screen a little to the right of the direct image, because the electron beam travels from left to right across the screen.

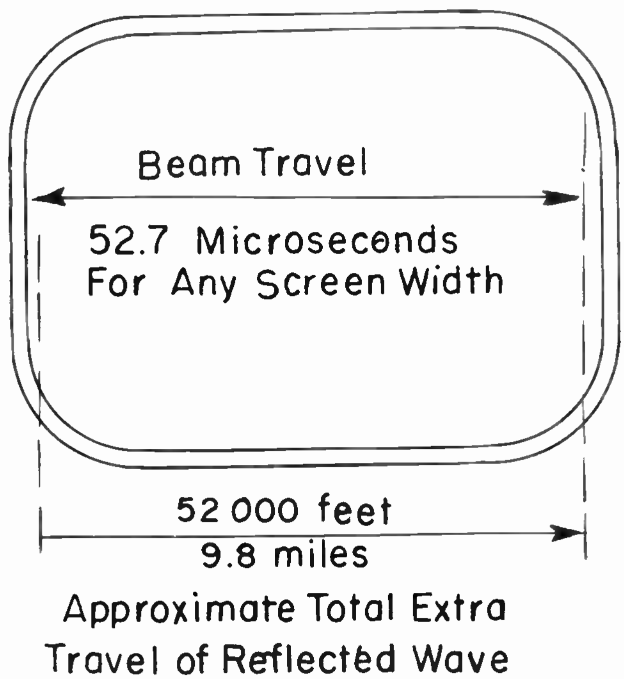

Fig. 16. Relations between travel of the electron beam in the picture tube and travel of carrier waves in space.

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Fig. 16 illustrates relations between distances traveled by carrier waves and by the electron beam in a picture tube. The electron beam moves from left to right across the picture area in 52.7 microseconds, no matter what may be the width of the screen. During this time a carrier wave travels about 52,000 feet or about 9.8 miles in space.

Supposing that the receiver has a 21-inch picture tube allowing a picture 19 inches wide, and that a ghost image is 1/5 inch farther to the right than the regular image. This is 1/95 of the total picture width. The reflected wave causing the ghost must have traveled about 1/95 of 52,000 feet farther than the direct wave, or must have traveled an extra total distance of about 550 feet. Since this reflected wave has gone past the receiving antenna position to the reflecting surface and back again, the reflecting surface probably is something like 270 or 280 feet from the receiving antenna.

By noting the separation between direct and ghost images as a fraction of maximum picture width, and beam travel, then taking this fraction of 52,000 feet and dividing by 2, you will have some idea as to where the reflecting surface probably is located.

There will be distinctly separate ghost image lines only when the reflecting surface is far enough away to delay arrival of reflected signals while the beam travels an appreciable distance across the picture tube screen. If the reflection path is short, ghost lines will be so close to regular image lines as to cause only fuzzy, blurred pictures with poor definition.

Reflected signals do not cause poor reproduction of sound. Our ears are not sensitive to time differences or phase differences so small as those resulting from reflections.

A reflecting surface must be either a conductor or else a non-conductor whose dielectric constant is several times that of air. Metal reflecting surfaces may be water tanks, gas storage tanks, bridges, any structures with steel frames, and even metal roofs. Reflections may come from pipes, conduits, cables, and wires when these are quite close to the receiving antenna. A non-conductive reflecting surface may be any building or other structure of masonry, it could be a pavement, or surface of the earth.

Reflection troubles are likely to be serious at receivers located within possibly six to twelve miles from transmitters. This is partly because such districts often have many buildings close together, and many other reflecting surfaces. It is partly because carrier waves are there so strong as to cause strong reflected waves. At distances more than about fifteen miles from transmitters there is less likelihood of reflection troubles; direct carrier waves are weaker, and absorption of energy by reflecting surfaces makes reflected waves even weaker.

The higher the carrier frequency and the larger the reflecting surface the more likely are reflection troubles. To cause strong reflections, the dimensions of a reflecting surface must be comparable to the length of a carrier wave. Length of carrier waves is about $13\frac{1}{2}$ feet in the middle of the vhf low band, but is only about 5 feet in the middle of the high band. Reflections may cause much trouble in ultra-high frequency reception, because the length of carrier waves is less than $1\frac{1}{2}$ feet for the mid-frequency of the uhf band.

Reflected waves do not always come toward the back of a receiving antenna, and cannot always be cut off by a reflector element on the antenna. It is possible to have front reflections, as in diagram <u>1</u> of Fig. 17. To reduce or eliminate the effects of front reflections it is necessary to use a highly directional antenna, probably a type having several director elements as well as a reflector. Careful orientation then should provide strong pickup from the direct wave, and very little pickup from the reflected wave.

In closely built up districts there may be multiple reflections, as in diagram <u>2.</u> Were the antenna rotated or oriented toward the transmitter, for reception of a direct wave, reflections from waves <u>x</u> and <u>y</u> could cause very poor reproduction of pictures. It would be better to turn the receiving antenna away from the transmitter and try to pick up a

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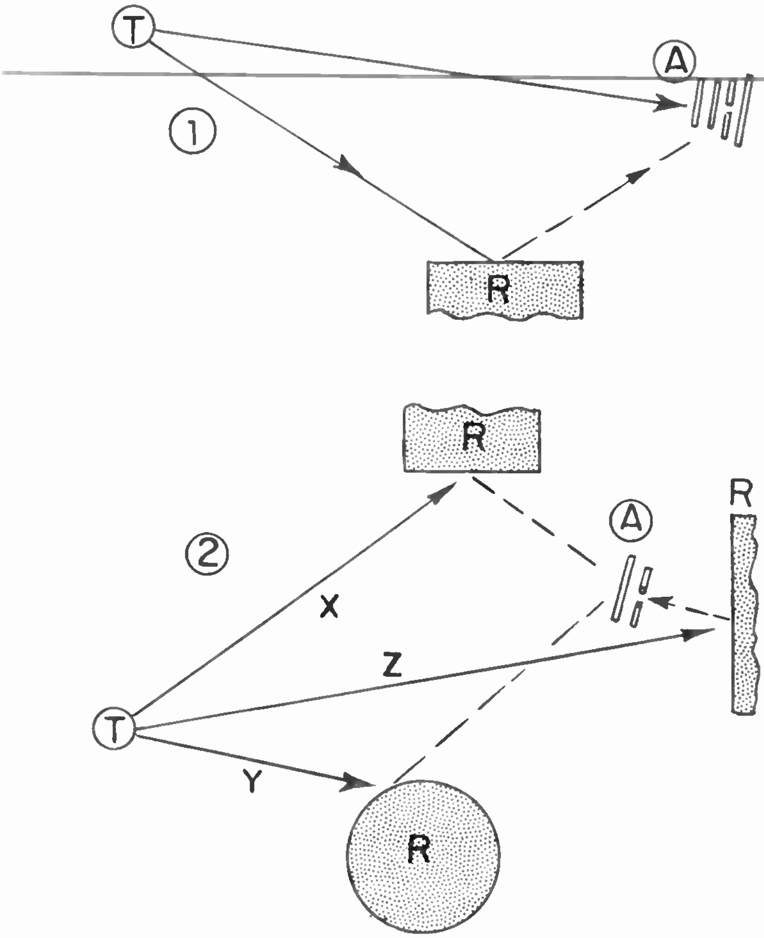

Fig. 17. Antenna directors may be effective where there are front reflections (1). Best reception sometimes is from reflected signals (2).

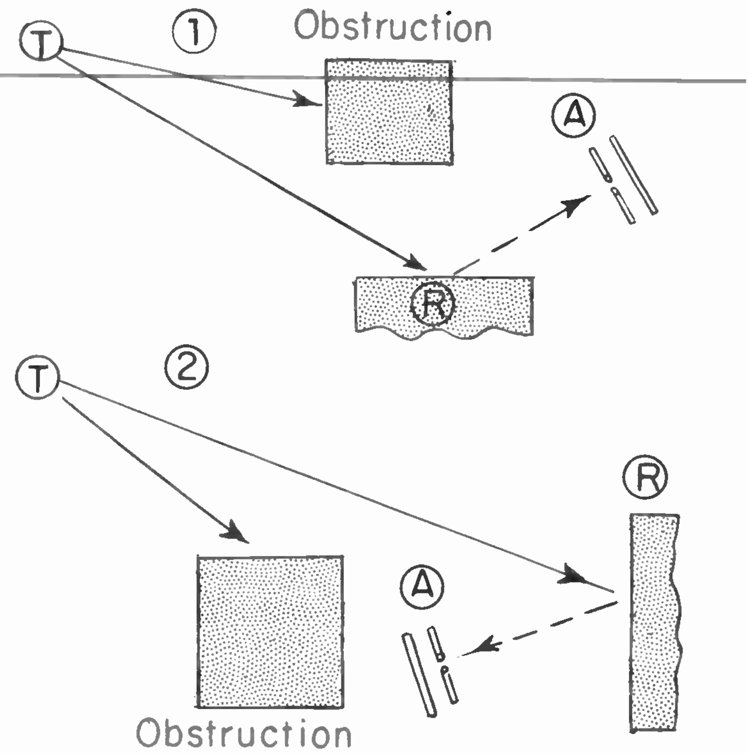

Fig. 18. Where the receiving antenna is in a "wave shadow", reception can be had from reflected signals.

strong reflection from the opposite direction, such as the reflection from wave z of the diagram. Since any reflected wave is weaker than a direct wave, the antenna would have to be of a type possessing high gain.

When some large obstruction, such as a building, is on a line from receiving antenna to transmitter the antenna is in a wave shadow and it will be impossible to pick up signals from a direct wave. Conditions of this kind are illustrated by Fig. 18. In diagram 1 the receiving antenna is turned far enough away from the transmitter direction to pick up a strong reflection. In diagram B the receiving antenna is oriented in a direction almost opposite to that of the transmitter in order to pick up a strong reflection from this opposite direction. As in all cases where a reflected wave is used for reception, the antenna must have high gain.

Should you run into a situation in which elimination of ghost images is impossible, it is probable that the reflected wave originates from some surface much closer to the transmitter than to the receiver. Then direct and reflected waves come to the receiver from practically the same direction, and orienting cannot help matters.

Before deciding that a suitable antenna properly oriented will not prevent trouble due to wave reflections, always move the antenna to different positions and different elevations. As you examine the various reflection paths and angles shown by Figs. 17 and 18 it becomes apparent that only a little shifting of antenna position may bring it out of or into these paths. Oftentimes a shift of only a few feet one way or another will make the difference between success and failure in ghost elimination or in pickup where there are shadow effects.

<u>TWO-BAND ANTENNAS.</u> The great majority of television receiving antennas are designed for pickup in both the low and high bands of the vhf range, and many types include combinations of elements that allow

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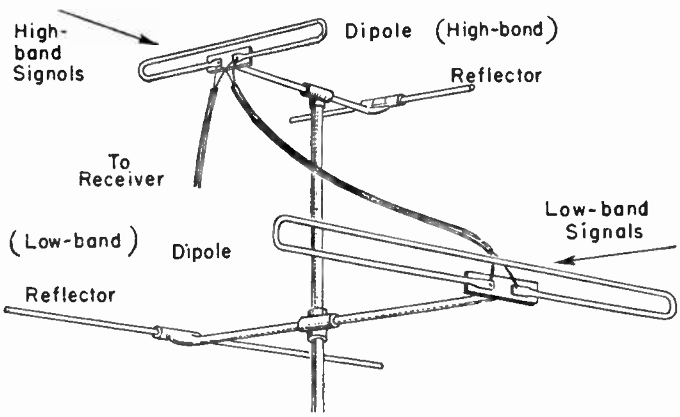

Fig. 19. A high-low antenna or two-band antenna, sometimes a "piggy-back" type.

reception also in the uhf range. Among the earliest antennas designed for the entire vhf range is the combination high-low type of Fig. 19. This antenna consists of one folded dipole and reflector cut for the high band and another folded dipole and reflector cut for the low band.

Two straight dipoles with reflectors sometimes are used in a similar combination, while again there may be a straight dipole for either band and a folded dipole for the other band. Practically always there is a separate reflector for each dipole. This type of antenna is useful where transmitters in the two bands are in decidedly different directions from the receiver, since the high-band and low-band elements may be independently oriented for best reception in each band.

Vertical separation between low-band and high-band elements may be almost anything from less than a quarter-wavelength to as much as a half-wavelength at the middle of the low band, or from less than 30 to as much as 80 or more inches, as specified by the manufacturer.

In Fig. 19 the transmission line connects to the high-band dipole, with an additional piece of line from there to the low-band dipole. Sometimes the line from the receiver goes first to the low-band dipole. In still other cases the transmission line connects to a link at a point between the two dipoles.

It is, of course, desirable that all possible energy from signals in each band go into the transmission line, rather than being partially wasted by going into the antenna for the other band. It is desirable also that signals for each band, as delivered into the transmission line, be only those picked up by the antenna for that band and not a mixture of out-of-phase signals from both antennas at once. Phasing trouble may occur principally because any low-band antenna responds fairly well to high-band signals provided the high-band signals come from certain directions.

Various ways of making each antenna perform independently of the other are illustrated by Fig. 20. At A the receiver transmission line is connected to the high-band dipole. The two dipoles are connected together by a length of 300-ohm ribbon line or any equivalent line long enough to allow free rotation or orientation of each antenna. To the low-frequency dipole is connected also an open stub cut for a quarter-wavelength at the middle of the high band. When this stub is made from 300-ohm ribbon line its length should be about 12 inches. The stub acts as a short circuit (series resonant) for high-band signals picked up by the low-band dipole.

The reason for mentioning only approximate lengths and spacings in these explanations is that tuning and phasing is for the approximate middle of a band, not for some particular channel. Slight variations in dimensions will merely shift best performance a little lower or higher in the same band.

Diagram B of Fig. 20 shows the two dipoles connected together by a piece of 300-ohm ribbon line having total length of 44 to 48 inches. The receiver transmission line is connected at a point 11 to 12 inches from the high-band dipole. This connection is conveniently supported by a standoff insulator on the mast. To the low-band dipole is connected a quarter-wave open stub just like the one of diagram A, and serving the same purpose.

Diagram C shows connections often used where separation between high-band and low-band dipoles is 24 inches or less. The receiver transmission line is connected to the low-band dipole. The length of 300-ohm ribbon line between the two dipoles is trans-

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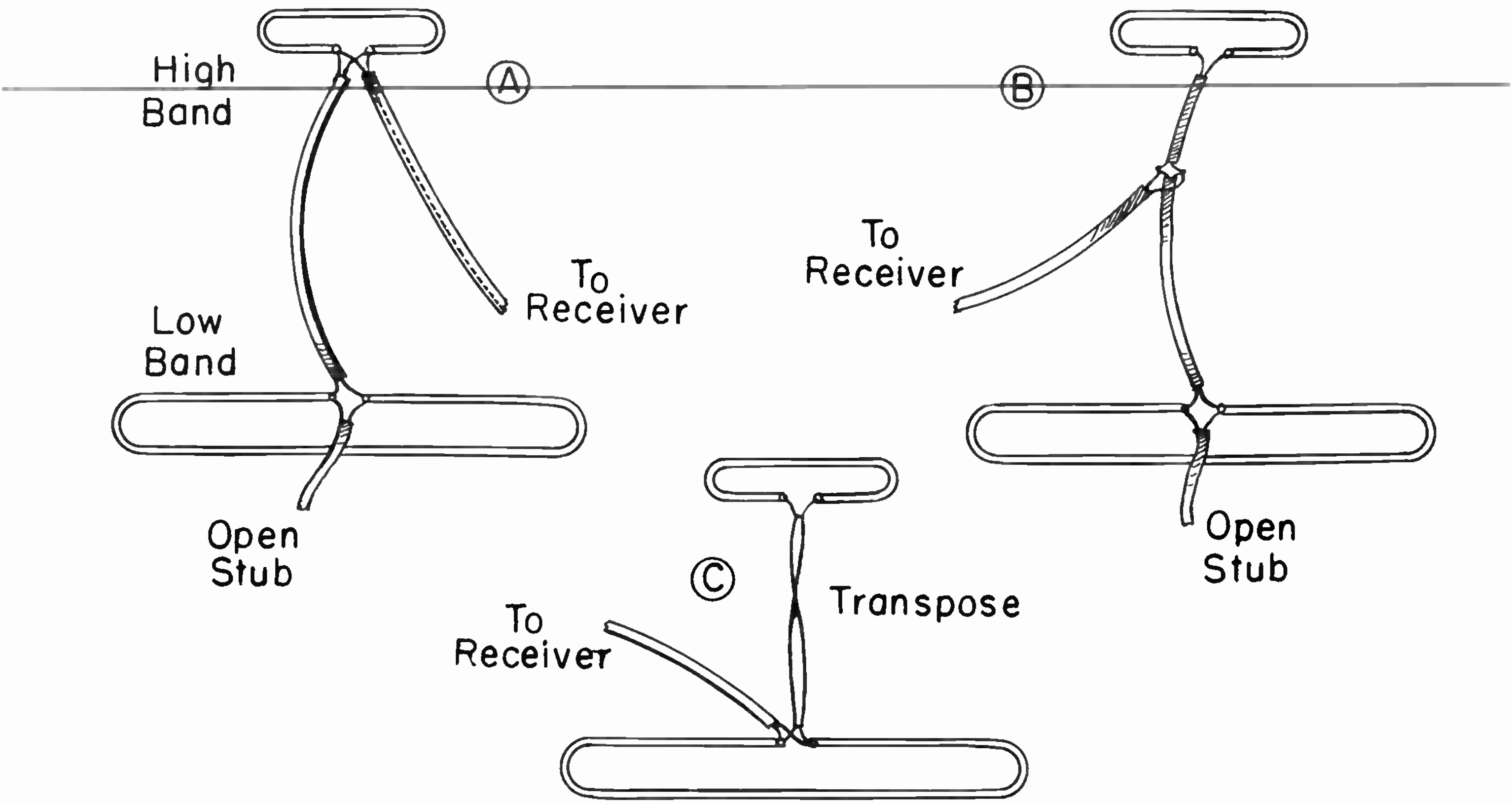

Fig. 20. Phasing connections for high-low antennas.

posed or given a half-turn between its end connections.

Fig. 21 shows an arrangement of elements in a two-band antenna suitable for locations where all transmitters are in the same general direction from the receiver. Out in front is a high-band folded dipole. Back of it is the low-band folded dipole which is the pickup element for low-band signals, and which acts also as a reflector for the high-band dipole. Back of the low-band folded dipole is a reflector for this element. The receiver transmission line is connected to the low-band dipole, with an additional short piece of line between the two dipoles.

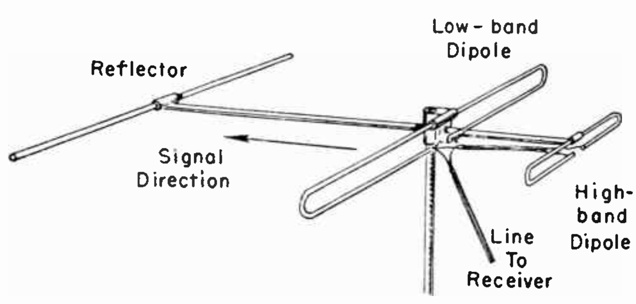

Fig. 21. A two-band antenna of the in-line type.

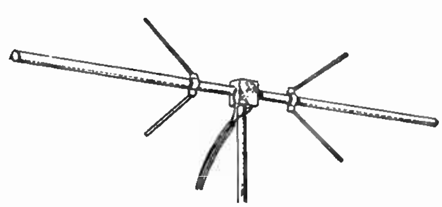

Fig. 22. A two-band antenna with V-attachments for good response in the high band, and a straight dipole for the low band.

Fig. 22 illustrates an entirely different approach to the problem of providing two-band reception. The straight half-wave dipole is cut for best response in the low band. At points 9 inches out from the center of the straight dipole are clamped V-attachments consisting of slender solid rods whose angle with each other is 90 degrees, and with the straight dipole tubing is 45 degrees. This spacing of the V's allows these elements and the portion of the straight dipole between them to act as an antenna having suitable electrical length for the high band. The entire straight dipole is an antenna for the low band.

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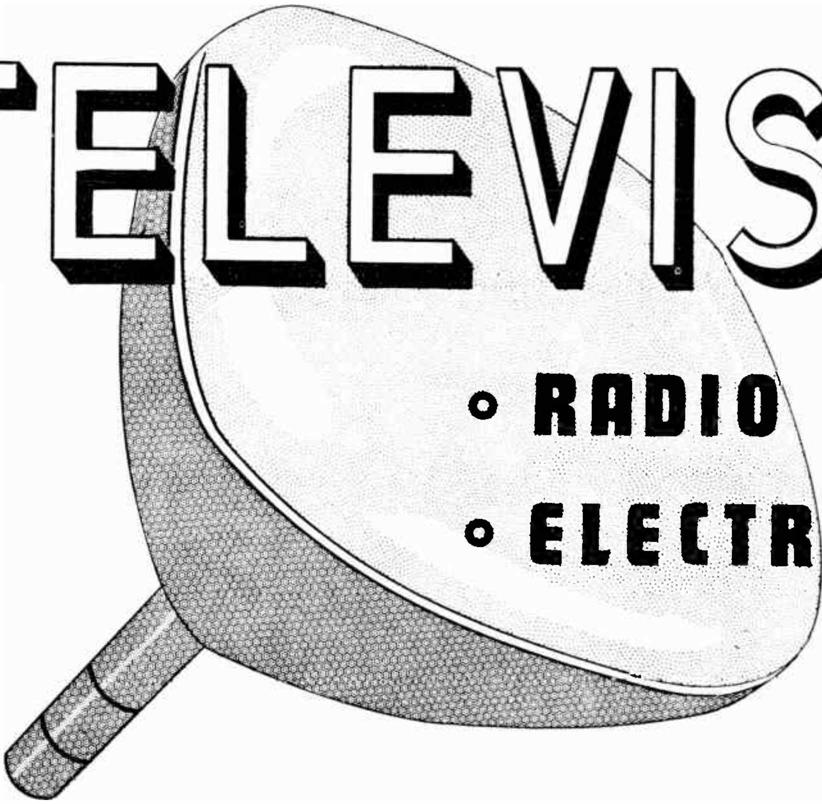

• RADIO
• ELECTRONICS

LESSON 91 — HARMONIC ANTENNAS AND RESONANT LINES

Coyne School

practical home training

Chicago, Illinois

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Lesson 91

HARMONIC ANTENNAS AND RESONANT LINES

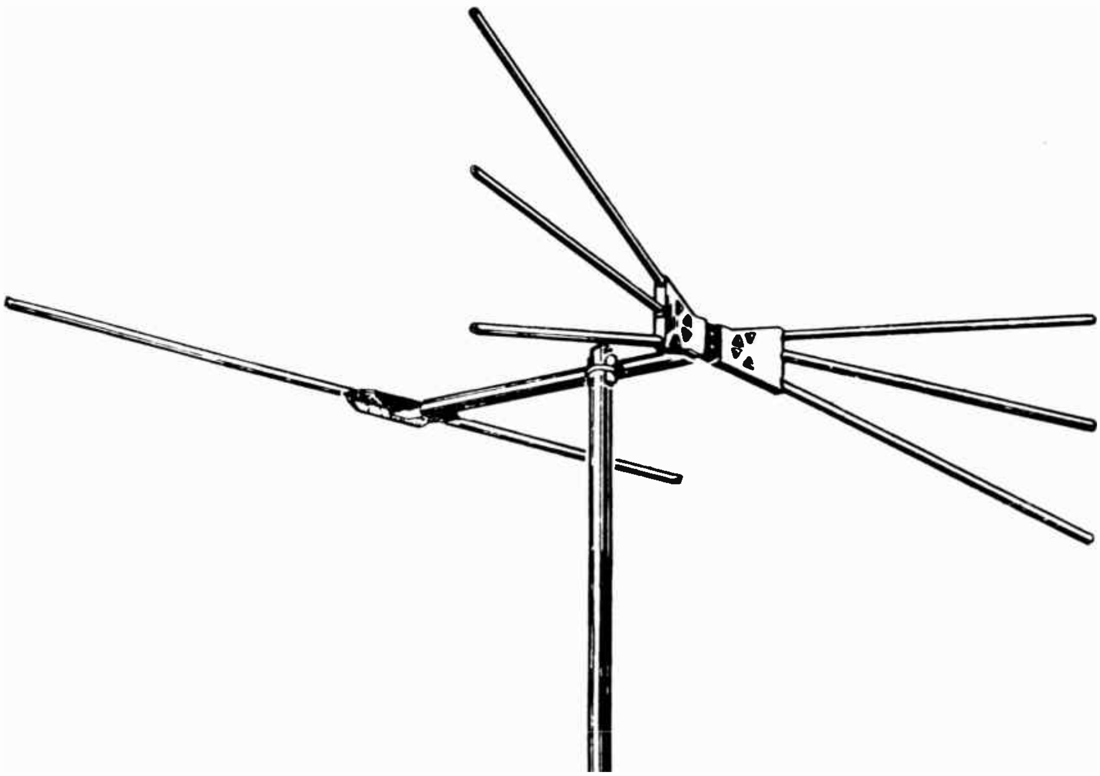

Fig. 1. A conical antenna for reception in the entire vhf range.

You must have noticed, on roof tops everywhere, the many television antennas having the general form illustrated by Fig. 1. The outer ends of two sets of oppositely extending conductors are inclined forward, in the direction of signals to be received. This type is commonly called a conical antenna, or may be called a fan antenna.

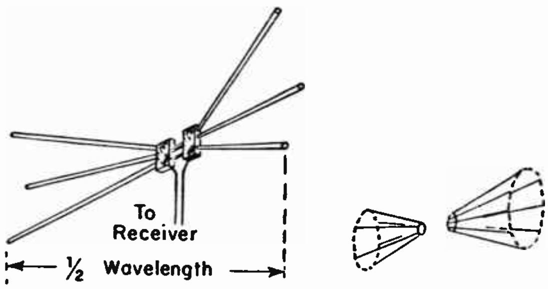

Fig. 2. Conductors of a conical antenna are like portions of two opposed cones.

The name conical comes from the fact that, were there enough radial conductors and were they suitably positioned, the result would be as shown at the right in Fig. 2, where we have two cones with their apexes toward each other. Such complete conical antennas have been used for both transmission and reception at ultra-high frequencies. The name fan antenna derives, quite obviously, from the fact that conductors on opposite sides spread out like a fan.

Were we to remove from a conical antenna all but two conductors extending horizontally, there would be reduction of bandwidth and some loss of signal pickup. Were we to push the outer ends of these two conductors back, to make them lie on a straight line, we would lose the advantage of good reception in the high band channels, and would have remaining only a straight dipole cut for the low band.

Fig. 3 shows our remaining straight dipole, cut for a frequency at the middle of

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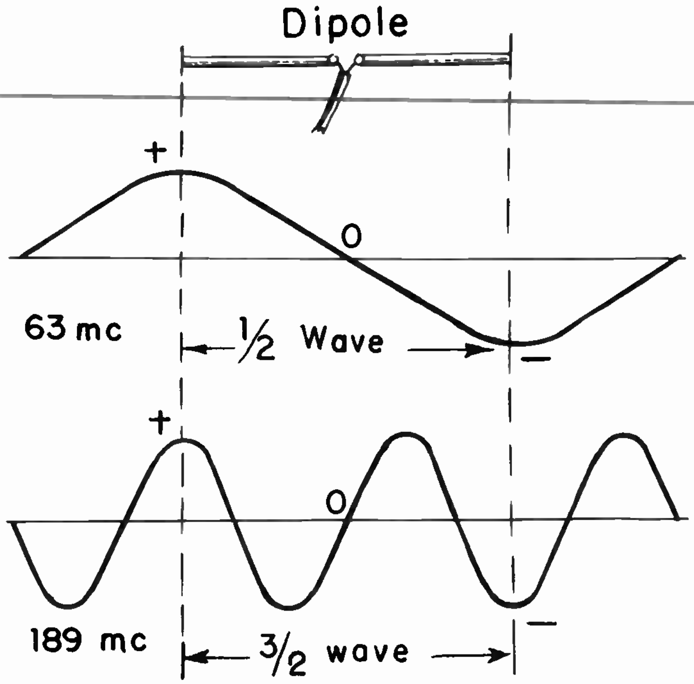

Fig. 3. A dipole is resonant at the third harmonic of its fundamental frequency.

channel 3, or for 63 mc. Immediately below the dipole is represented one carrier wave for this frequency. At certain instants the opposite ends of the dipole are at maximum positive and negative amplitudes of the carrier wave, as would be the case with any straight dipole cut for a certain frequency.

Supposing now that the straight dipole cut for channel 3 is reached by signals in channel 9. Frequency at the middle of channel 9 is 189 mc, just three times the frequency at the middle of channel 3, for which our dipole is cut. As represented at the bottom of Fig. 3, there will be three carrier waves for channel 9 during the time required for one carrier wave in channel 3. Frequency at the middle of channel 9 is the third harmonic of frequency at the middle of channel 3. By looking at a list of channel frequencies you will find that everything in the vhf high band is a third harmonic of some frequency in the low band.

Antenna conductors cut for a half-wavelength in the low band will be of overall length equal to three half-wavelengths in the high band, which is to say that a dipole operating on a fundamental frequency in the low band would have to operate on a third harmonic frequency in the high band.

Directional response for low-band signals will be as shown at A of Fig. 4, but for high-band signals the pattern will be about as at B. The two large lobes in opposite directions for the low band have shrunk to small dimensions in the high-band pattern. Four new major lobes have appeared for the high band, each inclined from the dipole conductors by about 40 degrees.

High-band signals might be received from any of the four 40-degree directions at B of Fig. 4 with acceptable strength, but strongest low-band signals could be picked

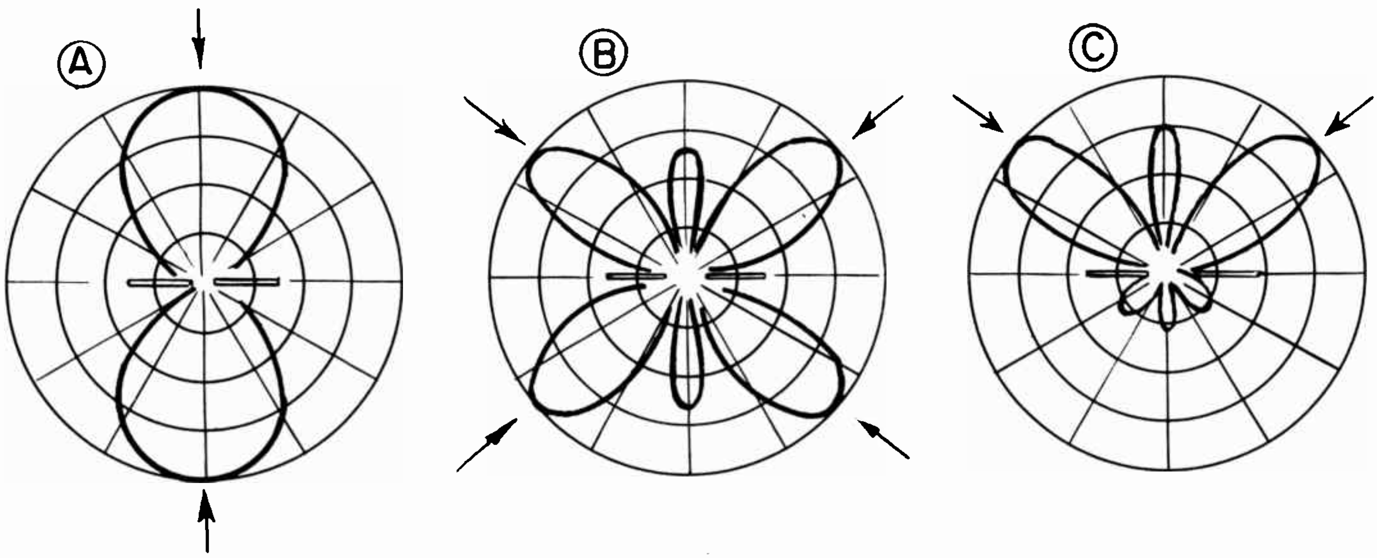

Fig. 4. Directional responses of a dipole to its fundamental and to a third harmonic frequency.

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up only from directions at right angles to the dipole conductors. Adding a reflector will eliminate much of the back response, as at C, but directions for best reception of high-band and low-band signals remain widely different.

Our next step is to incline the dipole conductors forward or toward the direction of desired signals, bringing their outer ends ahead of the gap at which is connected the transmission line. The divergent lobes of pattern C in Fig. 4 now come together, and for high-band reception we have a directional pattern about as shown at A of Fig. 5. The low-band directional pattern shown at B remains of practically the same form in a forward direction as that for the straight dipole.

Now we have an antenna of simple construction providing good response in both bands of the vhf range for signals coming from the same or nearly the same direction. The directional patterns do not remain exactly the same from channel to channel in either band, but do remain of essentially the forms shown by Fig. 5.

Varying the inclination of the dipole connectors toward each other will vary the width of the major front lobe for high-band reception, also will change the directions of the small black lobes. Bringing the forward lobes together, instead of leaving them separated as at C of Fig. 4, provides decided improvement in gain over that from either lobe alone.

A conical antenna is series resonant at a low-band frequency for which its conductors are cut, as shown by Fig. 3. When series resonant there is zero voltage and maximum signal current at the center, where the transmission line is connected. This type of antenna is series resonant also at the third harmonic frequency. But at a frequency for which dipole length is equal to one full wavelength, which would be the second harmonic, the antenna acts like a parallel resonant circuit, and at its center there is maximum voltage but zero or minimum signal current.

The simple conical antenna has impedance of approximately 150 ohms at the frequency for which it is series resonant. With transmission lines of either 300-ohm or 72-ohm impedance, mismatch is not great enough to cause serious loss of signal energy. There is so little change of antenna impedance with variations of frequency that the conical antenna is a broad band type.

The principle of bringing together the divergent lobes which appear with third harmonic operation is utilized also in constructions called V-antennas or V-beam antennas. The example illustrated by Fig. 6 is a double-V with all conductors in the same horizontal plane. High-band directional lobes which would diverge with a straight dipole are brought together, and maximum response in the entire vhf range is from a direction in line through the center of the V-angle.

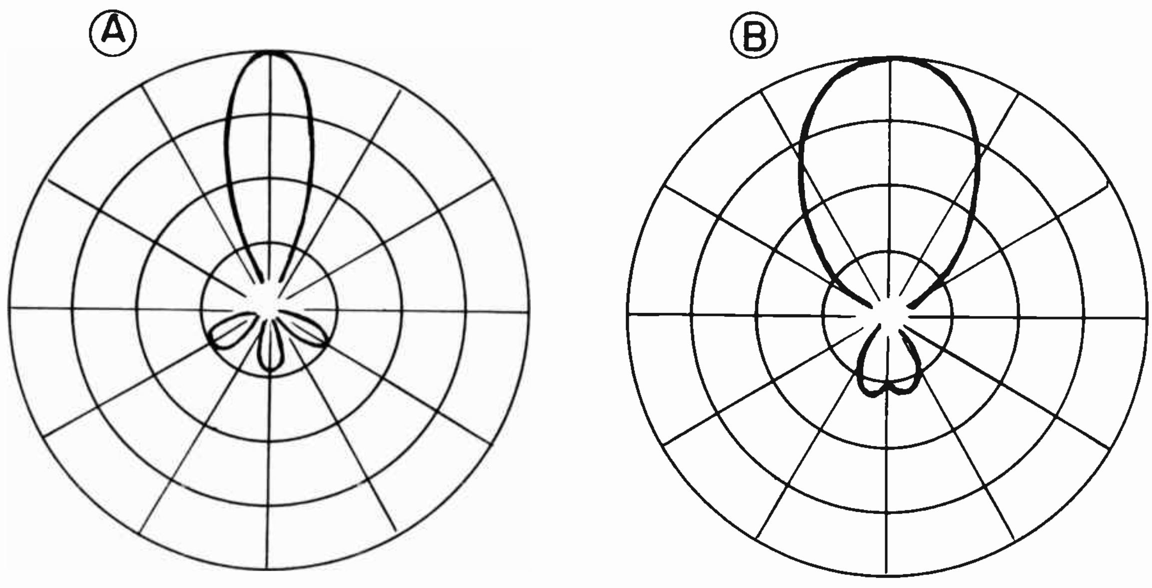

Fig. 5. Typical high-band and low-band directional patterns for a conical antenna.

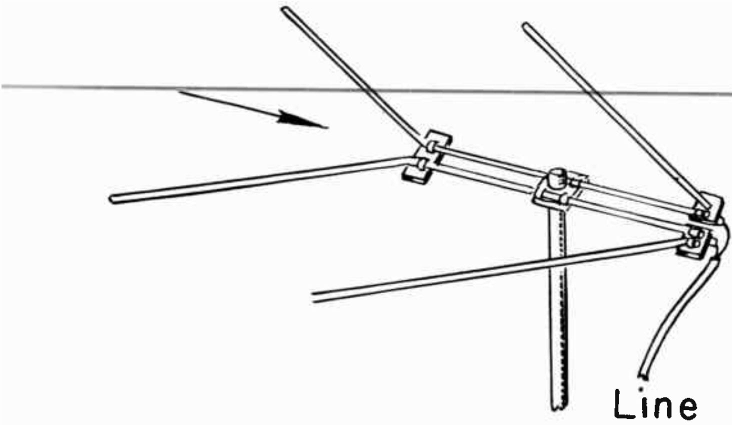

Fig. 6. A V-antenna operating on fundamental and harmonic frequencies.

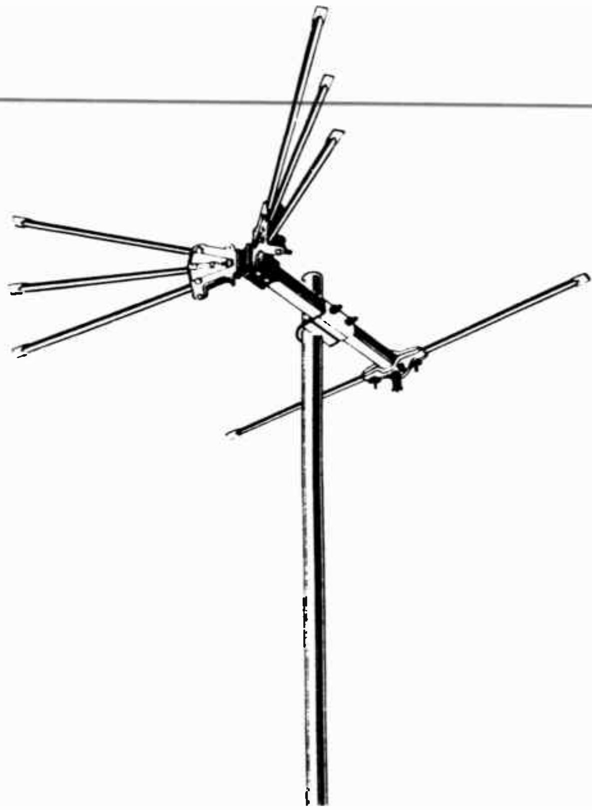

Fig. 7-A

STACKED ANTENNAS. When two or four antennas of the same type and dimensions are mounted one above another, suitably connected together and to a receiver transmission line, the antennas are said to be stacked. The purpose is to have greater gain and greater signal input to the receiver than could be had from one of the antennas.

At A of Fig. 7 is a single conical antenna with reflector. At B two similar antennas are stacked, with connections between them and to the transmission line such that carrier signal voltages combine at the input to the line. The two antennas should, in theory, pick up twice as much signal power as either alone. Then signal voltage from the two antennas would be 1.41 times that from one of them. This would be a voltage gain of 3 decibels.

It is possible to obtain a further theoretical gain of 3 decibels by using four sets of elements suitably connected, as at C. Then total gain should be 6 decibels more than gain of one set of elements used alone as an antenna. All these added gains are with reference to signal strength from a standard dipole cut for the channel on which comparisons are made.

Antennas of any type may be stacked. Each complete antenna, consisting of dipole, reflector, and directors if used, usually is called a bay when stacked. The entire combination of stacked antenna elements or bays is called the array. At B of Fig. 7 we have a two-bay stacked array, and at C a four-bay stacked array.

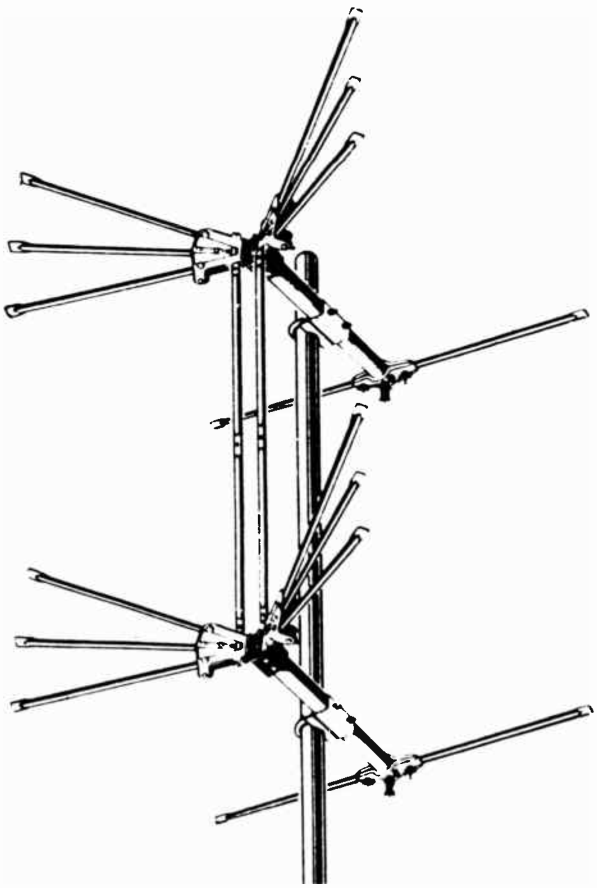

Fig. 7-B

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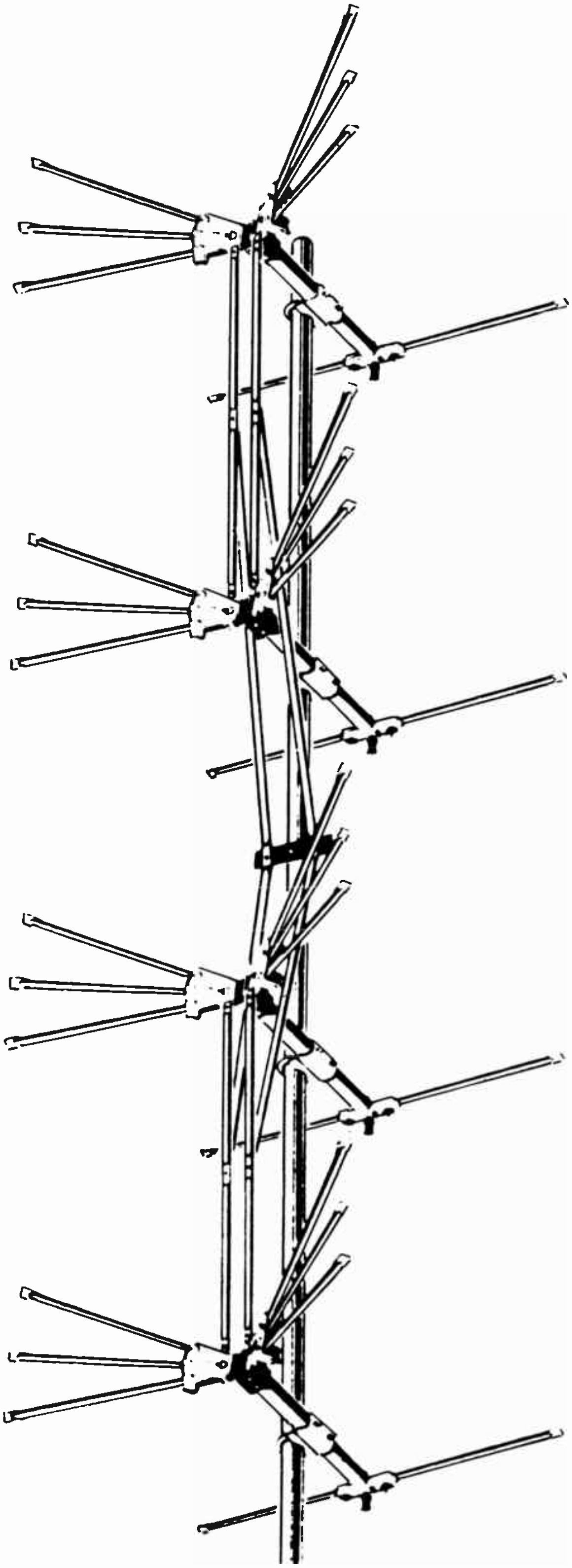

Fig. 7-C.

Fig. 7. Any type of antenna may be used alone, or stacked as two bays, or stacked as four bays.

If antennas of different types are mounted one above another and connected to the same transmission line the antennas are not said to be stacked. For instance, types which we have called two-band antennas mounted one above the other are simply two independent antennas, one for each band. Signal strengths from these two antennas do not combine to increase the gain in either band. In fact, we take precautions to prevent their signal voltages from combining.

Fairly typical actual gains of stacked antennas are shown by the curves of Fig. 8. The curves for one bay apply to a single group of elements, usually a dipole and reflector, used as a complete antenna. The other curves show gains when using two bays or four bays.

Although gains are not uniform throughout the frequency ranges, in the low-band channels the actual gain of two bays over one remains quite close to 3 decil ls, and gain with four bays is approximately 3 decibels more than with two. In the high-band channels there usually is more variation, and using four bays seldom adds 3 decibels to the gain of two bays.

Directional patterns of two-bay and four-bay stacked arrays are practically the same as patterns for single groups of similar elements. This, at least, is true for signals approaching the antenna along horizontal lines. But each bay of a stack acts somewhat like a shield for bays above or below, and greatly weakens interference fields or signal fields approaching from angles below or above the horizontal. This gives a stacked antenna the advantage, in addition to extra gain, of helping reduce effects of electrical interference which might be troublesome with a single antenna.

When using stacked arrays it is highly important to have proper connections between the bays and to the transmission line. Otherwise the signals from separate bays may partially cancel rather than combine their strengths. Connections from one bay to another are attached at the center gaps of the dipoles. These connections may be with pieces of transmission line or else with lengths of rigid tubing commonly called

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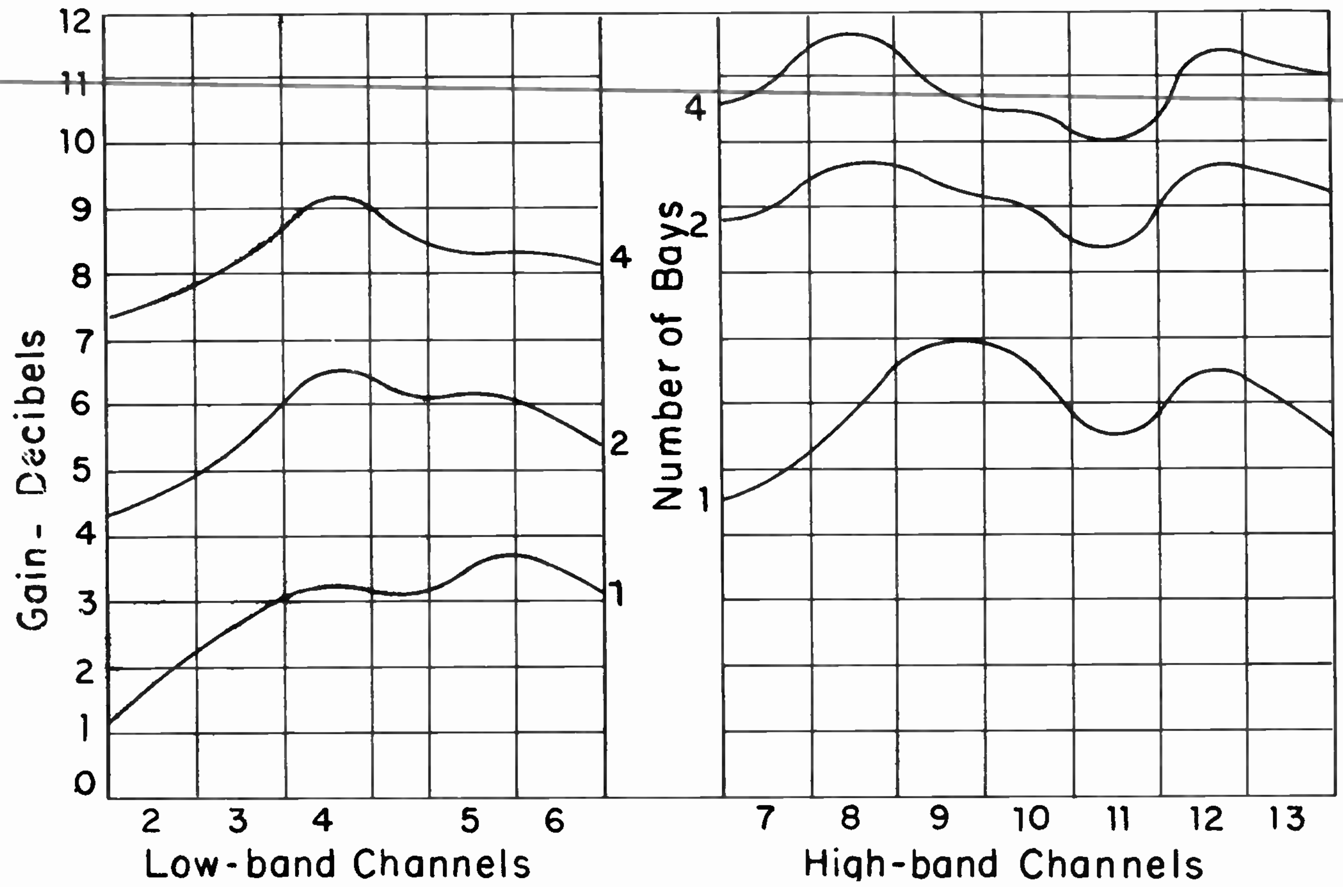

Fig. 8. Typical gains of a single antenna and of two-bay and four-bay stacked arrays employing the same elements for each bay.

stacking bars. The receiver transmission line sometimes is connected to the center gap of one dipole, but more often to the stacking bars or link at a point between the bays.

Vertical spacing between bays often is a quarter-wavelength as measured at the middle of the low band, or may be somewhat greater. This is equivalent approximately to half-wave spacing as measured at the middle of the vhf range (for an antenna operating in both hands) and is more than half-wave spacing measured at the middle of the high band. In general, gain increases with more spacing, as measured in wavelengths or fractions. Therefore, the relatively greater wavelength spacing for high-band operation helps to give the greater gain which is so desirable in this band.

Where two bays are connected together with side-by-side stacking bars, as at the left in Fig. 9, the receiver transmission line connects to the two bars at points midway between the bays. Where the transmission line is connected to either one bay or the other, as at the right, the interconnections between bays are transposed. Since rigid bars or tubes are rather difficult to transpose, this kind of connection often is made with flexible transmission line.

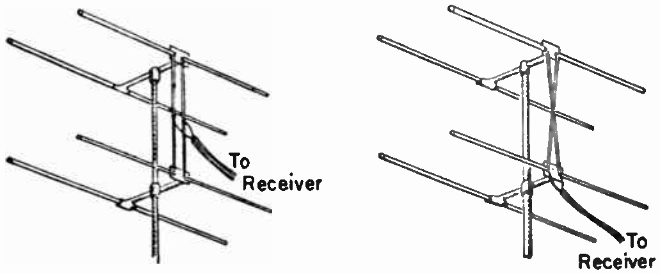

Fig. 9. Transmission line connections for two-bay stacked antennas.

The same principles are employed for connection of transmission lines to four-bay stacked arrays, as in Fig. 10. At the left are stacking bars with center takeoffs between the two bays at the top, and again between the two bays at the bottom of the array.

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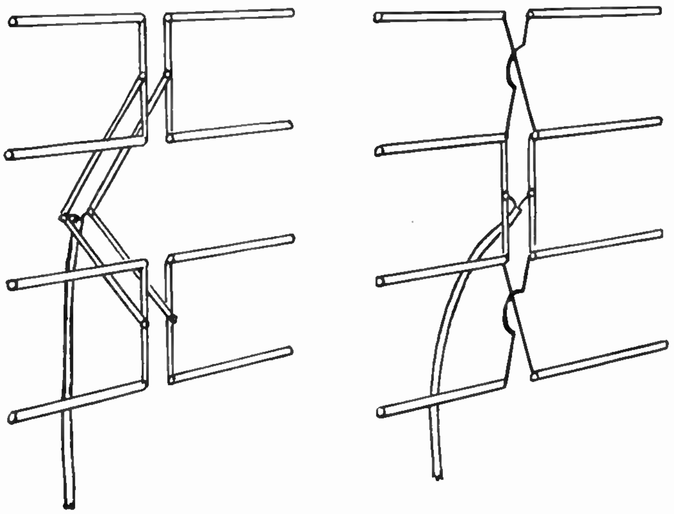

Fig. 10. Phasing connections for four-bay stacked arrays.

These center takeoffs are connected together through additional bars, or might be similarly connected with a piece of transmission line. To the center of this connection between pairs of bays is attached the receiver transmission line.

In the right-hand diagram the pairs of bays at top and bottom of the array are connected together through transposed sections of line, because the takeoffs are from the lower element of the top pair of bays, and from the upper element of the bottom pair of bays. These takeoff points are electrically equivalent to the connection in the right-hand diagram of Fig. 9. Takeoffs for the top and bottom pairs of bays are connected together by stacking bars, which might be replaced by a section of flexible line, and at the center of this interconnection is attached the receiver transmission line.

Impedance relations in stacked arrays become rather involved at times. To begin with, a connection as at the left in Fig. 9 places impedances of the bays in parallel, and at the transmission line takeoff the antenna impedance is half that of either bay alone. For example, two 600-ohm bays would present 300-ohm impedance at the center takeoff.

With a connection as at the right in Fig. 9, impedance at the line takeoff is essentially the same as that of either bay alone, although being somewhat less because the second bay is present. All these impedance relations hold true at resonant frequencies for which vertical separation between bays is a half-wavelength. For other frequencies, and correspondingly different spacings measured in wavelength, the impedances would vary.

Where there are four bays stacked as upper and lower pairs (Fig. 10) impedances at transmission line takeoffs conform to rules mentioned in the preceding paragraph. Then, so far as the transmission line connection is concerned, the pairs of bays are in parallel, and impedance presented to the line is half that of either pair of bays considered alone.

Connections between stacked bays and the transmission line sometimes are made of such lengths as to form quarter-wave impedance matching transformers. Lengths of such matching sections, in inches, are determined in the same manner as lengths of quarter-wave matching transformers used on single non-stacked antennas. This requires allowing for velocity constant of the type of line used for the quarter-wave matching section, or for the velocity constant of air-insulated conductors when rigid tubing is employed. Impedance required for each matching section is computed from this formula.

$$\text{Matching impedance} = \sqrt{\begin{matrix}\text{impedance of bay} \\ \text{or pair of bays}\end{matrix} \times \begin{matrix}\text{impedance} \\ \text{of line}\end{matrix}}$$

Impedances of the bays or of pairs of bays will depend on their type and construction, on what parasitic elements are used and how these elements are spaced, and on the points at which connections are made as explained in connection with Figs. 9 and 10.

If vertical separation between bays, or between takeoffs from pairs of bays, is a half-wavelength at some selected frequency, the two quarter-wave matching transformers may be straight bars or tubes. This is because total length of two quarter-wave sections will just equal the half-wave total separation. If, however, vertical separation between bays or pairs of bays is less than a half-wavelength, the total length of two matching sections will be greater than the separation. Then the matching sections must

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extend at such angles as allow for their extra length. Such an allowance for length might be made as at the left in Fig. 10.

Quarter-wave matching transformers used as connections improve gain at the frequency for which electrical length of these sections equals a quarter-wavelength. Bandwidth is narrowed at the same time, because the sections are effective only at one frequency. If interconnections between stacked elements are of lengths which do not form quarter-wave matching transformers at any received carrier frequency, bandwidth for a given gain will be broader than for similar antenna elements used as a single antenna. That is, ordinary stacking tends to increase bandwidth.

RESONANT LINES

While talking about antennas it was mentioned that a "stub", made from a piece of transmission line, might be used to correct a poor impedance match at the receiver. It was mentioned also that a stub would prevent high-frequency signals picked up on a low-frequency dipole from mixing with signals picked up on a high-frequency dipole connected to the same transmission line.

Although these stubs are made from pieces of transmission line, they do not act as transmission lines, because they transmit no signal power. Instead they are resonant lines or linear circuits (line circuits) which have all the characteristics of circuits made with coils and fixed or variable capacitors. Because linear circuits have so many applications at very-high and ultra-high frequencies they deserve careful study.

As we go higher in the ranges of television frequencies, Q-factors of circuits made with ordinary coils and capacitors go down, and these elements waste more and more signal energy from circuits in which they are connected. At the higher frequencies in the vhf range, and all through the uhf range, Q-factors of correctly constructed resonant lines or linear circuits are much higher, and energy losses much lower, than in otherwise equivalent coil-capacitor circuits.

Linear circuits will provide either parallel resonance or series resonance wherever needed. At frequencies more or less off resonance the linear circuits will provide various amounts of either inductive or capacitive reactance, which may be added to tuned circuits of any kind.

First we shall examine the peculiar behavior of linear circuits operating at resonant frequencies, which makes them resonant lines. It will be convenient to experiment with the familiar 300-ohm ribbon type transmission line, and to commence operations at a frequency of 100 mc. Earlier we learned how to determine the inches of line giving electrical length equal to a half-wavelength at any frequency, by dividing the number of megacycles into 5905, then multiplying the quotient by the velocity constant.

Dividing our proposed frequency of 100 mc into 5905 gives 59.05. Multiplying by the velocity constant of 300-ohm ribbon line, which is 0.82, gives 48.42 inches as the resonant length.

At A of Fig. 11 the piece of line is connected to a source of alternating voltage, such as a signal generator, with a current meter in series. The far end of the line is open, its conductors are not connected together or to anything else. With the source adjusted first to a frequency considerably higher than 100 mc there will be moderate flow of current into the line. Alternating current can flow into the line, and pass from one conductor to the other through capacitance between the conductors.

If frequency is gradually decreased, current will continue at about the same rate until we approach 100 mc, whereupon the meter will show a sharp drop of current. There will be minimum current at 100 mc. As frequency is made still lower, current will rise to about its original rate.

The piece of transmission line is a parallel resonant circuit tuned for 100 mc. A parallel resonant circuit has maximum impedance at resonance. This is why current into the piece of line drops to minimum at 100 mc. The line is resonant at 100 mc.

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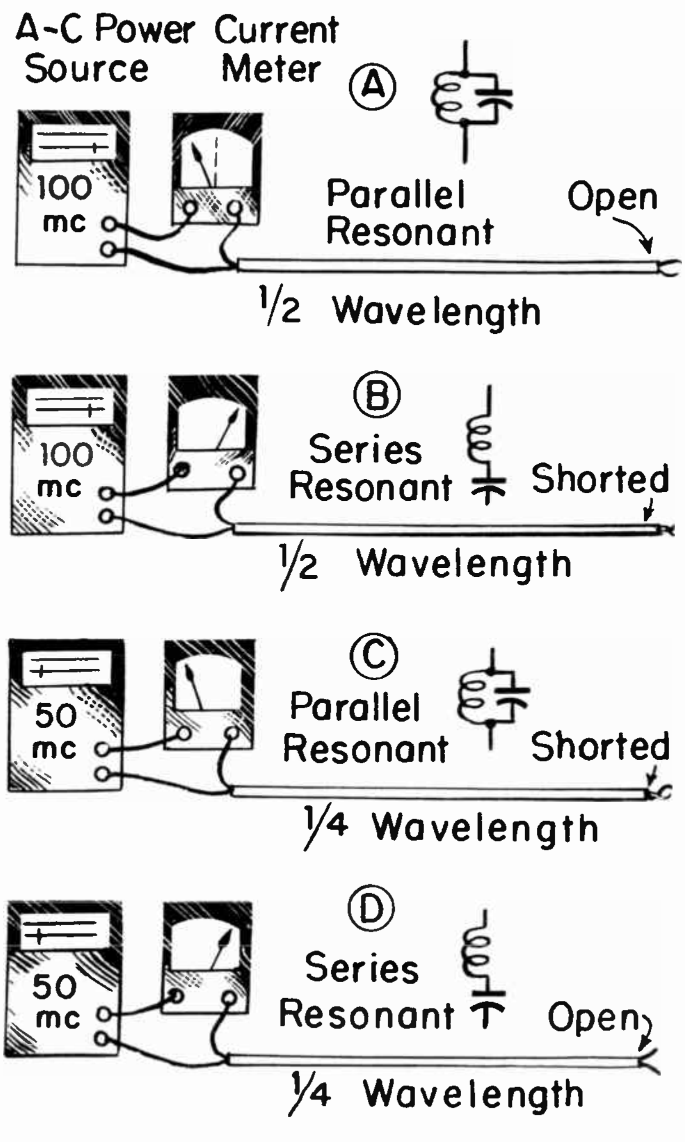

Fig. 11. Behavior of a piece of transmission line when it becomes a resonant line.

because its electrical length equals a half-wavelength at 100 mc.

Next, as in diagram B, we short the conductors on each other at the far end of the line, while holding applied frequency at 100 mc. Current increases to relatively high value. This we might expect, for it would be natural to have large current with a short circuit. But if frequency is raised above 100 mc, current decreases. If frequency is made less than 100 mc, current decreases. There is maximum current only at a frequency of 100 mc, in spite of the fact that the far end of the line remains shorted for all frequencies. Now the line is a series resonant circuit, in which there is minimum impedance and maximum current at resonance. The electrical length of the line still is a half-wavelength at 100 mc.

Now we shall keep the far end of the line shorted while, as in diagram C, dropping the applied frequency to 50 mc. Right at 50 mc there will be a sharp drop of current, just as in diagram A with frequency at 100 mc. At frequencies either above or below 50 mc, current will be greater than at 50 mc. The piece of line again is a parallel resonant circuit, tuned for 50 mc instead of the former 100 mc.

In diagram A, with frequency of 100 mc, electrical length of the line is a half-wavelength, and at B with frequency of 50 mc the electrical length is a quarter-wavelength. The wavelength changes because frequency changes, not because of any change of line length as measured in inches. At A a half-wave open line is a parallel resonant circuit. At C a quarter-wave shorted line is a parallel resonant circuit.

Finally, as in diagram D, we shall open the far end of the line while keeping applied frequency at 50 mc. Current now rises to a peak, as it did in diagram B. At frequencies either lower or higher than 50 mc, current will be less than at 50 mc. At this frequency, with the far end open, the line is a series resonant circuit. Electrical length of the line at this frequency is a quarter-wavelength.

The accompanying table summarizes the behavior of the piece of transmission line, as observed in Fig. 11.

LINEAR CIRCUITS AT RESONANCE

Electrical Length of Line	Condition At Far End Of Line	
	Open	Shorted
Half-wave	Parallel resonant	Series resonant
Quarter-wave	Series resonant	Parallel resonant

It will help in future investigations of very-high and ultra-high frequency circuits to know why the resonant line behaves as it does. Let's commence with Fig. 12, where

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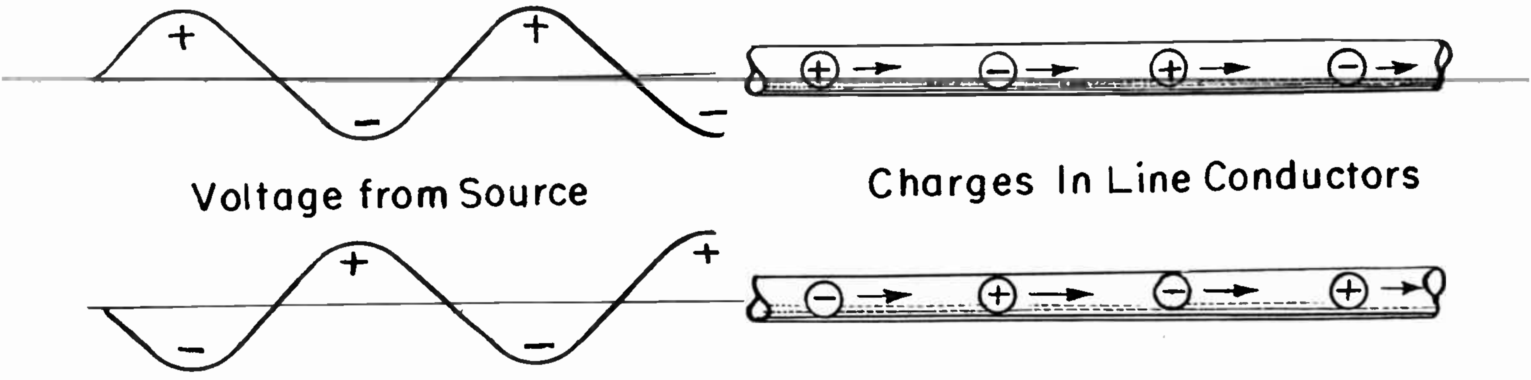

Fig. 12. Alternating voltage from a source causes charges to flow in line conductors.

alternating voltage from a source is represented at the left. As we learned long ago, voltages occurring simultaneously at opposite terminals of an a-c source are of opposite polarity or opposite phase.

These voltages cause in the line conductors charges which move at a speed proportional to velocity constant of the line. The negative charges are concentrations of electrons. Positive charges are merely points at which there are minimum quantities of electrons, midway between the negative charges. Neither kind of charge is so sharply defined in the conductors as in the diagram, but it makes for easier understanding to show them this way. Since the same action occurs in both conductors, we may consider either one alone in the following explanation.

In Fig. 13 we have one conductor of a line whose electrical length is one wavelength at the frequency being applied, whatever that may be. At 1 a charge starts from the left-hand end of the conductor. After a time corresponding to a half-wavelength this charge reaches the middle of the conductor, as at 2. After a time corresponding to a full wavelength the charge reaches the right-hand end of the line, as at 3.

The right-hand end of the line is open. The charge is reflected, and starts back in the opposite direction. In the brief instant when this charge stops moving, at the open end of the line, there is no current. There is no current at the open end of the line because current means moving electrons, and electrons in the charge have stopped.

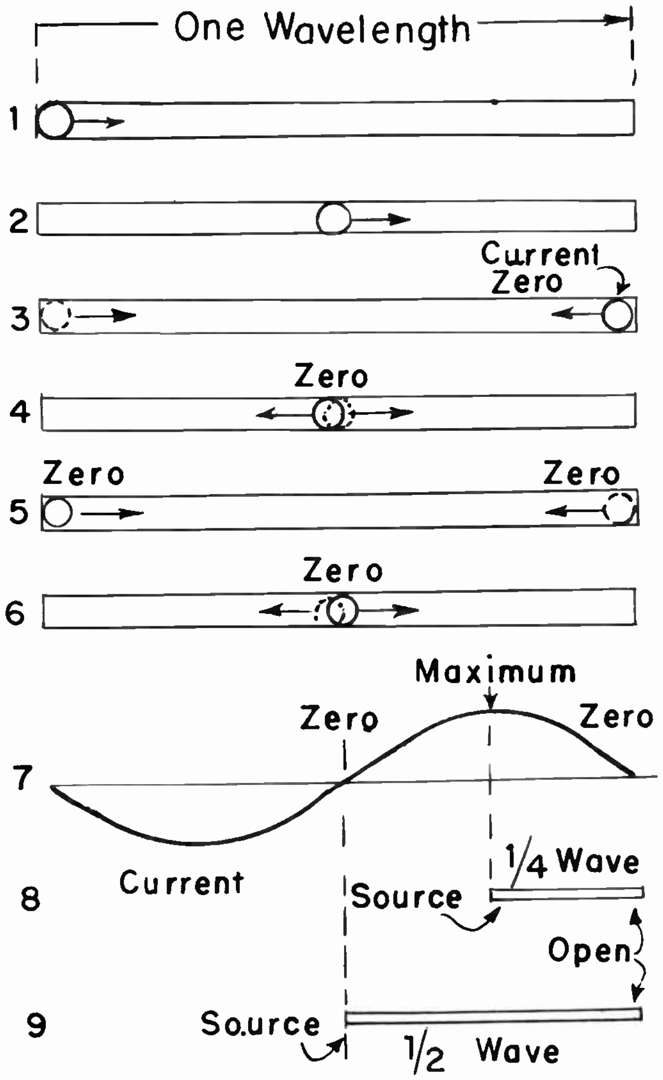

Fig. 13. Points of zero and maximum current along a line conductor in which there is reflection of charges.

At the instant in which the first charge is being reflected from the open end of the line another similar charge starts from the source at the left-hand end. This second

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charge is represented by a broken-line circle. At 4 the two charges, going opposite directions, meet at the center of the line. Each charge, which consists of moving electrons, is a current. The equal currents in opposite directions balance their effects, and at the center of the line we have what amounts to zero current.

Then the charges continue in opposite directions until, as at 5, they reach opposite ends of the line. Again there is reflection at the open end of the line. At the other end the returning charge disappears in a new charge produced by the source. Once more, as at 6, the charges meet at the middle of the line, and so the action continues.

Because moving charges or moving electrons constitute electric current, we may show at 7 the points along the line at which current always is zero, and points in between at which current always must be maximum.

Supposing, as at 8, we connect the source to a portion of the line a quarter-wavelength long. Still there must be zero current at the open end of the line, but current at the source must be maximum. This is the condition observed at D of Fig. 11, where there is a quarter-wave open line, maximum current from the source into the line, and where the line is a series resonant circuit.

Now look at Fig. 14. On the open-line conductor at M is shown the same current distribution as at 7 of Fig. 13, with zero current at the open end. Imagine that this open point is not at the end of a resonant line, but is in any ordinary electric circuit connected to a source of voltage. Current at any open circuit must be zero. Then what will be voltage at the open point? As you well know, voltage at any open circuit is equal to maximum voltage applied by the source. Then at the open end of the resonant line there must be maximum voltage, and voltage distribution along the open line may be shown as at N of Fig. 14. At the open end of this resonant line there is maximum voltage and minimum or zero current.

Were the source moved to point a, leaving the line only a quarter-wavelength long from source to open end, there would be

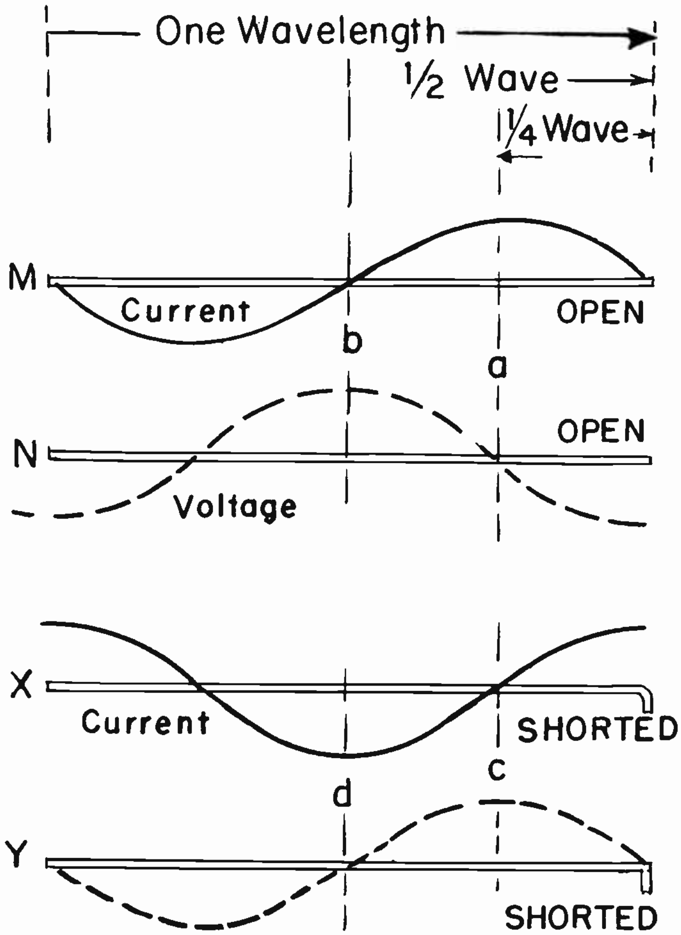

Fig. 14. Current and voltage distributions in open and shorted lines wherein reflections occur.

maximum current and zero voltage at the source end of this quarter-wave open line. This is the condition observed at D of Fig. 11, where the quarter-wave open line is a series resonant circuit.

Were the source moved to b, making the open line a half-wavelength long, there would be zero current and maximum voltage at the source end of this half-wave open line. This is the condition observed at A of Fig. 11, where the half-wave open line is a parallel resonant circuit.

At X of Fig. 14 is represented one conductor of a shorted resonant line. At the right-hand shorted end there must be maximum current, because at any short in any kind of circuit there always is maximum current. What is the voltage across this short circuit? Voltage is zero, of course. So, at Y, we must show zero voltage at the shorted end of the conductor.

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Supposing we have the source at c on the conductor represented at X and Y of Fig. 14, with the line a quarter-wavelength long from source to shorted end. At the source there will be minimum or zero current, but maximum voltage. This is the condition observed at C of Fig. 11, where the quarter-wave shorted line is a parallel resonant circuit.

If the source were at d of Fig. 14, with the line a half-wavelength long from source to shorted end, there would be maximum current and zero or minimum voltage at the source. This is the condition observed at B of Fig. 11, where the half-wave shorted line is a series resonant circuit.

STANDING WAVES. In Figs. 13 and 14 there are certain points along the line conductors at which current always is zero, and other intermediate points at which current always is maximum. There are zero and maximum points also for voltage which accompanies the current. Although the electric charges are in continual back and forth motion in the line conductors, the points of minimum and maximum current and voltage remain stationary.

When representing points of minimum and maximum current or voltage by means of curves, as in Fig. 14, the curves would remain in fixed positions on the conductors. If we think of these curves as waves, the waves stand still. Points of minimum or maximum current or voltage also stand still. These points form what are called standing waves.

Standing waves exist on any conductor when its length, the applied frequency, and conditions at the end of the line are such as to allow reflections. When a single isolated conductor carries standing waves, r-f energy is radiated from that conductor into space. The portion of the energy radiated cannot, of course, be delivered to a load.

If the conductor capable of supporting standing waves has along side another conductor connected to the other side of the same source, standing waves on these two conductors would be of opposite phase at equal distances from the source. You can see the reason in Fig. 12. Then fields due to standing waves cancel; there are no standing waves and no radiation of energy. This would be true at frequencies for which the conductor length is a half-wavelength or some simple multiple of a half-wavelength. The side-by-side conductors would be a transmission line.

If a transmission line is connected to a load whose resistance or resonant impedance is equal to characteristic impedance of the line there can be no reflections and no standing waves. Energy is not radiated, all of it passes into the load. This is why correct matching of impedances is so desirable.

TUNING THE LINE. In Fig. 11 the frequency of a source is varied to cause resonance in a two-conductor line of fixed length. Instead of varying frequency to suit the line, we may vary the length of line and make it resonant at any frequency. Resonant frequency of a two-conductor line depends on the three factors of capacitance, inductance, and length of line as corrected for the velocity constant.

All lines have certain values of capacitance and inductance per foot of length. If you reduce the length to half, there remains half the original inductance and half the original capacitance. Any formula for resonant frequencies will show that half the inductance and half the capacitance means twice the resonant frequency, also that doubling both inductance and capacitance will halve the resonant frequency. This means that frequency of resonance is inversely proportional to length of a two-conductor line.

Fig. 15 shows lengths in inches of half-wave and quarter-wave lines which are resonant at various frequencies when made with 300-ohm ribbon transmission line having velocity constant of 0.82. If a quarter-wave line is shorted at the far end, it is a parallel resonant circuit at frequencies shown on the graph, and if open at the far end the quarter-wave line is a series resonant circuit at the same frequencies. A shorter half-wave line is series resonant at the frequencies shown, and an open half-wave line is parallel resonant at the same frequencies.

Supposing we want a quarter-wave line which is resonant at 100 mc. The graph

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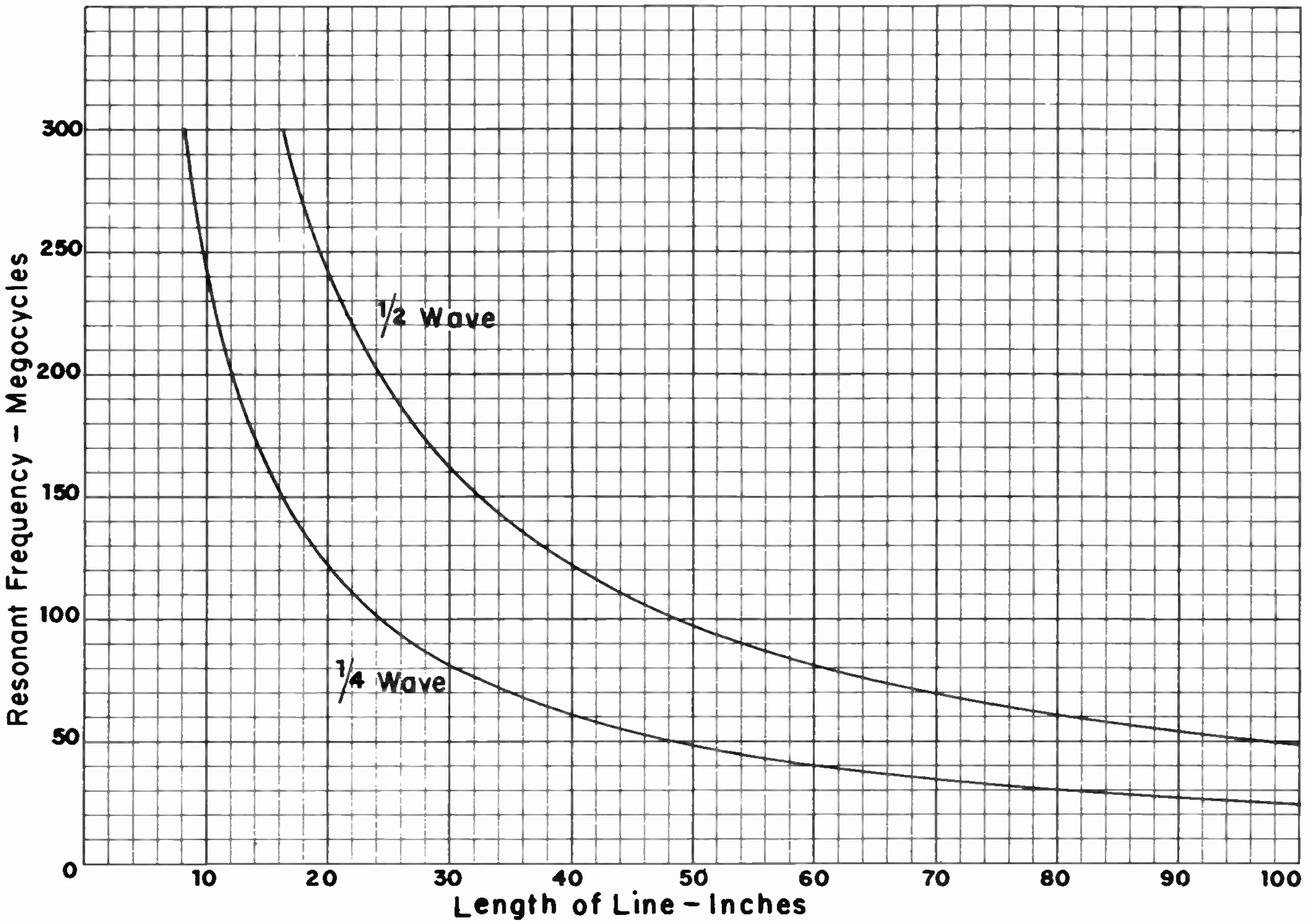

Fig. 15. Resonant frequencies of quarter-wave and half-wave linear circuits made of 300-ohm ribbon transmission line cut to various lengths.

shows that this line must be a little more than 24 inches long. For double the frequency, or for 200 mc, the quarter-wave line need be only a trifle more than 12 inches long. For half the original frequency, or for 50 mc, the quarter-wave line must be somewhat more than 48 inches long. All this applies to 300-ohm ribbon line.

The line might be tuned or made resonant at any frequency by making it of suitable length. A half-wave line resonant at a given frequency must be twice as long as a quarter-wave line resonant at the same frequency. You may check these relations anywhere on Fig. 15. Conversely, a quarter-wave line must be half as long as a half-wave line for resonance at the same frequency. Whether a line is parallel resonant or series resonant depends on whether the far end is open or shorted, as well as on the length.

Note how short the lines become, in inches, as frequency goes up. In the uhf range of 470 to 890 mc, half-wave lines made of 300-ohm ribbon transmission line would be only about 10.3 to 5.4 inches long, and quarter-wave lines would be approximately 5.2 to 2.7 inches long. Probably we would not use 300-ohm ribbon transmission line for uhf tuning, but even air insulated lines would be only about 20 per cent longer.

Going the other way in frequency, note how rapidly the line length increases. A quarter-wave line resonant at the standard broadcast frequency of 1,000 kc or 1 mc would be more than 40 feet long. This explains why resonant lines are not used at the lower frequencies, they would be highly efficient, but too bulky.

To mention, even briefly, all the uses for resonant lines at high frequencies would take

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much space. Many important uses appear in lessons dealing with ultra-high frequency reception. For the present we shall examine one important use in the vhf range, how pieces of transmission line may be used for interference traps.

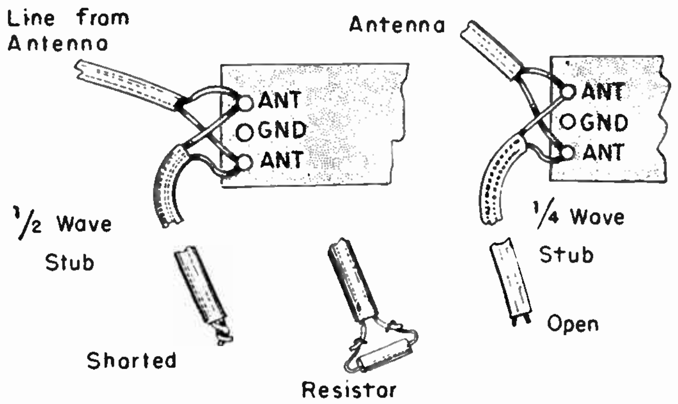

Fig. 16. Interference traps made with a half-wave shorted stub and with a quarter-wave open stub.

STUBS AS INTERFERENCE TRAPS. A piece of transmission line used as an interference trap usually is called a stub. It is connected to the antenna terminals of the receiver as in Fig. 16, without any change in connections of the transmission line coming from the antenna. Since the purpose of the stub is to short circuit the interference frequency, we use either a half-wave shorted line as at the left, or else a quarter-wave open line as at the right. Both of these types are series resonant and provide minimum impedance at an interference frequency for which they are cut.

The stub may be made from any type of transmission line, regardless of input impedance of the receiver or characteristic impedance of the transmission line from the antenna. Usually it is convenient to make all stubs from 300-ohm ribbon line.

The approximate length of the stub is determined from Fig. 15, in accordance with the interference frequency. For example, if interference is from an f-m broadcast station its frequency will be between 88 and 108 mc. A quarter-wave open stub then would be something between 28 and 22 inches long, while a half-wave shorted stub would be twice as long. Always commence with a piece of line at least one-fourth longer than the length determined from Fig. 15.

To arrive at the exact length of a shorted stub, press a razor blade through the insulation of the stub to make contact with both conductors. Keeping your fingers on the blade makes no difference. Commencing at the far end, try shorting the stub at points separated by 1/8 to 1/4 inch until finding the point at which interference becomes least apparent with the receiver in operation. Cut off the stub and bare its conductors so that, when the conductors are soldered together, this permanent short will be at the same point as was the razor blade short for best results.

To arrive at the exact length for an open stub, commence at the far end and use cutting pliers to clip off successive pieces about 1/8-inch long, until interference becomes minimum. To make sure of the length for minimum interference it usually is necessary to continue the clipping until interference returns, then cut a new stub of the length which gave maximum reduction of interference.

When mounting a stub, keep it as far as possible from the chassis and from all other metal, also away from the regular transmission line. It is desirable to let the stub extend in an approximately straight line, but long stubs for low frequencies may be coiled if you make proper allowance for the effects of coiling.

Coiling any stub decreases its effective capacitance, while increasing its effective inductance. These changes, unfortunately, are not in such proportions as to maintain the resonant frequency of a straight stub of the same overall length. Coiling a quarter-wave open stub will decrease the resonant frequency by as much as 5 per cent, or maybe more. Then a little more of the stub must be cut off to bring resonance back to the original frequency.

Coiling a half-wave shorted stub increases the resonant frequency, often as much as 20 to 30 per cent. This means that final length of a coiled shorted stub must be quite a bit greater than that of a straight

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stub for the same resonant frequency. Any coiled stub reduces interference over a somewhat broader band of frequencies than does a straight stub, but does not provide quite as much attenuation of interference as does a straight stub.

Sometimes you encounter interference from a high-band channel when receiving a low-band channel. Then the stub must be cut for the frequency of the high-band channel. When you tune the receiver to that high-band channel, the stub will cause poor reception or no reception, because it shorts the frequency of the high-band channel.

It may be possible to receive the high-band channel by using a non-inductive carbon resistor instead of a direct short at the far end of a half-wave stub, as illustrated at the center of Fig. 16. Commence with resistance of about 150 ohms. If this does not satisfactorily reduce interference on the low-band channel, try less resistance. Use the greatest resistance that sufficiently reduces interference. Then, if reception is not satisfactory on the high-band channel, it will be necessary to connect the stub to the antenna terminals of the receiver through a two-pole single-throw switch. Open the switch to disconnect the stub for reception on the high-band channel, and close the switch to reduce interference on the low-band channel.

After fitting any interference stub, be sure to check reception on all active channels. Under some conditions the stub may affect harmonics of the frequency for which it is cut. A stub for attenuating interference at some relatively low frequency may attenuate also a harmonic frequency which lies in a channel to be received. This would be another case requiring switching of the stub.

OFF-RESONANCE EFFECTS. Now let's return to the subject of linear circuits in general, and ask what happens when a line resonant at some certain frequency has applied to it a frequency either lower or higher than that of resonance? If you remember what happens with circuits composed of coils and capacitors, under similar circumstances, that is the answer. Coil-capacitor circuits provide either an excess of capacitive reactance or else an excess of inductance reactance at frequencies off resonance. Linear circuits behave the same way. Here is a summary.

LINEAR CIRCUITS, OFF RESONANCE

Kind Of Circuit	When Applied Frequency Is Lower Than Resonant	When Applied Frequency Is Higher Than Resonant
Series Resonant. Shorted 1/2-wave or open 1/4 wave	Capacitive reactance	Inductive reactance
Parallel Resonant. Open 1/2-wave or shorted 1/4-wave	Inductive reactance	Capacitive reactance

What this means may be illustrated by an example. Supposing that you have a shorted half-wave line which is resonant at 100 mc, and apply voltage at 80 mc, how will the line act? Such a line is series resonant at 100 mc. The applied frequency of 80 mc is lower than for resonance. The table shows the result of this combination is "capacitive reactance". This means that the linear circuit will have capacitive reactance in excess of its inductive reactance, and will act as though it were a capacitor. It is possible to determine similarly the kind of reactance furnished by any type of line when applied frequency is below or above resonance.

ADDING HALF-WAVELENGTHS TO A LINE. At the top of Fig. 17, over at the right, are the same curves shown at M and N of Fig. 14, but here both curves are on the same zero axis. When there is a half-wavelength between the source and the end of the line, current at the source is zero and voltage is maximum. Supposing we move the source back to a, by adding a half-wavelength to the line. Current at the source again would be zero, and voltage maximum. With the source moved to b, making the line 1½ wavelengths long, current and voltage at the source still would be the same. With the source at c, and the line 2 wavelengths long, there still would be zero current and maximum voltage at the source. No matter how many half-wavelengths you add to a line, the source always sees the same relations of current and voltage.

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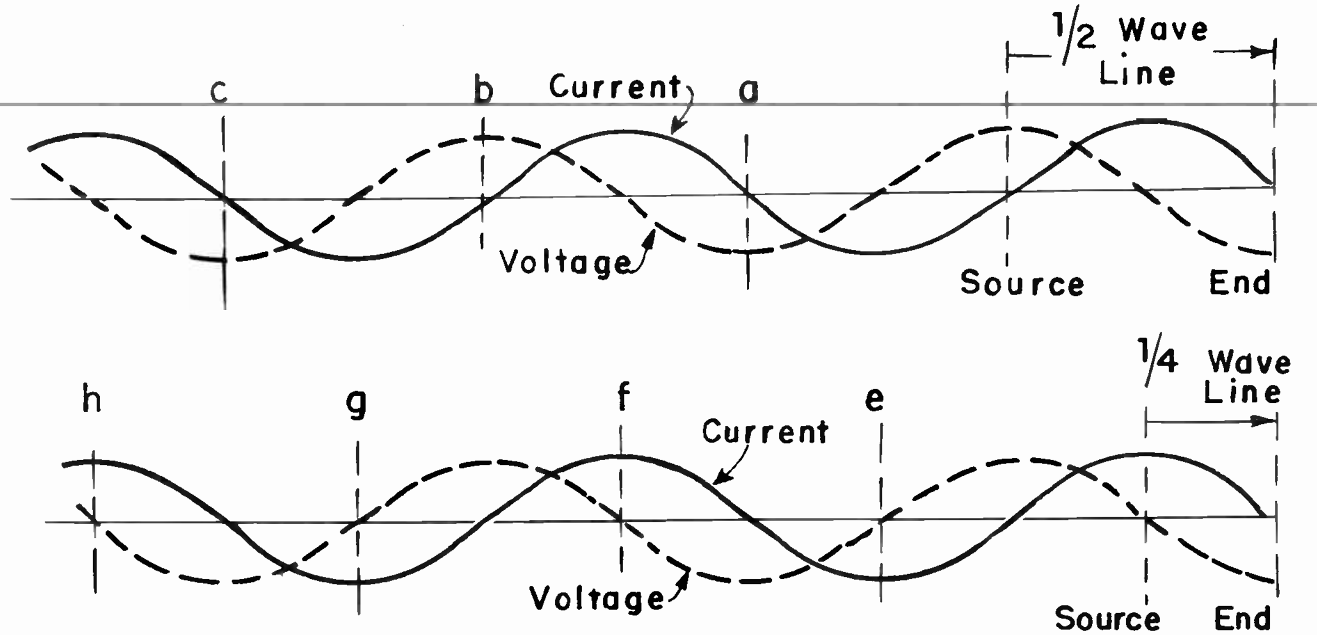

Fig. 17. Addition of any number of half-wavelengths to a line does not change relations of current and voltage as seen by the source.

At the bottom of Fig. 17 we commence, at the right, with a quarter-wave open line. The source sees maximum current and zero voltage. Adding a half-wavelength to the quarter-wave line, and placing the source at e, makes no difference. We still have maximum current and minimum voltage at the source with a line 3/4 wavelength long. Adding more half-wavelengths, and placing the source successively at f, g, and h, always allows the source to see maximum current and zero voltage.

Any number of half-wavelengths may be added to any line, and the source always will see the same relations between current and voltage. Whether the far end of the line is open, shorted, or connected to some impedance or load, adding half-wavelengths to the line will make no change in what the source sees. The trouble is, a half-wavelength as measured in inches varies with every change of frequency, and a line equal to some number of half-waves at one frequency will be of other fractional wavelengths at other frequencies.

Here is something important about lengths of shorted lines. Any or all of the conductors beyond a short may be left in place or removed with no effect on performance. This makes it easy to tune a shorted line simply by varying the position of the short, without changing the actual length of line measured in inches. An open line is not so easy to tune, because the open point must be at the end of the line. The only way to tune an open line is to cut off a portion. If tuning turns out to be wrong, you have to commence all over again with a new piece of line.

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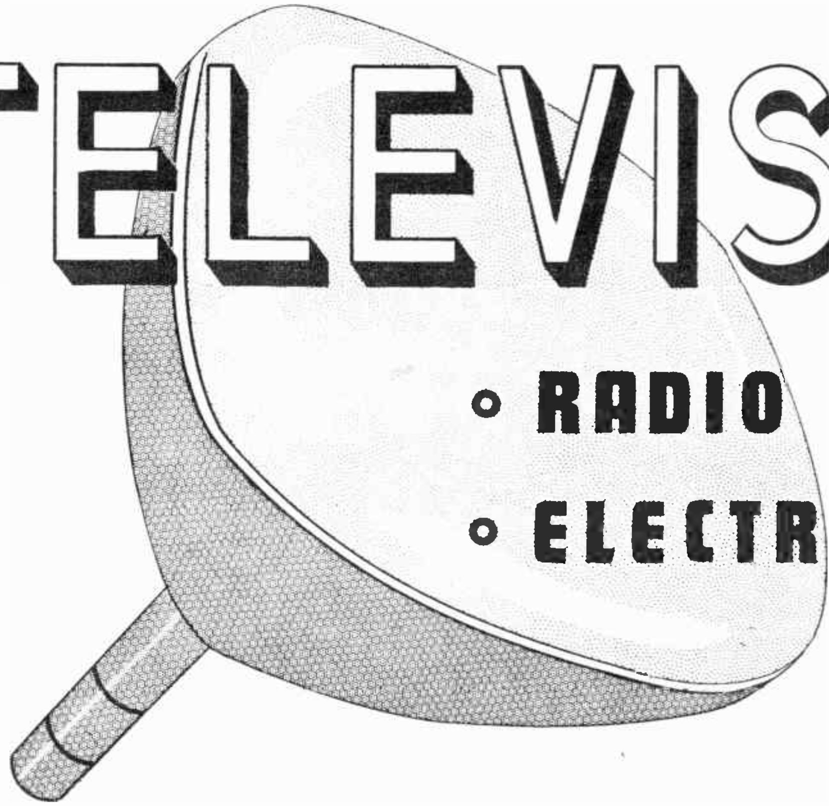

• RADIO
• ELECTRONICS

LESSON 92 — ULTRA-HIGH FREQUENCY RECEPTION — PART ONE

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Lesson 92

ULTRA-HIGH FREQUENCY RECEPTION — PART ONE

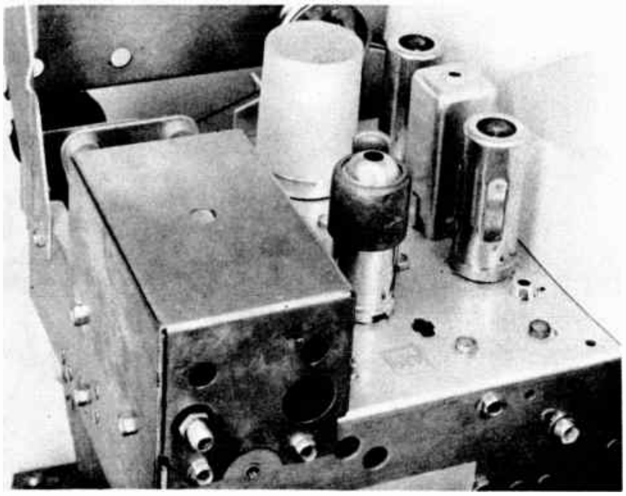

Fig. 1. Antenna and mixer tuning mechanism is within the box-like shield at the left. Oscillator and i-f amplifiers are on top of the main chassis.

In the ultra-high frequency television band, which extends from 470 mc to 890 mc, there are 70 channels of 6 mc each. These channels are numbered from 14 to 83. The accompanying table lists the frequency range of each channel, also the video carrier and sound carrier frequencies.

Except for their higher carrier frequencies, uhf signals are exactly like those in the vhf bands. The video carrier is 1.25 mc above the low limit in each channel. The sound carrier is 4.5 mc higher than the video carrier, and 0.25 mc below the upper limit of each channel. Picture signals, sync pulses, blanking, and the various amplitude levels are of the same forms for ultra-high as for very-high frequency transmission and reception.

Differences between receiving systems which handle only vhf signals and those which handle both uhf and vhf signals are entirely in tuner circuits, between the antenna and the i-f amplifier section of the receiver. In a system for reception of both uhf and vhf signals there must be, in the tuning circuits, one section or one group of elements which operate on uhf carrier and oscillator frequencies, and another section or group of elements which operate on vhf carrier and oscillator frequencies. Both sections feed eventually into the i-f amplifier of the receiver. This i-f amplifier and everything beyond it, all the way to picture tube and speaker, is unchanged no matter what carrier-frequency band is being received.

All uhf tuners or tuner sections employ the same superheterodyne principles as found in vhf tuners with which we are familiar. Connected to the uhf antenna are tuning circuits which select uhf carrier frequencies of the channel to be received. These selected carrier frequencies are fed to a mixer. To the mixer are fed also suitable frequencies from a uhf oscillator. Carrier and oscillator frequencies beat together in the uhf mixer to produce a beat frequency or intermediate frequency.

Tuner sections or elements for uhf are quite different in form from those for vhf reception, because of the higher carrier and oscillator frequencies in the uhf band. Exceedingly small inductances and capacitances are needed for tuning. Were variable inductors and capacitors of forms used for vhf tuning to be made small enough to tune the entire uhf band, their signal energy losses would be excessive.

<u>CONVERSION METHODS.</u> Before examining circuit elements suitable for tuning at ultra-high frequencies it may be well to get acquainted with some of the combinations in which such elements are used. First, we should understand that all uhf receiving systems may be grouped in either of two classes, those employing single conversion and those employing double conversion.

Single conversion is illustrated by the upper diagram of Fig. 2. The uhf tuner consists of a channel selector, an oscillator, and a mixer. The channel selector is equivalent to tuned circuits between antenna and r-f amplifier grid in vhf tuners with which we

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UHF CHANNEL FREQUENCIES

Chan. No.	Range mc	Carriers		Chan. No.	Range mc	Carriers		Chan. No.	Range mc	Carriers	
		Video	Sound			Video	Sound			Video	Sound
14	470-476	471.25	475.75	35	596-602	597.25	601.75	60	746-752	747.25	751.75
15	476-482	477.25	481.75	36	602-608	603.25	607.75	61	752-758	753.25	757.75
16	482-488	483.25	487.75	37	608-614	609.25	613.75	62	758-764	759.25	763.75
17	488-494	489.25	493.75	38	614-620	615.25	619.75	63	764-770	765.25	769.75
18	494-500	495.25	499.75	39	620-626	621.25	625.75	64	770-776	771.25	775.75
19	500-506	501.25	505.75								
20	506-512	507.25	511.75	40	626-632	627.25	631.75	65	776-782	777.25	781.75
21	512-518	513.25	517.75	41	632-638	633.25	637.75	66	782-788	783.25	787.75
22	518-524	519.25	523.75	42	638-644	639.25	643.75	67	788-794	789.25	793.75
23	524-530	525.25	529.75	43	644-650	645.25	649.75	68	794-800	795.25	799.75
24	530-536	531.25	535.75	44	650-656	651.25	655.75	69	800-806	801.25	805.75
25	536-542	537.25	541.75	45	656-662	657.25	661.75	70	806-812	807.25	811.75
26	542-548	543.25	547.75	46	662-668	663.25	667.75	71	812-818	813.25	817.75
27	548-554	549.25	553.75	47	668-674	669.25	673.75	72	818-824	819.25	823.75
28	554-560	555.25	559.75	48	674-680	675.25	679.75	73	824-830	825.25	829.75
29	560-566	561.25	565.75	49	680-686	681.25	685.75	74	830-836	831.25	835.75
30	566-572	567.25	571.75	50	686-692	687.25	691.75	75	836-842	837.25	841.75
31	572-578	573.25	577.75	51	692-698	693.25	697.75	76	842-848	843.25	847.75
32	578-584	579.25	583.75	52	698-704	699.25	703.74	77	848-854	849.25	853.75
33	584-590	585.25	589.75	53	704-710	705.25	709.75	78	854-860	855.25	859.75
34	590-596	591.25	595.75	54	710-716	711.25	715.75	79	860-866	861.25	865.75
				55	716-722	717.25	721.75	80	866-872	867.25	871.75
				56	722-728	723.25	727.75	81	872-878	873.25	877.75
				57	728-734	729.25	733.75	82	878-884	879.25	883.75
				58	734-740	735.25	739.75	83	884-890	885.25	889.75
				59	740-746	741.25	745.75				

are familiar. In most uhf tuners there is no r-f amplifier tube, the output of the channel selector goes directly to the mixer. For uhf reception the output of the uhf mixer goes through a switch to the input of the i-f amplifier of the receiver. For vhf reception this switch connects the input of the i-f amplifier to the output of the vhf tuner.

For an example of how single conversion works out, assume that our uhf tuner is adjusted for reception of channel 26, and that the tuned frequency is midway between video and sound carriers of this channel, or is 545.5 mc. Of course, we actually would tune to a range of frequencies sufficient to cover all video and sound frequencies of the channel, but matters are simplified by considering only center frequencies.

Assume also that the i-f amplifier in the receiver operates with sound intermediate of 41.25 mc and video intermediate of 45.75 mc, midway between which is the frequency of 43.5 mc. To preserve correct relations between sound and video intermediates, the uhf oscillator must operate at a frequency higher than the carrier by the amount of the intermediate frequency. This means an oscillator frequency of 589 mc. Note that carrier frequencies are converted to intermediate frequencies in only a single step.

Double conversion is illustrated by the lower diagram of Fig. 2. The uhf tuner contains the same elements as before, namely a channel selector, an oscillator, and a mixer. But the output of the uhf mixer does not go directly to the input of the receiver i-f amplifier, rather it goes to the antenna terminals

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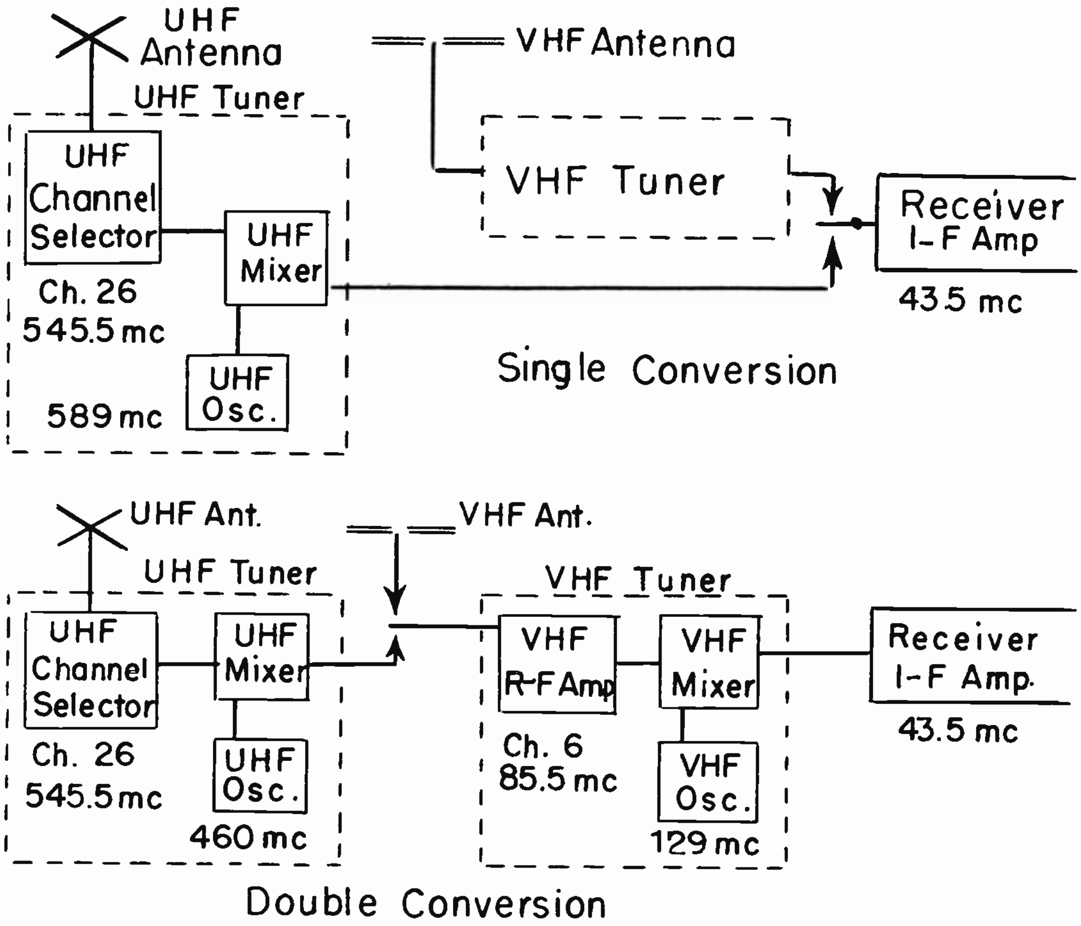

Fig. 2. With single conversion there is one mixer and one intermediate frequency. Double conversion employs two mixers and there are two intermediates.

and the r-f amplifier of the vhf tuner. The vhf tuner treats the frequencies from the uhf mixer just as it would treat vhf carrier frequencies from the vhf antenna. The output of the vhf tuner goes to the i-f amplifier of the receiver.

For uhf reception with double conversion the input of the vhf tuner is switched to the output of the uhf tuner. For vhf reception the input of the vhf tuner is switched to the vhf antenna. There are two frequency conversions, first from uhf carrier to uhf mixer output in the uhf tuner, second from this mixer output frequency to the receiver intermediate frequency in the vhf tuner.

Let's assume that channel 26 is being received with the double conversion system, and that the vhf tuner is set for reception of channel 6, but is connected to the output of the uhf tuner. The uhf channel selector is tuned to the carrier frequency of channel 26, which is 545.5 mc. The uhf oscillator is tuned to 460 mc. The difference between carrier and oscillator frequencies is 85.5 mc, which appears at the output of the uhf mixer.

On channel 6, to which the vhf tuner is adjusted, the frequency midway between video and sound carriers is 85.5 mc. This is the frequency fed to the vhf tuner from the uhf tuner. The vhf oscillator operates at 129 mc. The difference between this oscillator frequency and the frequency from the uhf tuner is 43.5 mc. This difference or beat frequency goes from the vhf mixer to the i-f amplifier of the receiver.

<u>SINGLE CONVERSION SYSTEMS.</u> In the single conversion system shown at the top of Fig. 2 there is increase of vhf signal strength in the r-f amplifier and the mixer of the vhf tuner. During uhf reception there is no gain similar to that of the vhf r-f amplifier, because the uhf selector contains no tube.

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There is no conversion gain in the uhf mixer when, as often is the case, it is a crystal diode instead of a tube. Consequently, there is less overall gain during uhf reception than during vhf reception.

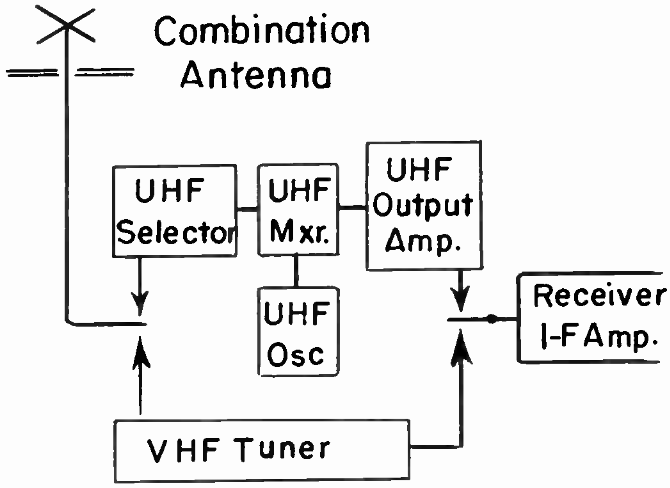

Fig. 3. In a single conversion uhf tuner there often is an amplifier operating at the receiver intermediate frequency.

Fig. 3 illustrates a common method of providing additional gain for uhf reception. Following the uhf mixer, and ahead of the switch connection to the i-f amplifier of the receiver, is a uhf output amplifier tuned to the output frequency of the uhf mixer, which is the intermediate frequency for the receiver. This uhf output amplifier commonly is a cascode type, although it may be a two-stage amplifier with a grounded grid amplifier followed by a pentode amplifier, or may be a single-stage pentode amplifier.

Fig. 4 illustrates a widely used method of providing ample gain for uhf reception with a single conversion system. The uhf tuner comprises only a selector, an oscillator, and a mixer. Output of the uhf mixer goes to the vhf tuner. The vhf tuner may be a switch type or a turret type. With either of these tuners there will be one or more positions for uhf reception, in addition to positions for vhf channels.

In any of the positions for vhf reception the couplers connected into the circuits are tuned to such frequencies that the first tube acts as an r-f amplifier for the selected vhf channel, the second tube acts as a mixer, and the third tube acts as an r-f oscillator. The output of the mixer, at the receiver intermediate frequency, goes to the i-f amplifier section in the usual manner.

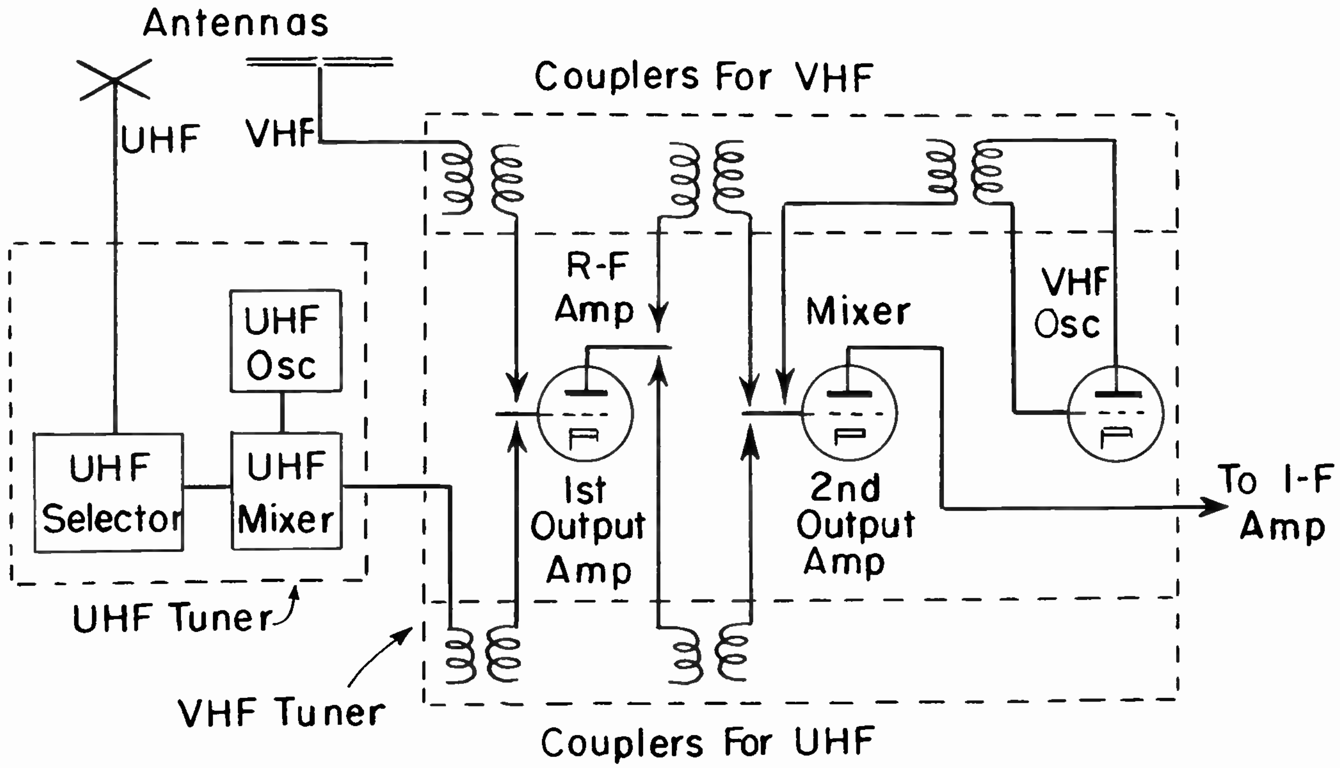

Fig. 4. Tubes in the vhf tuner are used as amplifiers for uhf mixer output.

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In any of the positions for uhf reception the vhf couplers are disconnected from the tubes, and uhf couplers are connected to the first and second tubes. These uhf couplers are tuned to the output frequency of the uhf mixer, which is also the frequency of the receiver i-f amplifier. Now the tube which formerly acted as a vhf r-f amplifier acts as a first output amplifier in the uhf system, and the tube which acted as a vhf mixer now acts as a second output amplifier in the uhf system. In any of the uhf positions the vhf oscillator is made inoperative, usually by providing no tuning inductors for the oscillator, and possibly cutting off its plate voltage as well. Plate voltage may be cut off the uhf oscillator during vhf reception.

Where the vhf tuner is a switch type, such as many of the incremental tuners, there may be twelve positions for the vhf channels and a thirteenth position for uhf reception. The channel selector knob or dial is placed at this thirteenth position for all uhf reception. Then the uhf tuner is adjusted for the desired uhf channel. Uhf tuning may be handled by a separate knob or dial which adjusts circuits of the uhf selector and oscillator. With another method the uhf tuner is adjusted through a pulley and cord arrangement driven from the fine tuning control of the vhf tuner.

Where the vhf tuner is a turret type it is not necessary to provide additional positions for uhf tuning. In no locality will all twelve vhf channels be active or allocated to broadcasters, and any channel positions not needed for vhf reception may be fitted with strips for uhf reception.

In any single conversion system there will be only one oscillator and one mixer. The oscillator will operate in conjunction with uhf carriers to produce, in the mixer, an intermediate frequency at which operates the i-f amplifier section of the receiver. It is single conversion that is used in all vhf tuners. The difference between vhf and uhf systems is only in carrier and oscillator frequencies.

Single conversion seldom is used with receivers whose intermediate frequency is in the 20 to 30 mc range. This is because the oscillator frequency then is only 20 to 30 mc from receiver carrier frequencies, and the percentage difference is so small that there is likely to be "pulling" of oscillator frequency, with possible failure of oscillation. Receiver intermediates in the 40 to 46 mc range are satisfactory for single conversion, since the percentage difference between oscillator and carrier frequencies is great enough to prevent pulling.

Fig. 5 shows a single conversion system in which a single oscillator tube and a single crystal-diode mixer are used for both uhf and vhf reception. The oscillator, the mixer, and the first i-f amplifier are mounted in the chassis of a turret tuner. In strips carried by the turret drum are tuned circuits or coupling circuits for channel selection and for oscillator tuning.

When the turret drum is rotated to bring a uhf strip into operating position, the uhf selector section of the strip couples the uhf antenna to the mixer, while the oscillator section tunes the oscillator in the uhf range. A vhf strip couples the vhf antenna to the grid of an r-f amplifier used only during vhf reception. This strip also tunes the oscillator for vhf reception on the selected channel. The turret drum may be equipped with strips allowing reception of any desired combination of uhf channels and vhf channels.

DOUBLE CONVERSION SYSTEMS. In all double conversion systems, including the variety shown at the bottom of Fig. 2, we find the following features.

There are two mixers, which may be either crystal diodes or tubes. In the first mixer are combined the uhf carrier frequency and a uhf oscillator frequency, to produce what may be called a first intermediate frequency. In the second mixer are combined the first intermediate frequency and a frequency from a second oscillator, to produce the intermediate frequency used in the i-f amplifier section of the receiver.

The uhf channel selector, oscillator, and mixer may be built onto or made a part of the vhf tuner in a receiver, with the vhf tuner providing the second selector (the r-f amplifier circuits), the second mixer, and the

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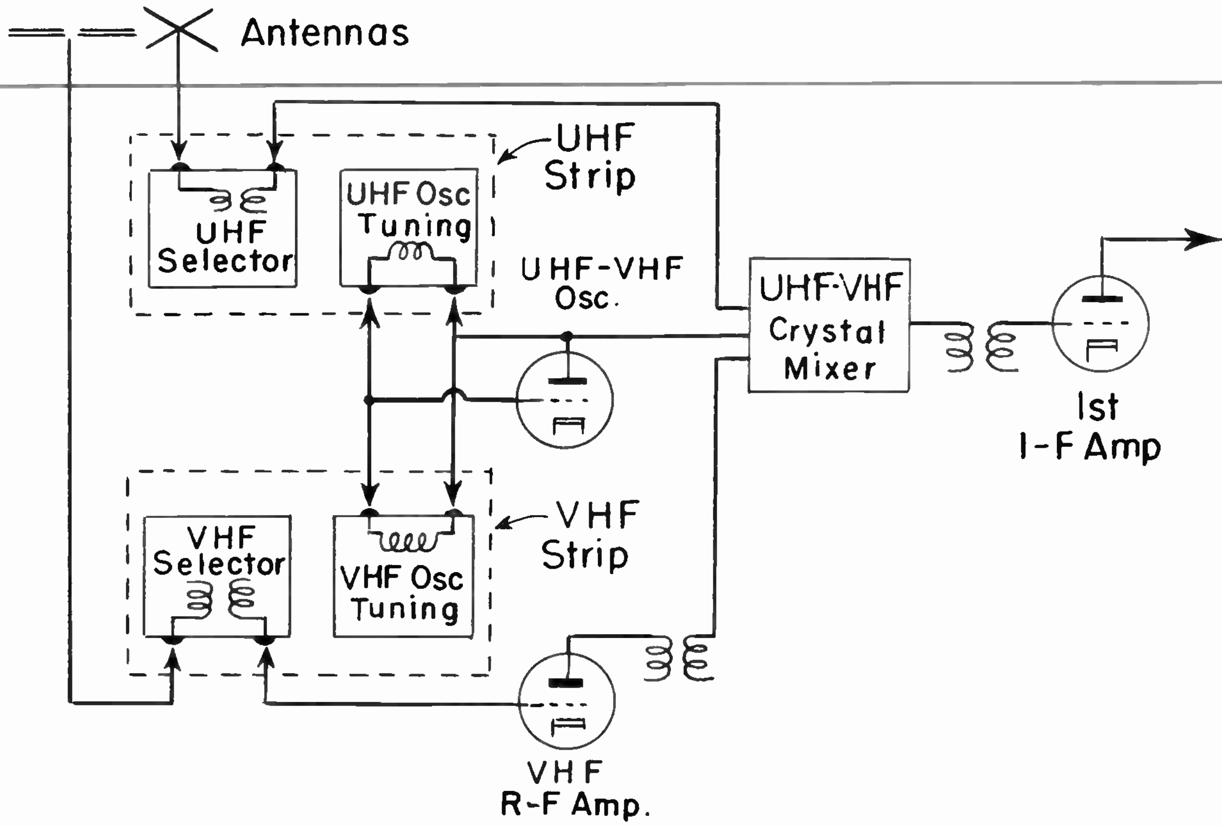

Fig. 5. An oscillator tube and a mixer crystal are used for both uhf and vhf reception.

second oscillator, which is the regular vhf oscillator.

Otherwise the uhf tuner with its channel selector, oscillator, and mixer may be mounted in a separate cabinet, with the output of this uhf tuner connected to the antenna input terminals of the regular vhf tuner in any receiver. A separate uhf tuner usually is called a uhf converter. The majority of uhf converters contain between their mixer and the output to the vhf receiver one or more stages of amplification for the first intermediate frequency. The interior of such a converter is pictured by Fig. 6.

The first intermediate frequency from a converter, either built-in or separate, most often is the same as the carrier frequency for vhf channel 5 or for vhf channel 6. Then, for uhf reception, the vhf tuner is set for reception on whichever of these two channels is not occupied by a vhf station within range of the receiver. If there is a local vhf station on channel 5, the channel 6 position is used for all uhf reception. With a local station on channel 6, the channel 5 position is used for uhf reception.

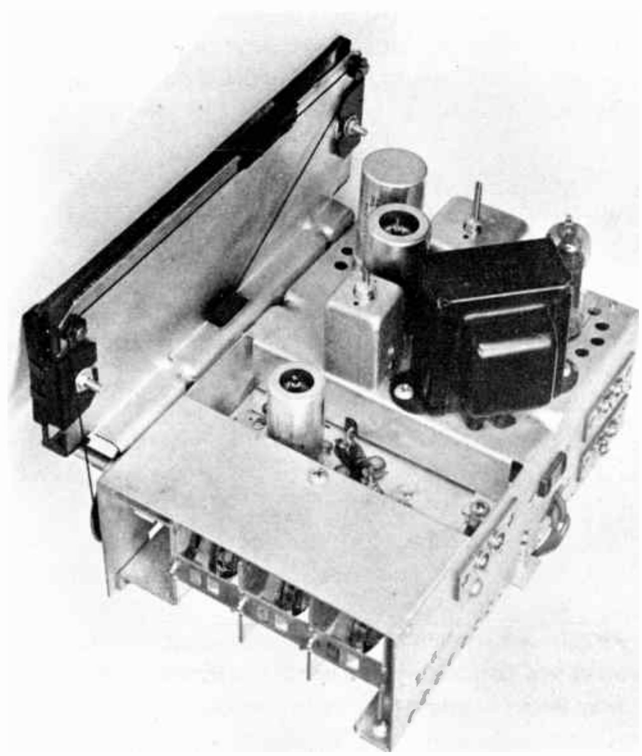

Fig. 6. A uhf converter which employs the double conversion system.

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In many uhf converters there are adjustments for tuning the converter output either to the frequency of vhf channel 5 or to the frequency of channel 6. In some converters the output frequency range is broad enough to accomodate either of these channels without making any adjustment in the converter.

With a built-in converter, or with an external unit designed to operate with one certain receiver, the first intermediate output of the converter may be at some frequency between the carriers for vhf channels 6 and 7, as, for example, a center frequency of about 130 mc. Then the vhf tuner will have a position accomodating this uhf intermediate frequency, or, with some continuous vhf tuners, the vhf channel selector will be set for the uhf intermediate frequency.

Probably you noticed, in Fig. 2, that for single conversion the uhf oscillator frequency is higher than the received carrier frequency while for double conversion the uhf oscillator frequency is lower than the received carrier frequency. Why this lower oscillator frequency is necessary is best illustrated by an example. Assume that uhf reception is in channel 26, that receiver intermediates are 45.75 mc for video and 41.25 mc for sound, and that the vhf tuner is adjusted for channel 6. The uhf tuner or converter operates thus:

Carriers	Video	543.25	Sound	547.75
Uhf osc.		460.00		460.00
1st IF.		83.25		87.75

Here we obtain first intermediate frequencies which are the same as carrier frequencies for vhf channel 6. The vhf tuner operates this way.

Vhf osc.	Video	129.00	Sound	129.00
1st IF.		82.25		87.75
2nd IF.		45.75		41.25

Here we have the correct intermediate frequencies for the i-f section of the receiver. The sound intermediate is lower than the video intermediate, as it must be for reproduction of program signals.

Supposing now that we make the uhf oscillator frequency higher than received carrier frequencies by enough to obtain the same first video IF as before, 83.25 mc. The uhf tuner or converter will operate this way.

Uhf osc.	Video	626.50	Sound	626.50
Carriers		543.25		547.75
1st IF		83.25		78.75

Now the vhf tuner, with its oscillator still operating as for vhf channel 6, will operate on these first IF's in this manner

Vhf osc.	Video	129.00	Sound	129.00
1st IF		83.25		78.75
2nd IF		45.75		50.25

Instead of having a sound intermediate 4.5 mc lower than the video intermediate, the sound intermediate is 4.5 higher than the video intermediate - because we commenced with uhf oscillator frequency higher than carrier frequencies, and used double conversion.

TUNING WITH LUMPED CONSTANTS. For tuning only one or two uhf channels we may use resonant circuits consisting of inductors and capacitors of small electrical size, but otherwise not so very different from those used at very-high frequencies. Such tuning elements are referred to as lumped constants, because inductance is concentrated in the coils, and capacitance is concentrated in the capacitors. We speak of circuits made with inductors and capacitors as having lumped constants to distinguish them from linear circuits or resonant lines, which have distributed constants. That is in a linear circuit the inductance and capacitance are distributed quite uniformly all along the line rather than being concentrated or lumped at certain points.

It is not too difficult to design a lumped constant circuit for tuning any one channel. You may see examples in any uhf strip designed for insertion in a turret tuner. Fig. 7 shows coils and capacitors which are resonant at carrier frequencies in uhf channel 39, which extends from 620 mc to 626 mc. Stationary plates of the tuning capacitors consist of the little pieces of foil at the bottoms of the coil windings. The coil forms are the capacitor dielectric. The adjustable plate of each capacitor is a metal screw inside the coil form.

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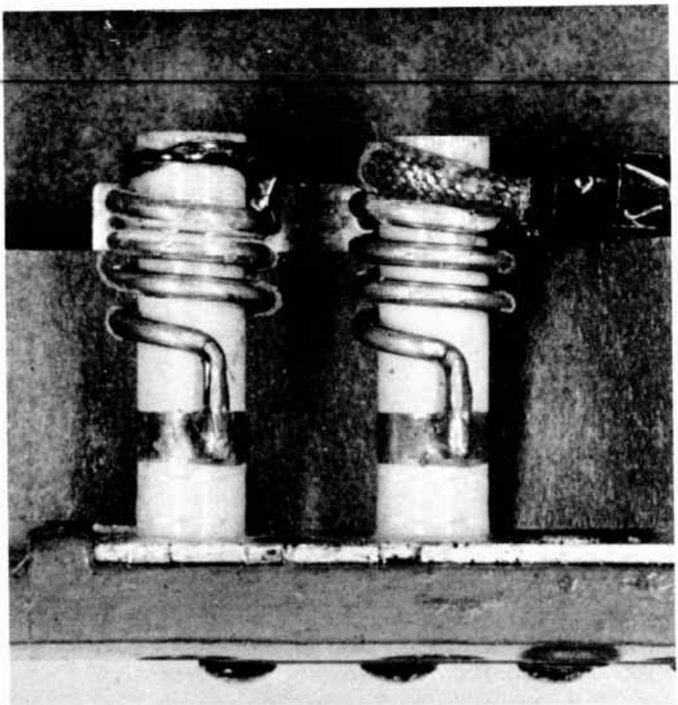

Fig. 7. Coils and capacitors resonant at carrier frequencies of uhf channel 39.

Coil forms of Fig. 7 are about 1/6 inch in diameter. The windings are less than 1/4 inch long from top to bottom. Inductance of each coil, by itself, would be about 0.05 microhenry. This inductance would be resonant at the center of channel 39 with total connected capacitance of about 1.3 mmf. We speak of only approximate inductances and capacitances, because actual circuit values would be influenced largely by surrounding conductors and dielectric materials, as well as by connected conductors and coupled circuits.

Real difficulties arise when tuning over a wide range of ultra-high frequencies with variable lumped constants. As an illustration of the small constants required let's assume that our inductor is a straight piece of number 20 hookup wire one inch long. Inductance will be about 0.0128 microhenry. For resonance at the bottom of the uhf band, 470 mc, we would need total capacitance of about 9 mmf. For resonance at the top of the band, 890 mc, total capacitance would have to be dropped to about 2.5 mmf. This is a capacitance variation of 3.6 to 1, a change quite difficult to obtain in view of the fact that part of the total always will be stray capacitance, which cannot be varied for tuning.

At the center of the uhf band, 680 mc, it would be necessary to use capacitance of about 4.28 mmf for resonance with our one-inch straight inductor. Were we to keep this same capacitance, it would be possible to tune to the top of the uhf band by shortening the inductor wire to 0.68 inch, and to tune to the bottom of the band by lengthening the wire to 1.72 inches.

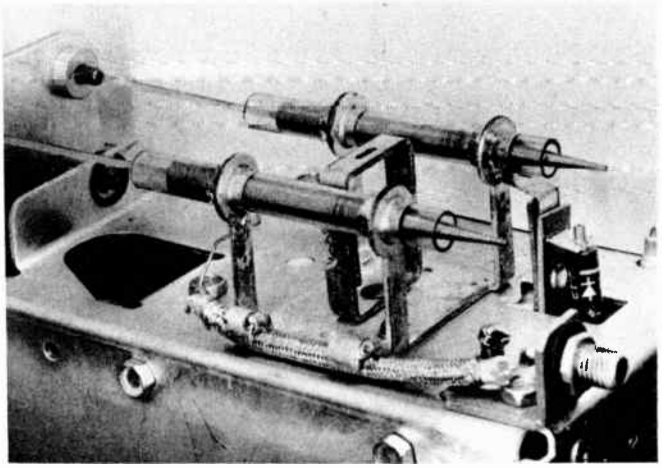

Fig. 8. Variable capacitors and fixed inductors which tune through the entire range of uhf carrier frequencies.

A practical method of variable tuning with lumped constants is pictured by Fig. 8. Connected to the uhf antenna is a circuit tuned to channel frequencies by one variable capacitor. This antenna circuit is link coupled to a mixer circuit which is tuned by a second variable capacitor. The two capacitors are ganged and varied together by the tuning dial mechanism.

Details of this particular channel selector are shown at the left in Fig. 9, while at the right is the equivalent electrical circuit drawn with symbols. Inductance for the antenna circuit is provided by two straight upright bars, La and Lb, grounded at the bottom on chassis metal, and at the top supporting variable capacitor Ca. The mixer circuit consists of similar bars, Lc and Ld, supporting variable capacitor Cb.

Each variable capacitor consists of the following parts: Two short metal cylinders at the tops of the two inductor bars. A long dielectric tube passing through the metal cylinders. A movable tapered brass plunger

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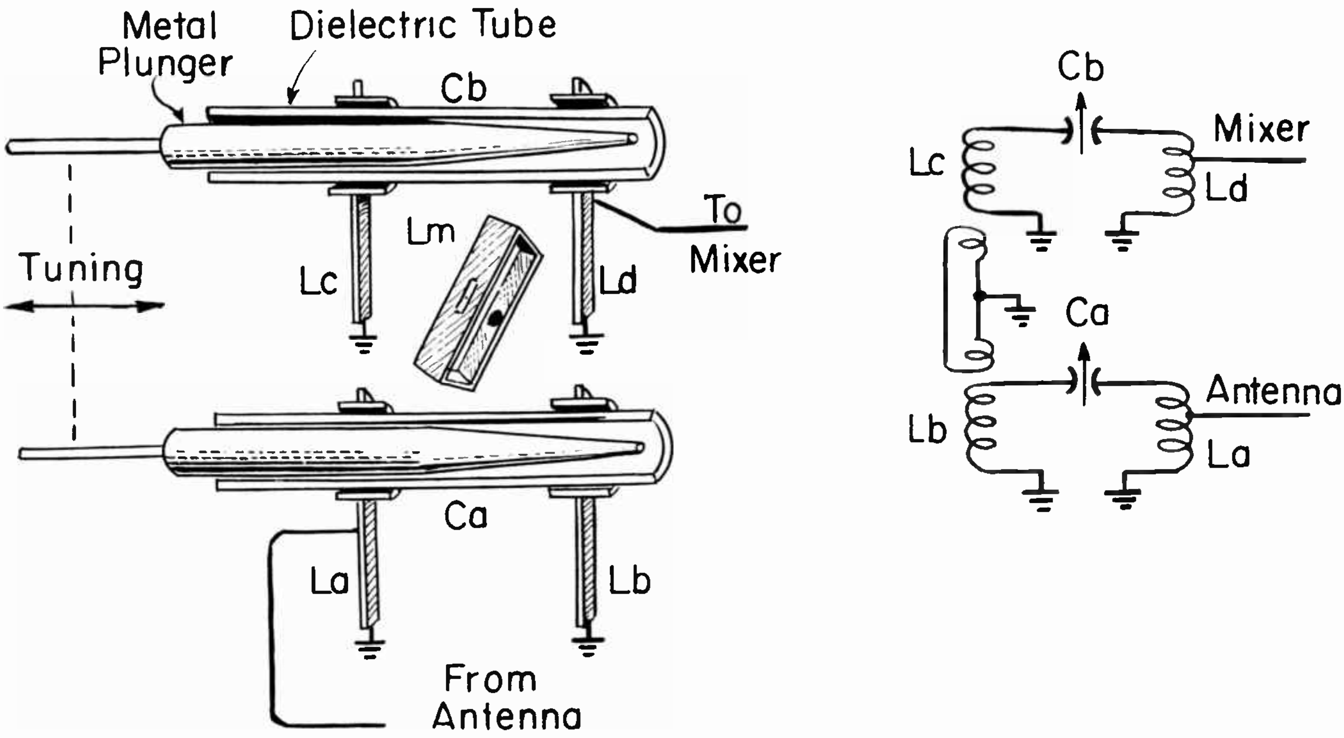

Fig. 9. Details of the channel selector and mixer circuits that tune through the uhf band.

which slides one way or the other within the dielectric tube as tuning is varied. Moving the plungers to the right brings their tapered surfaces closer to the inside of the metal cylinders mounted on inductor bars Lb and Ld, thus increasing capacitance and lowering resonant frequency. Opposite movement of the plungers increases the spacing, to lessen capacitance and raise the frequency.

The coupling link between antenna and mixer circuits is a metal rectangle on a pivot mounting. Turning the link on its pivot brings the sides closer to or farther from the capacitor plungers, thus varying the degree of coupling. This link may be turned by means of a screw driver slot in the top. Other adjustments allow shifting the capacitor plungers to the right or left with reference to the bar that moves these plungers for tuning. This bar is driven by the tuning dial.

There are, of course, various other ways of variable tuning with lumped constants. We have shown details of one method to bring out the fact that tuning inductors may be almost any pieces of metal, straight or otherwise formed for electrical or mechanical convenience. Capacitors usually are of forms very different from those used at lower frequencies. You can identify the various elements, and their service adjustments, only when you understand the principles utilized in this field.

RESONANT LINES. Uhf tuned circuits not made with lumped constants nearly always consist of linear circuits of the quarter-wave shorted type. Such a linear circuit is the electrical equivalent of a parallel resonant circuit made with lumped constants.

In its simplest form the quarter-wave shorted line consists of two side by side conductors with insulation or dielectric material everywhere between except at the ends. At one end of the line its conductors are shorted on each other. At the other end is the source of uhf signal power, or a load. The shorted line is resonant at a frequency for which a quarter-wavelength equals electrical length of the line between the source or load and the short.

Since a quarter-wave shorted line is the equivalent of a coil and capacitor in parallel, the line may be used in the same manner as the more familiar coil-capacitor combination. For example, at the left in Fig. 10 is an oscillar circuit tuned by a coil and capacitor,

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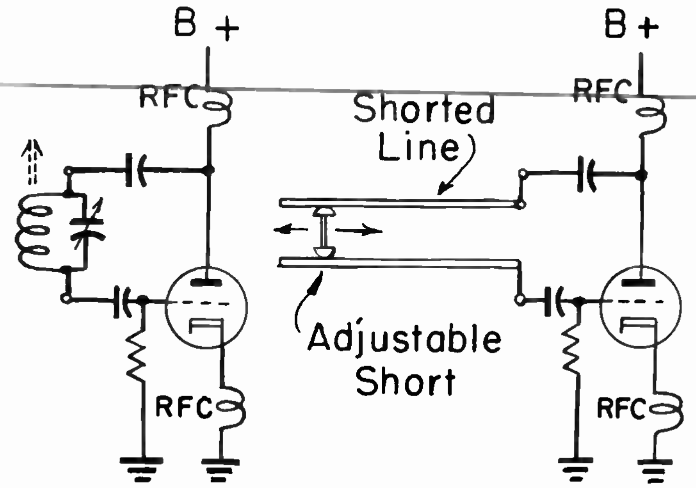

Fig. 10. A coil-capacitor oscillator circuit and an equivalent linear circuit.

which are lumped constants. At the right is the equivalent linear circuit employing a quarter-wave shorted line.

The lumped constant circuit may be adjusted for resonance at a desired frequency by varying the inductance or by varying the capacitance. The shorted line is adjusted for resonance at a desired frequency by varying its effective or electrical length. Line length may be varied, as in Fig. 10, by sliding a shorting bar one way or the other along the conductors. Moving the shorting bar toward the oscillator tube, to lessen the effective length of line, raises the resonant frequency. Increasing effective length of the line lowers the frequency.

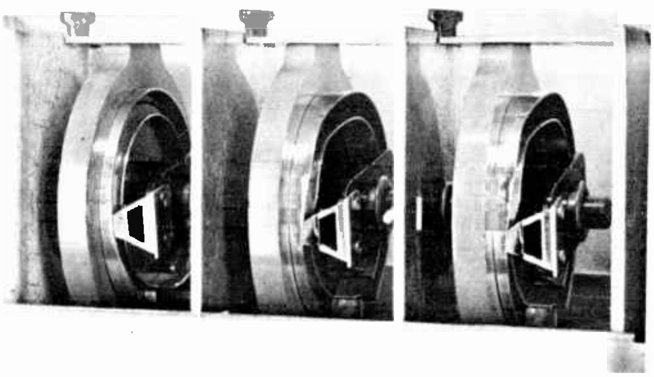

Fig. 11. Three quarter-wave shorted lines whose electrical length is adjusted for tuning by the movable bars.

A practical application of quarter-wave shorted lines is pictured by Fig. 11. There are three resonant lines, one for the antenna circuit, a second for the mixer circuit, and a third for the oscillator circuit. As shown by Fig. 12, each line consists of two circular strips of metal embedded in an insulating support. The movable shorting bar is attached to and rotating by the tuning shaft. The ends of the line conductors farthest from the live terminals are shorted together, thus preventing this end of the line conductors from acting as a secondary resonant line.

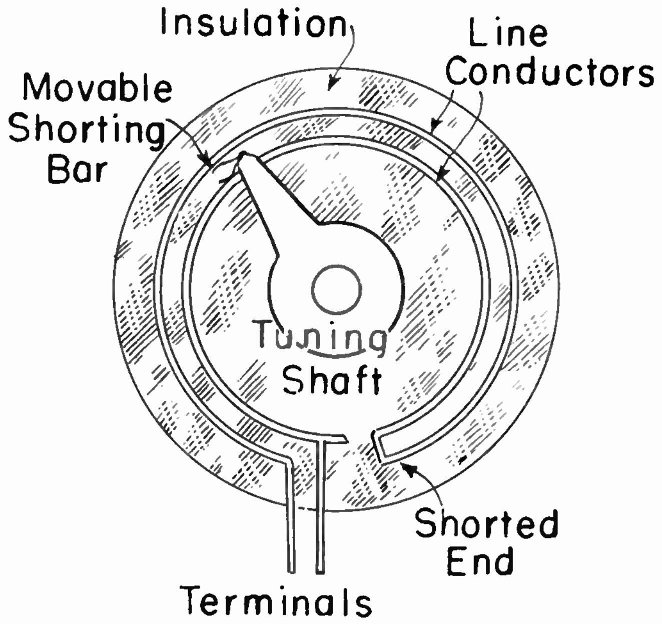

Fig. 12. One of the circular shorted lines whose length is adjusted by a movable shorting bar or slider.

Fig. 13 shows connections for one quarter-wave shorted line which tunes an antenna circuit, and another similar line which tunes the mixer circuit. The diagram at the left has symbols for the tunable resonant lines. The diagram at the right shows symbols for equivalent parallel resonant circuits consisting of coils and capacitors.

Connected to one side of each resonant line is a trimmer capacitor, Ct. These are service adjustments used in the same manner as adjustments for r-f plate and mixer grid circuits in vhf tuners. The degree of coupling between antenna and mixer circuits is adjusted by capacitor Cc. This coupling affects bandwidth and gain. There are no other service adjustments in this portion of the tuner.

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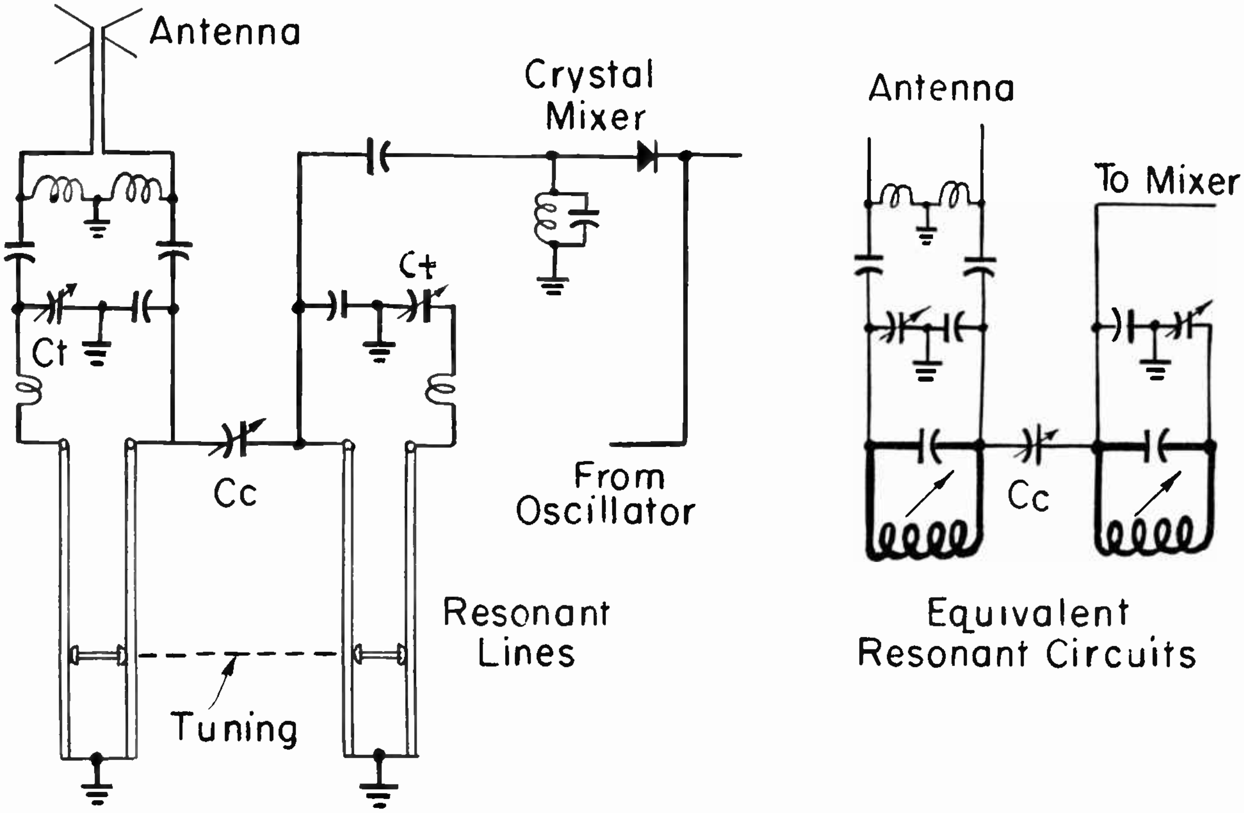

Fig. 13. Antenna and mixer circuits tuned by adjustable quarter-wave shorted lines.

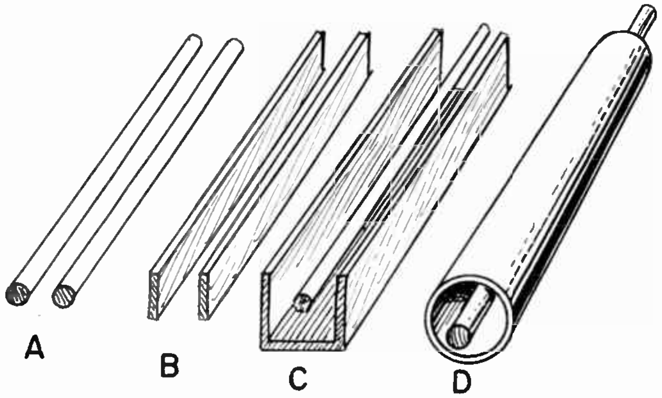

Fig. 14. Resonant line conductors may be of various forms or shapes.

In uhf tuning devices you will find quarter-wave resonant lines in a great variety of forms. It would be entirely possible to use a pair of side by side round conductors, as at A in Fig. 14. This would be like the linear circuits made with pieces of transmission line. The quarter-wave tuning line may be made with flat strips of metal, as at B. An example of this construction was illustrated by Fig. 11. As at C, one of the conductors may be a cylindrical rod, and the other of channel shape. The conductor within the channel need not be round, it may be square, or of oblong section.

At D of Fig. 14 a resonant line is formed by a central conductor surrounded by a metal tube. Here we have a coaxial line. It would be possible to operate a shorting contactor in the space between inner and outer conductors of the coaxial line, but there are other simpler methods.

One method of varying the effective length of a coaxial shorted line is illustrated by Fig. 15. The outer conductor of the line is shown as a cylinder. It might be of rectangular cross section or any other from. The inner or central conductor is a movable metal plunger attached to the tuning dial. With the plunger well out of the inner space the effective length of line is relatively short, and resonant frequency is relatively high. With the plunger moved farther into the line, as at the right, effective length of line is increased, and resonant frequency is lowered. This general principle is utilized in a variety of mechancial constructions.

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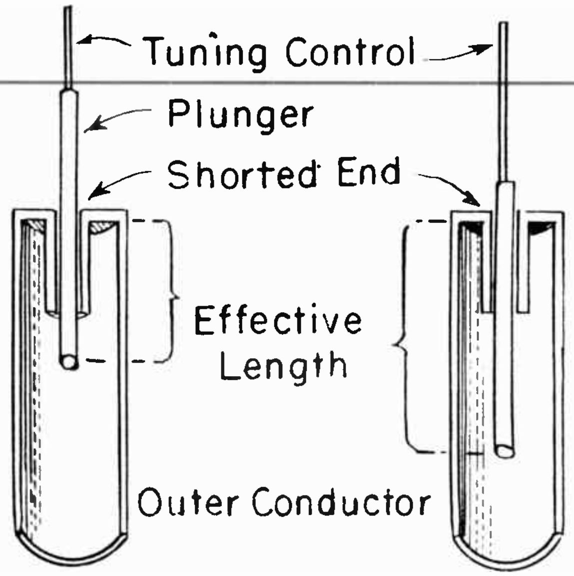

Fig. 15. Effective length of a resonant line may be varied by a movable plunger which is a part of the inner conductor.

Note that the line remains a true linear circuit regardless of where the plunger is moved. With the plunger far out of the inner space, inductance is proportional to length of plunger inside the shorted end. Since the plunger acts like one plate of a capacitor and the outer conductor as the other plate, capacitance is proportional to the length of air dielectric between these two "plates". Moving the plunger farther into the dielectric space increases the length of dielectric and increases capacitance. Inductance and capacitance decrease and increase together, just as in any linear circuit.

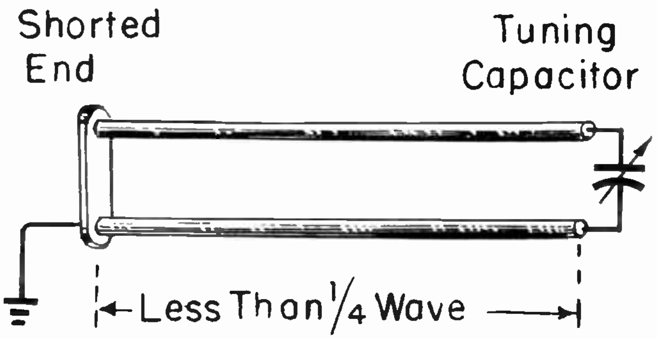

Fig. 16. "End tuning" a quarter-wave shorted line with an adjustable capacitor.

Another principle widely used for resonating a shorted line makes use of a tuning capacitor, as shown by Fig. 16. Electrical length of line conductors, considered by themselves, is less than a quarter-wavelength at any frequency to be tuned. Then the conductors, by themselves, are parallel resonant only at frequencies above the normal range to be tuned. To say this the other way around, all tuned frequencies or channel frequencies are lower than the resonant frequency of the line conductors. When we have this relation between resonant frequency and frequencies actually applied to any kind of parallel resonant circuit, the circuit has an excess of inductance and of inductive reactance.

By adding capacitance between the line conductors, and thus balancing the excess inductance, it is possible to bring this type of linear circuit to resonance at any frequency within the range for which the combination is designed. The tuning capacitor may be connected anywhere along the line conductors, but with the end connection illustrated there is greatest tuning effect for any given capacitor.

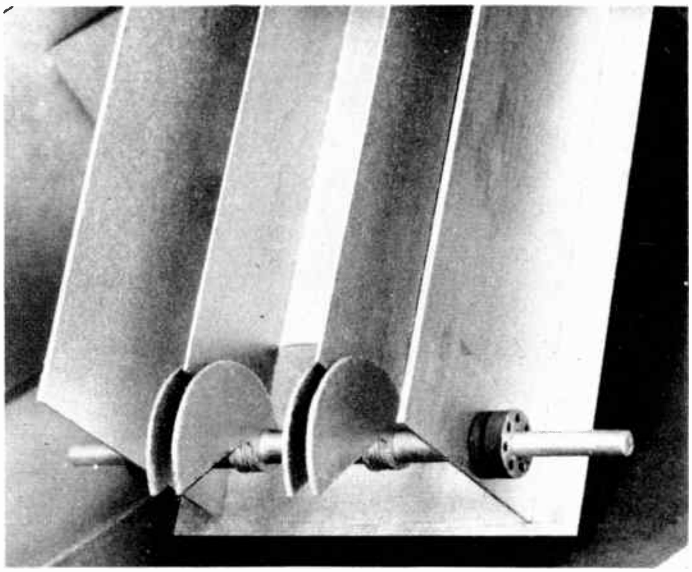

Fig. 17. Rotor plates are on the tuning shaft. Stator plates are extensions of the inner conductor of a shorted resonant line.

A method of applying this principle of capacitance tuning in practice is illustrated by Fig. 17. The inner and outer line conductors are both of channel shape. The near side of the outer conductor has been cut down to expose the tuning mechanism. The illustration shows only the open end of the

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line and its tuning capacitor. The two conductor channels are shorted together at the other end. The outer conductor is grounded, so that it acts as a shield when two or more of these resonant lines are mounted close together.

Extensions on the two sides of the inner channel act as capacitor stator plates. On opposite sides of each stator extension are rotor plates. All four rotors are connected to the outer channel conductor through the tuning shaft on which they are mounted. The rotor plates may be shaped to allow uniform distribution of channel frequencies across the tuning dial.

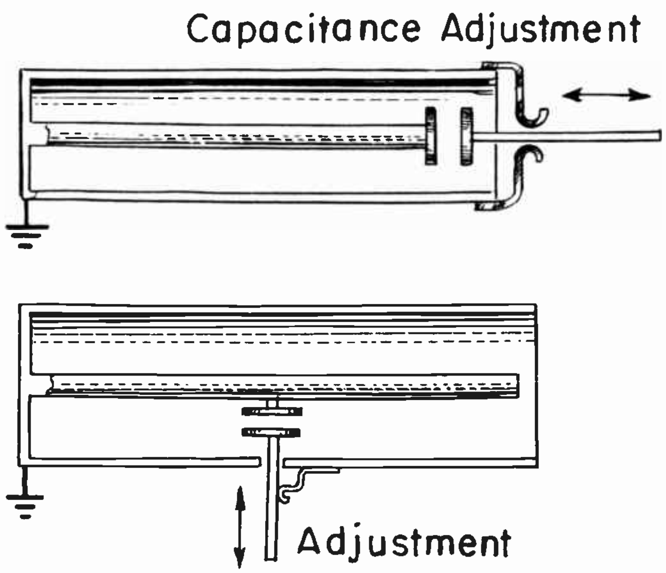

Fig. 18. Other methods of varying the resonant frequency of a shorted line by means of capacitors.

Fig. 18 illustrates other methods of altering the effective length and resonant frequency of shorted coaxial lines. In the upper drawing one capacitor plate is a disc on the unshorted end of the inner conductor. The other capacitor plate is a similar disc mounted on the outer conductor and arranged for movement toward or away from the first disc.

In the lower drawing one of the capacitor discs is mounted on the side of the inner conductor, with the other disc connected to the outer conductor and arranged for movement toward or away from the inner disc. Separating the capacitor plates decreases capacitance and raises the resonant frequency, while bringing the discs closer together increases capacitance and lowers the resonant frequency.

RESONANT LINE COUPLINGS. Fig. 19 shows a few circuit connections and couplings to coaxial resonant lines. When a resonant line is used as a coupling between circuits, one circuit may be connected to one point along the inner conductor while the other circuit is connected to another point along the same conductor, as at 1. Circuits may be coupled, as at 2, through connections made at two points along the outer conductor of the resonant line.

It is more common practice to couple into or out of the coaxial resonant line by means of a conductor or conductors placed within the dielectric space. An example is shown at 3. At 4 there is coupling between two separate coaxial lines by means of a conductor which extends from one line to the other and passes into the dielectric spaces of both lines.

Quite often we find two or more resonant lines constructed as a single mechanical unit , as at 5, with a single partition or single shield acting as part of the outer conductors for adjacent lines. Coupling between adjacent lines may be through a small loop extending through both dielectric spaces, or it might be with a larger loop such as used in diagram 4.

Diagram 6 shows how a wire forming part of an external circuit may be passed through the resonant line, either to impart energy to the line or to take energy from the line. As an example, one end of the coupling wire might go to the grid of an oscillator, and the other end to a grid biasing resistor such as ordinarily connected between oscillator grid and cathode.

At 7 is shown a method of coupling a balanced transmission line from an antenna into the resonant circuit which is a coaxial line. This coupling is effectively the same as that with which the two conductors of an antenna transmission line connect to opposite ends of an inductor whose center tap goes to ground.

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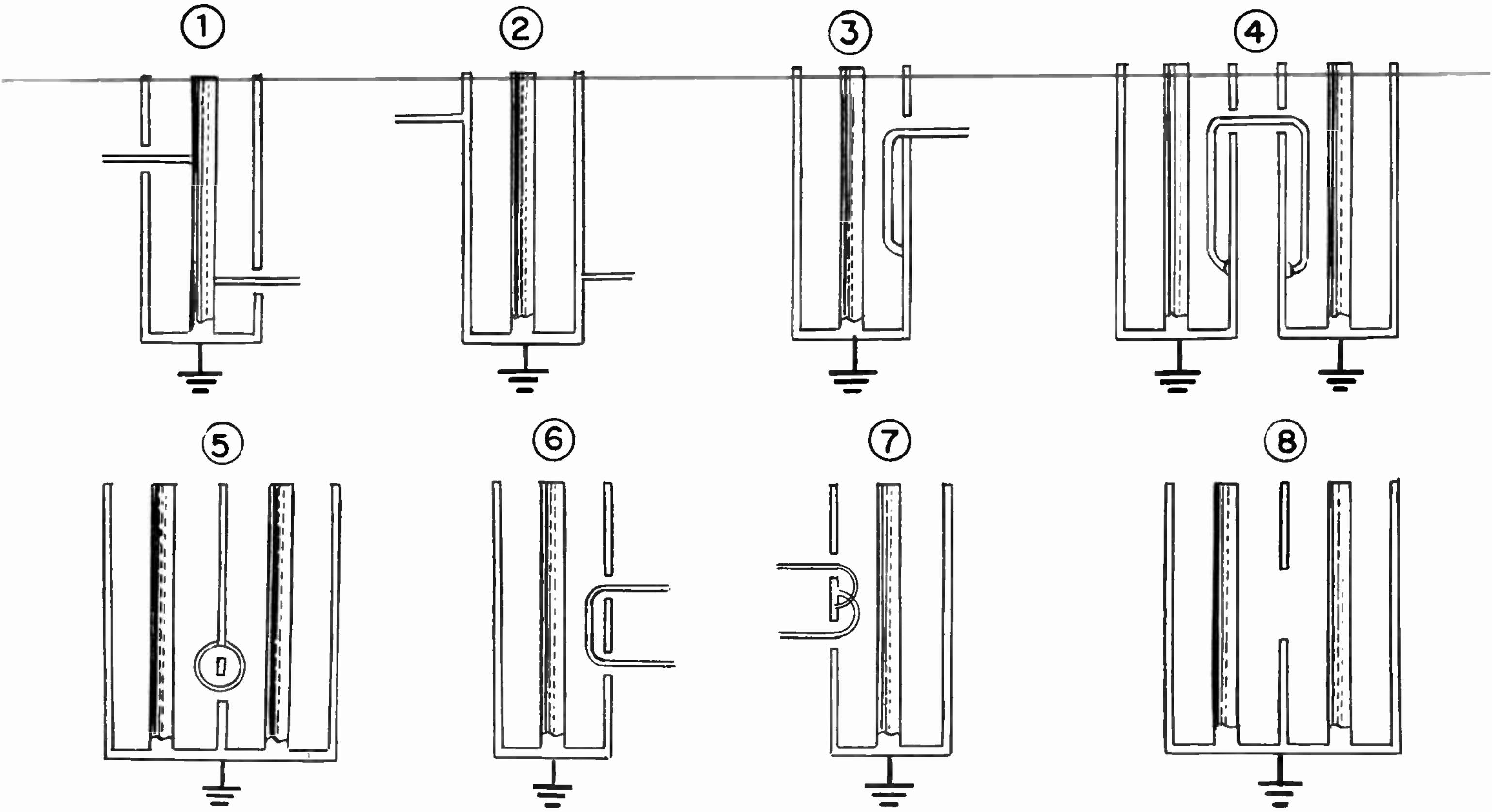

Fig. 19. Couplings used with coaxial resonant lines of the quarter-wave shorted type.

Diagram 8 illustrates coupling between adjacent coaxial lines through an opening that communicates with the dielectric spaces of both lines. The field between inner and outer conductors of one line joins the field between inner and outer conductors of the other line to transfer energy in either direction.

The couplings which are illustrated, and others which are generally equivalent may be combined in various ways for a single resonant line. For instance, coupling from an antenna might be as in diagram 7, with signal energy transfer to a following mixer circuit as in diagram 3. A service diagram might show the antenna coupling on one side of the inner conductor, with the output coupling on the other side. Antenna and mixer circuits might be coupled as in diagram 4, with oscillator voltage introduced as in diagram 6. You will see many other combinations of input and output couplings in service diagrams.

Impedances for coupled linear circuits may be matched to impedances of sources or loads by suitable placing of coupling connections or loops along the line conductors. The explanation depends on facts brought out in our discussion of elementary principles relating to linear circuits. A summary follows.

At the shorted end of any linear circuit or resonant line there is maximum current and zero or practically zero voltage, as represented in Fig. 20. One quarter-wave-length from the shorted end of the line there is maximum voltage and zero current. Now, impedance of any a-c circuit is equal to voltage divided by current, or proportional to the ratio of voltage to current. At the shorted end of the quarter-wave line, where voltage is zero, impedance likewise must be zero - because anything divided by zero still is zero. At the source end or load end of the line there must be maximum impedance, because the highest voltage is divided by zero current.

Impedance at the open end of a shorted quarter-wave line ordinarily is several thousand ohms. Were the line constructed to have a very large Q-factor this impedance might be several hundred thousand ohms. In

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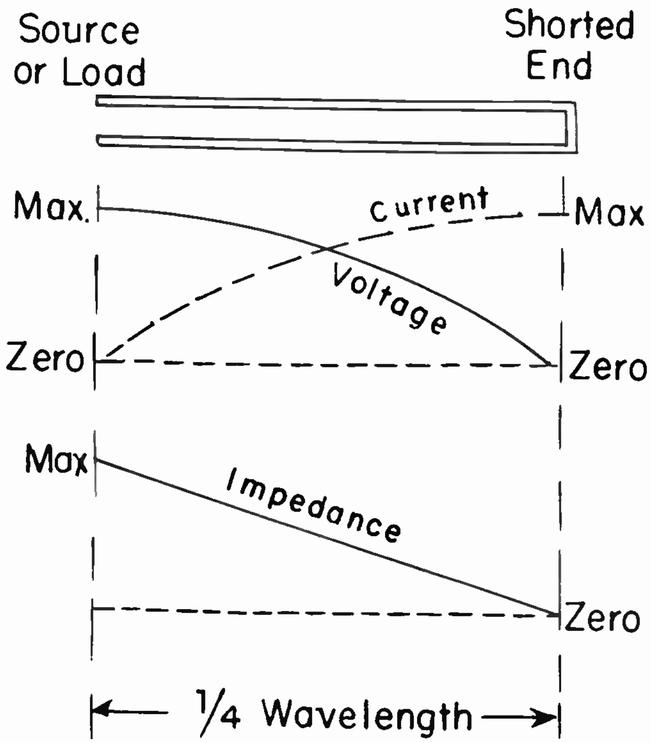

Fig. 20. Various coupling impedances are available along a quarter-wave line.

any event we have at various points along the line a choice of impedances ranging from zero to at least a few thousand ohms. By locating the coupling at a suitable point, the impedance of the resonant line may be made equal to the impedance of practically any source of any load.

As an example, were the coupling at 7 of Fig. 19 connected to an antenna whose resonant impedance is 300 ohms, this coupling would be located at a position where line impedance is 300 ohms. To match a 72-ohm antenna and transmission line the coupling would have to be moved closer to the shorted end of the line, where line impedance is lower. Were' the resonant line to match the relatively high input impedance of an amplifier tube, the coupling would be moved well toward the open end or load end, where line impedance is high.

Input and output impedances of resonant tuning lines seldom are adjustable, they are matters of original design. However, some tuners are so constructed that the coupling connection is moved at the same time that tuned frequency is varied.

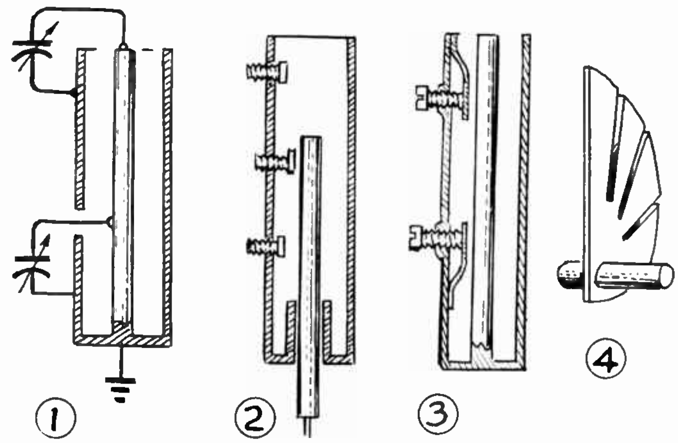

Fig. 21. Tracking adjustments used in uhf tuners.

TRACKING ADJUSTMENTS. Many uhf tuners, but not all, have service adjustments which allow the tuning dial and pointer to correctly indicate actual tuned frequencies. Ordinarily the tuned frequency is altered to match dial markings. This is called tracking. Frequencies at various points in the tuning range are altered by varying the capacitance between inner and outer conductors of a coaxial line, or between side by side conductors of a circular line. Some principles employed for tracking adjustments are illustrated by Fig. 21.

In diagram 1 there are small adjustable capacitors located outside the resonant line structure. These capacitors usually consist of a tubular ceramic form with a brass screw inside acting as one plate and with metal foil on the outside as the other plate of the capacitor. One or more such adjustments may be provided.

Diagram 2 shows several capacitance adjusters which are quite similar to the single adjuster at the bottom of Fig. 18. When capacitance adjusters of this type are used on a line having a movable plunger for tuning, the adjusters which are effective are only those opposite the plunger. When the plunger is nearly withdrawn from the outer conductor, only one of the tracking capacitors will be effective. Moving the plunger farther into the outer conductor, for tuning to lower frequencies, brings additional tracking capacitors into action.

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In diagram 3 the tracking adjustment screws move the ends of small metal plates closer to or farther from the inner conductor. These plates are mounted on the outer conductor. Moving a plate farther in increases capacitance and lowers resonant frequency.

At 4 is a slotted rotor plate which may be used for the outer plates of each pair in the capacitance tuning arrangement of Fig. 17. Portions of the plate between radial slots are bent toward the stator (an extension of the inner conductor) to increase capacitance and lower the resonant frequency, or are bent outward to decrease capacitance and raise resonant frequency. Adjustments are made in the same way as with slotted plates of tuning capacitors for radio broadcast frequencies. This means to commence tracing adjustment at the high end of the uhf band, bending the plate sector then in mesh with the stator extension. As additional sectors are brought into mesh when tuning to lower frequencies, each successive sector is adjusted for correct tracking.

When examining any kind of linear circuit used for uhf tuning you will notice that the line length, measured in inches, is very short. This is due largely to the fact that a quarter-wavelength at 470 mc is but slightly more than 6-1/4 inches, and at 890 mc is only about 3-5/16 inches.

The actual physical length of a tuning line is even shorter than a quarter-wavelength, because of capacitances and inductances in connected circuit elements. Take the case of Fig. 22, where a resonant line is connected to an oscillator tube. There is

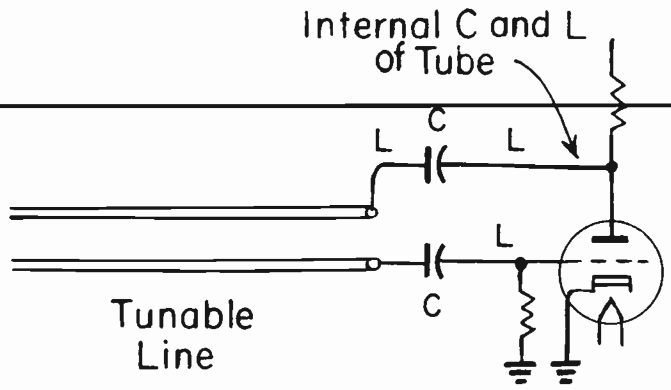

Fig. 22. Inductances and capacitances which add to those of the resonant line, and require shortening of the line conductors.

inductance (L) in all the connections, including those through the tube socket, and also in the element leads within the tube. There is capacitance in blocking and coupling capacitors, and more capacitance between elements and leads within the tube.

All of these additional inductances and capacitances have much the same effect on tuning as though they were in the resonant line; they act to lower the resonant frequency. Therefore, enough inductance and capacitance must be removed from the line to compensate for the effect of all the other circuit elements. This can be done only by making the line much shorter than a quarter-wavelength. The range of tunable frequencies is restricted because only the line conductors can be varied. Values of all the additional inductances and capacitances are fixed. The length in inches of tunable resonant lines seldom is more than 60 to 70 per cent of a quarter-wavelength.

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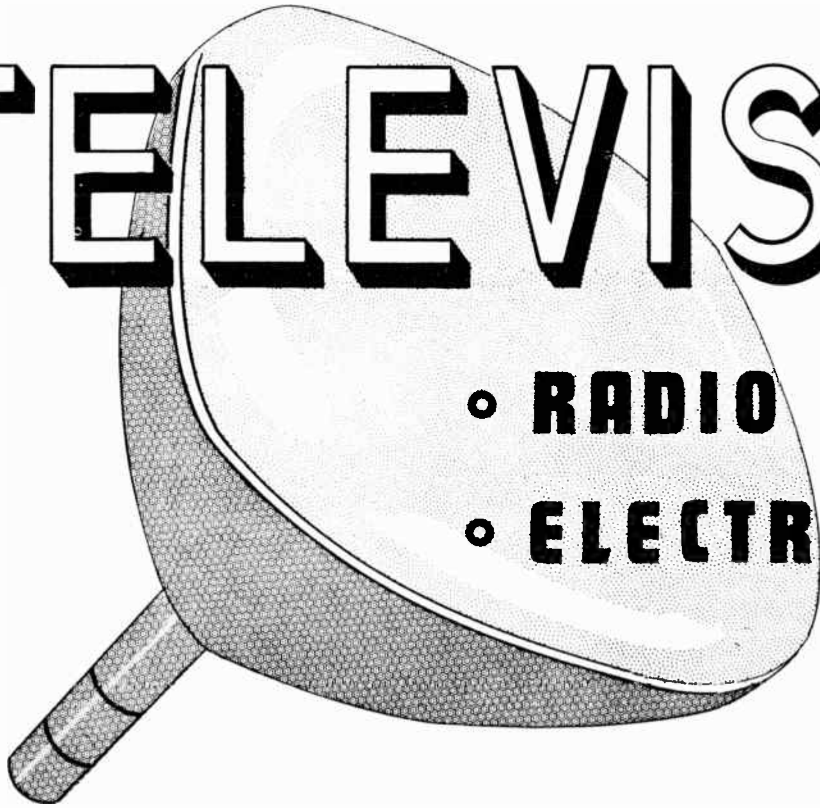

• RADIO
• ELECTRONICS

LESSON 93 — ULTRA-HIGH FREQUENCY RECEPTION — PART TWO

Coyne School

practical home training

Chicago, Illinois

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Lesson 93

ULTRA-HIGH FREQUENCY RECEPTION – PART TWO

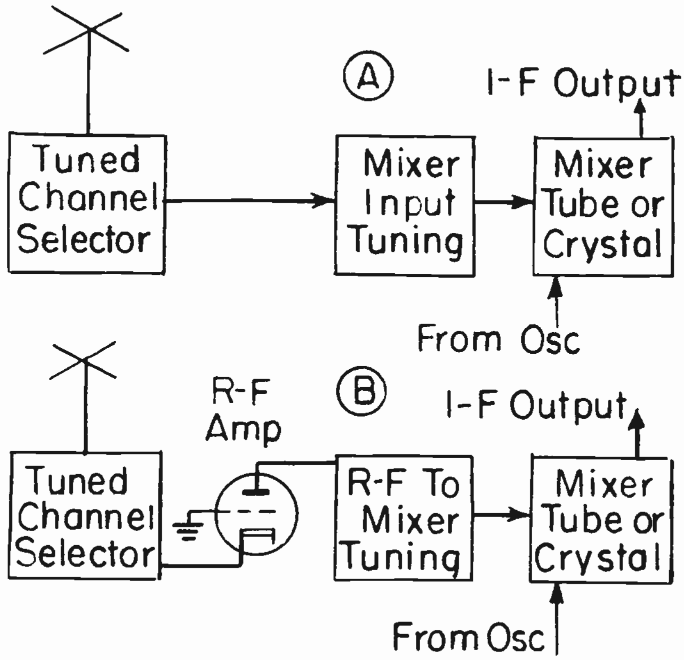

Fig. 1. An r-f amplifier tube may or may not be used in a uhf tuner.

Between the antenna or transmission line input and the mixer of a uhf tuner may be only tuned selector circuits, as at A of Fig. 1. In other designs there may be also an r-f amplifier tube operating at carrier frequencies, as at B. In any case it is the purpose of tuned circuits between antenna and mixer to select frequencies of a desired channel, while attenuating image frequencies, all other signal frequencies, and uhf oscillator frequencies which otherwise would reach the antenna and be radiated. These tuned circuits may be of any types suitable for ultra-high frequencies, such as those made with lumped constants or with various forms of resonant lines.

In some tuners the antenna input terminals are followed by a high-pass filter which has negligible attenuation for ultra-high frequencies, but cuts off very-high frequencies. Such a filter may consist of series capacitors and shunted inductors of such values as to completely attenuate all frequencies lower than about 350 to 400 mc.

R-f amplifier tubes for ultra-high frequencies are triodes used in grounded grid circuits. A triode produces less noise than a pentode. The grounded grid prevents plate-to-grid feedback which could cause oscillation, and at the same time reduces the chance of uhf oscillator power reaching the antenna. With signal input to the cathode of a grounded grid amplifier tube the input impedance is low enough to simplify the problem of matching the impedance of transmission lines. Several triodes have been developed especially for uhf amplification.

TUBES FOR ULTRA-HIGH FREQUENCIES. Even with special forms of inductance and capacitance elements it still would be impossible to tune at ultra-high frequencies with circuits employing ordinary tubes. The principal reason is that such tubes have excessive internal capacitances, while base pins and leads from pins to internal elements have excessive inductance.

A tube suitable for amplification, oscillation, or mixing at ultra-high frequencies must have small internal capacitances, with internal leads designed for least possible inductance. The tube base, also any socket, must have small dielectric losses. Transconductance must be high, usually on the order of 10,000 micromhos, to compensate for energy losses which are unavoidable at such high frequencies. Used as mixers, these tubes have conversion transconductance of about 3,000 micromhos.

Tubes designed especially for use as uhf amplifiers, mixers, and oscillators have more than one base pin and more than one internal lead to some of the elements. Connecting several internal and external leads in parallel from a single element to external circuits reduces inductance, since any conductors in parallel have less inductance than any one of them alone. Many uhf tubes have two leads and two base pins for the grid, with two leads and two base pins also for the plate. Some types have as many as five leads and pins for the grid.

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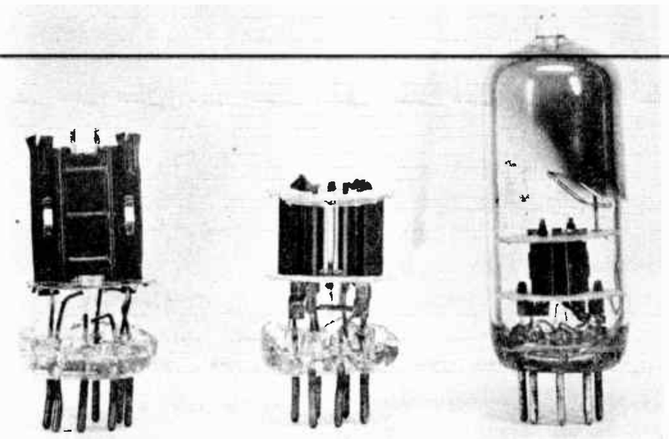

Fig. 2. The higher the frequency for which a tube is designed, the smaller are its elements and the shorter its internal leads.

At the left in Fig. 2 we may see the elements of a miniature pentode suitable for operation at frequencies up to something like 250 mc. At the center are shown the smaller elements and shorter leads of a twin triode which works well up to about 600 mc. At the right, within a miniature glass envelope, are the very small elements and very short leads of a triode used as an oscillator for ultra-high frequencies.

At ultra-high frequencies the time required for electrons to travel between internal elements of tubes becomes important. This is called transit time. To understand why transit time is important, consider the following facts.

The change from maximum positive to maximum negative grid voltage occurs during a period equal to a half-cycle of the applied signal. The rate of electron flow through the grid and toward the plate will be greatest when the grid is at maximum positive potenial, or at a potential least negative with reference to the cathode. Electron flow will be least when the grid is at maximum negative potential.

These maximum and minimum quantities of electrons passing through the grid take a measurable time in traveling from grid to plate. They arrive at the plate just a little later than they leave the grid. Consequently, changes of plate current due to changing electron flow through the grid will occur a little later than changes of grid voltage. Then plate current is not exactly in time with grid signal voltage, or is not in phase with signal voltage at the grid.

As an example, assume that the distance from grid to plate is 1/10 inch, and that plate potential is 140 volts above average grid potential. Under these conditions it will take electrons about 1/1400 microsecond to travel from grid to plate. At an operating frequency of 700 mc, a half-cycle of grid signal voltage occurs in 1/700 microsecond, and a quarter-cycle takes only 1/1400 microsecond. This means that time required for electrons to travel from grid to plate is the same as the time for a quarter-cycle of grid signal voltage. With our assumed conditions, plate current will be a quarter-cycle or 90 electrical degrees out of phase with grid signal voltage.

In the foregoing example there would be a great reduction of signal power output as compared with power when grid voltage and plate current are in phase. Furthermore, because electrons would reach the plate at varying velocities, alternating plate current and voltage would not be of the same waveform as alternating grid voltage. Were transit time to be so long as to equal the time of a half-cycle of grid voltage, output power would drop to zero. To reduce transit time, and maintain satisfactory signal power output, element spacing in uhf tubes is made very small.

Although tubes suitable only for very-high frequencies give poor results in the ultra-highs, those designed as voltage amplifiers, mixers, and oscillators at ultra-high frequencies perform well at very-high frequencies. It is for this reason that combination uhf-vhf tuning systems may have only a single set of tubes for both bands, although circuit elements other than tubes will be of forms quite different for uhf reception than for vhf reception.

MIXER TUBE CIRCUITS. A mixer tube, whether for ultra-high or very-high frequencies, must be operated with enough negative grid bias to cause non-symmetrical output current and voltage when the input signal

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voltages are symmetrical. That is, the tube must be biased so that the operating point is down toward plate current cutoff. Then variations of signal and oscillator voltages that make the mixer grid less negative cause greater changes of plate current than do variations that make the mixer grid more negative.

The action of a mixer is explained in detail by the lesson on "The Superheterodyne". If you do not recall the manner in which a mixer produces a difference frequency or a beat frequency it might be well to review that lesson.

Mixer tubes in vhf tuners usually are biased by the grid leak method, which allows the cathode to be grounded. Mixer tubes in uhf tuners more often are biased by a cathode resistor. This allows the uhf mixer circuit to be of the grounded grid type. Otherwise there is not a great deal of difference between uhf and vhf mixers, at least so far as principles are concerned.

Fig. 3 shows connections such as may be used for uhf mixer tubes. In diagram 1 the source of r-f signal voltage is shown as a shorted quarter-wave resonant line, but might be any other type of circuit coupling the mixer to a preceding antenna selector or to a preceding r-f amplifier. The r-f input is coupled to the mixer cathode. Cathode bias is provided by resistor Rk, bypassed by capacitor Ck. Voltage from the uhf oscillator is applied through a small capacitance Co to the mixer cathode. The mixer grid is connected directly to ground.

The mixer output circuit or plate circuit is similar in design and operation to mixer plate circuits used in many vhf receivers, and might be any other type commonly used in this position. The heater of the mixer tube is isolated from ground and the heater supply line, so far as uhf currents are concerned, by two r-f chokes and a decoupling capacitor. You will find such heater isolation on uhf amplifiers and oscillators, as well as on mixers.

Diagram 2 shows other connections for the mixer cathode and grid. R-f signal voltage from any type of preceding circuit is applied through capacitor Cr to the mixer cathode. Between cathode and ground we find an r-f choke, also cathode bias resistor Rk and a bypass capacitor Ck. Uhf oscillator voltage here is applied through capacitor Co to the mixer grid, instead of to the cathode. To avoid grounding the oscillator voltage, the mixer grid is grounded through an r-f choke, rather than directly.

The diagram of Fig. 3 illustrates only two fairly typical uhf mixer circuits. Many other arrangements and combinations are possible, as you will find when examining service diagrams and uhf tuners themselves.

CRYSTAL DIODE MIXERS. In many uhf tuners, also in combination uhf-vhf tuners, the mixer is either a silicon crystal diode or else a germanium crystal diode. At the left in Fig. 4 is a type 1N82 silicon diode and next to it is a type 1N72 germanium diode. Both of these are designed especially for use as

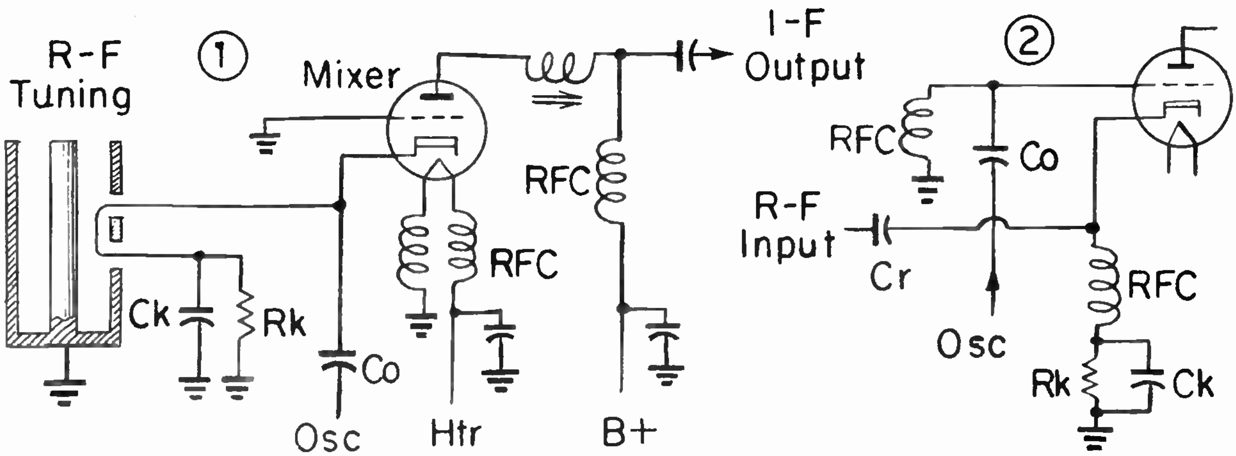

Fig. 3. Connections of mixer tubes in uhf tuners.

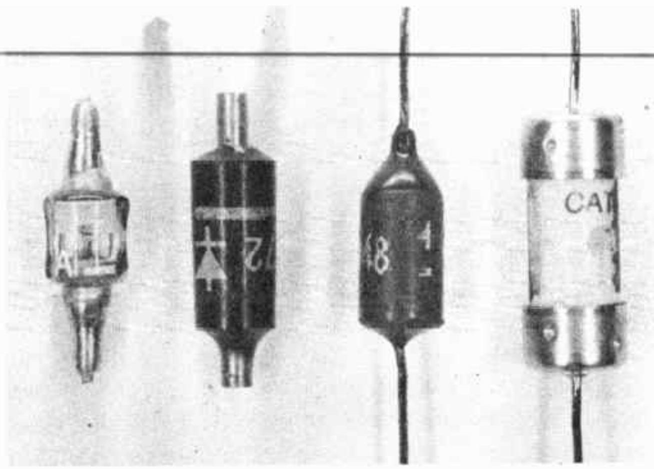

Fig. 4. The two crystal diodes at the left are used as uhf mixers, the other two are general purpose types.

uhf mixers. Both have end contacts for mounting in spring clips. Overall length of these uhf diodes is 3/4 inch. Their outside diameter is about 3/16 inch.

The two units at the right in Fig. 4, those with pigtail leads, are general purpose germanium crystal diodes of types 1N48 and 1N34. In the lesson on "I-F Traps And Video Detectors" you will find explanations of how crystal diodes are constructed, how they should be handled and mounted, and how their terminals may be identified. Although explanations in that lesson refer especially to crystal diodes used as video detectors, they apply in general to all such units.

In most tuners the silicon and germanium crystal diodes may be used interchangeably, or one may be substituted for the other without greatly affecting performance of the mixer circuit. A substitution may require some realignment, but again no readjustment may be necessary.

The crystal diode mixer, compared to a tube mixer, has these advantages: Simpler mounting, without a socket. No heater power needed. Requires less voltage or power from the uhf oscillator. Not affected by transit time.

The big disadvantage of a crystal mixer, compared with a tube, is loss of signal voltage. Conversion transconductance and gain with a triode mixer tube may almost completely overcome high-frequency losses of signal energy in the mixer circuit. Output signal voltage from a crystal mixer will be only about one-third to one-half of the input signal voltage. Although the crystal mixer requires less oscillator injection voltage than a tube mixer, performance of the crystal mixer is altered more greatly by variations of oscillator injection than is performance of the triode tube mixer.

The mixer crystal acts like a mixer tube in that both of them partially rectify a current in which are beats due to combining r-f signal voltages and oscillator voltages. It is rectification that produces a new frequency equal to the difference between carrier and oscillator frequencies. This new frequency is, of course, the intermediate frequency.

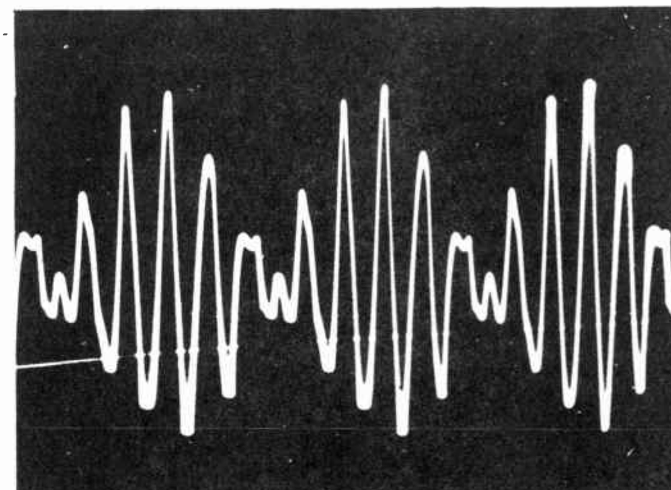

Fig. 5-A

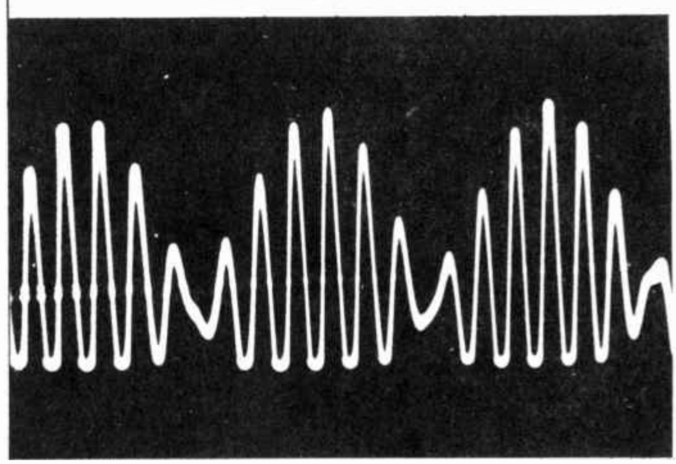

Fig. 5-B

Fig. 5. One polarity of beat frequency alternations is partially cut off by a mixer.

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We should keep in mind that voltages at different frequencies will beat together whether or not a mixer or rectifier is present. At A in Fig. 5 is a trace resulting from feeding to the oscilloscope two different frequencies. There are points of maximum amplitude at instants in which the two voltages are in phase, and points of minimum amplitude where the voltages are of opposite phase. But amplitudes are equal above and below zero, and their average at all instants is zero.

The trace at B results from passing the same two voltages through a crystal diode acting as a mixer. This effect would be had also with the two voltages fed to the input of a mixer tube. Now the negative alternations have been cut off, or nearly so. The average of this partially rectified beat voltage is not zero; it rises at points of maximum amplitude and falls at points of minimum amplitude. Were the rising and falling alternations filtered or smoothed out, we would have their average amplitude varying at a new frequency equal to the difference between carrier and oscillator frequencies.

Fig. 6 shows several crystal diode mixer circuits such as used in uhf tuners. Many other variations are in use. In all the circuits illustrated, and in all other crystal diode circuits, you should be able to follow a conductive path from either side of the crystal all the way around to the opposite side. There must be such a path because there must be one-way electron flow in the crystal, which is a type of rectifier. Without a conductive return between one side and the other of the crystal diode there could be no continuing electron flow in one direction. It is just as necessary to have a conductive return for a crystal diode as to have such returns from plates, grids, and other elements of a tube to its cathode.

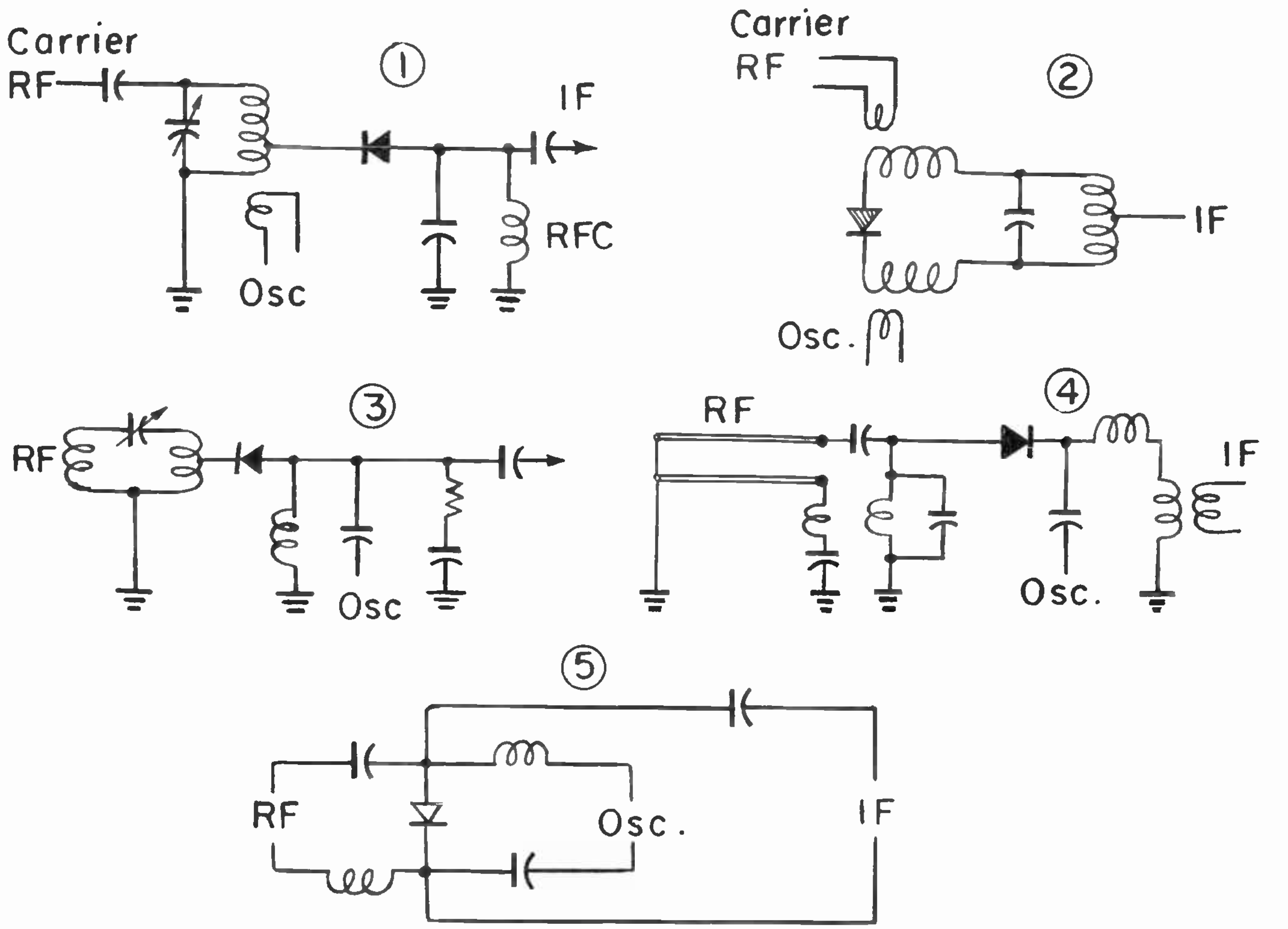

Fig. 6. Various circuits for crystal diode mixers.

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In diagram 1 of Fig. 6 the carrier signal voltages and the oscillator voltage are applied together to the cathode side of the crystal diode, while i-f output is from the anode side of the crystal. This is equivalent to introducing carrier and oscillator voltages at the input of a mixer tube, at either the cathode or grid, and taking the i-f output from the plate.

In diagrams 2, 3, and 4 the carrier signal voltage is applied to one side of the crystal, while oscillator voltage is applied to the opposite side. With this connection the partially rectified current that produces a beat frequency is the same as when applying both voltages to one side of the crystal, provided both voltages cause variation of current flowing through the crystal. The effect is equivalent to that which would be obtained with connections of diagram 5, where both the r-f circuit and the oscillator circuit are completed through the crystal, with i-f output taken from across the crystal.

UHF OSCILLATORS. Although many uhf tuners have no tubes for amplification of carrier voltages or for mixing, all of them secure oscillator voltage from a tube circuit. In some designs there is a separate oscillator tube for only uhf tuning. In others the same oscillator tube serves for both uhf and vhf reception. In still other cases the uhf oscillatory voltage is at a harmonic frequency from a vhf oscillator. All tubes designed especially as uhf oscillators are miniature triodes with small elements, small internal capacitances, short internal leads, and with multiple internal leads and base pins for plate and grid.

Oscillator circuits may employ either lumped constants or various types of resonant lines. As a general rule the method of oscillator tuning is like that used for channel selection and mixer tuning in the same tuner; all tuned circuits usually are of the lumped constant type or all are resonant lines. This, however, is not always true; r-f and mixer tuning sometimes are of one type, and oscillator tuning of a different type.

With single conversion systems the oscillator frequency always is higher than carrier frequencies, while with double conversion the oscillator frequency is lower than carrier frequencies. To provide the higher or lower oscillator frequency, resonant line oscillator circuits must be effectively shorter or longer than resonant line circuits handling carrier frequencies.

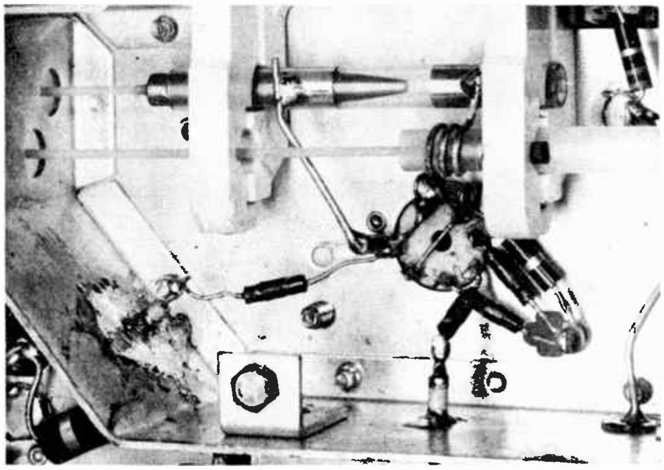

Fig. 7. Circuit elements connected to the oscillator tube socket within a shielded compartment of a uhf tuner.

Uhf oscillator circuits are electrically similar to circuits for vhf oscillators. Practically all are modifications of the basic Colpitts oscillator, with tuning in the grid-plate circuit, and biasing by grid leak action. But, so far as mechanical design and appearance are concerned, there isn't much resemblance between uhf oscillators and those for lower frequencies. Fig. 7 is a picture of the oscillator compartment of a uhf tuner, with the shield cover removed. Uhf oscillator circuits, and tubes, always are completely shielded from all other circuits.

Fig. 8 illustrates some features found in uhf oscillator circuits. Tuning, in diagram 1, is accomplished by an adjustable inductor and an adjustable capacitor connected in series between plate and grid. For a single channel tuner or for a strip on a turret tuner both of these might be alignment adjustments. Oscillator voltage is injected into the mixer circuit by capacitive coupling between a wire in the oscillator grid-plate line and a loop on the mixer circuit. Shifting this loop in relation to the wire will vary the oscillator injection.

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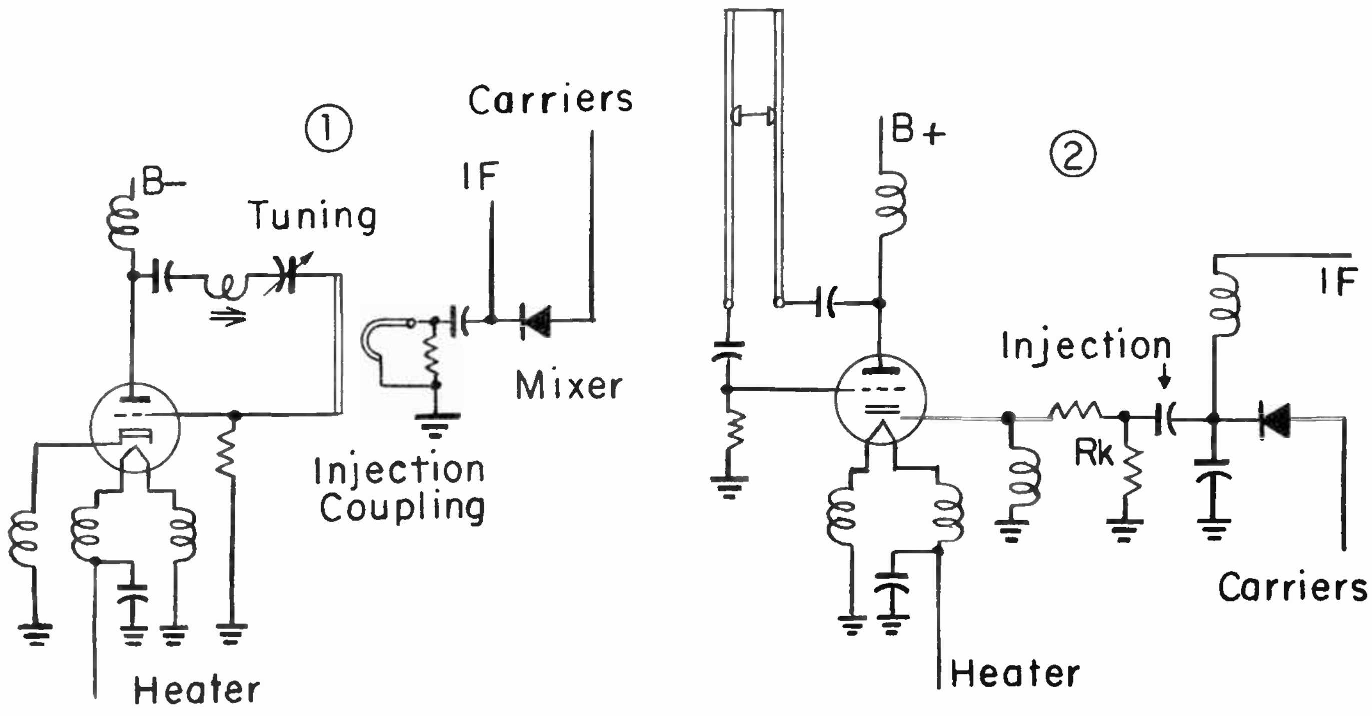

Fig. 8. Methods of taking injection voltage from uhf oscillators to mixers.

In uhf oscillators it is desired that the oscillatory circuit be completed only through grid and plate of the tube, without degeneration in a cathode impedance. Therefore, you will find oscillator cathodes isolated from ground and from other circuits by an r-f choke.

Because cathode-heater capacitance is fairly large, and its reactance very small at ultra-high frequencies, the heater is practically a unit with the cathode so far as uhf voltages are concerned. For this reason the heater nearly always is isolated from ground and other circuits by r-f chokes in both leads. When one side of the 6.3-volt heater supply is carried through ground, one of the heater chokes will connect to ground. The other choke goes to the live heater line and is bypassed to ground through a capacitor. These chokes have high opposition to uhf currents, but negligible opposition to heater current.

In diagram 2 of Fig. 8 the oscillator is tuned by a quarter-wave shorted line. Injection voltage for the mixer is taken from the oscillator cathode above the r-f choke. Between cathode and ground are two resistors, Rk, acting as a voltage divider, with injection voltage taken from their junction through a small capacitor to the mixer.

When working with uhf tuners do not forget that every connection and every conductor, straight or otherwise, which are in plate, grid, and cathode circuits may act as an inductor and affect the oscillator frequency. When one end of a conductor is grounded, even though the conductors be short in inches, the other end may not be at ground potential. This is because there is inductance and inductive reactance between ground and the ungrounded end. The ungrounded end of the conductor may be no more at ground potential than would be the ungrounded end of a coil.

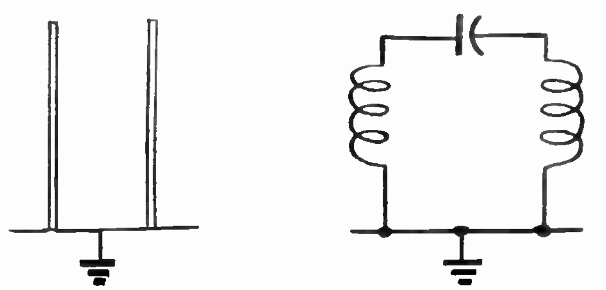

Fig. 9. A uhf inductance-capacitance circuit may consist of nothing more than two straight conductors.

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Fig. 9 shows a possible uhf circuit at the left, and at the right its electrical equivalent for lower frequencies. Straight conductors are equivalent to coils. The conductors and any kind of insulation between them are equivalent to a capacitor. Ungrounded portions of conductors in uhf circuits are equivalent to what we call the high sides of coil-capacitor circuits used at lower frequencies.

In Fig. 10 the oscillator of diagram 1 is tuned by end capacitance on a coaxial resonant line, in somewhat the same manner as explained earlier. The plate-grid circuit of the tube is completed through outer and inner conductors of the tuned line. Injection voltage for the mixer is taken from the grid side of the oscillator circuit, at the inner conductor of the resonant line, through a small capacitor to the mixer circuit.

In diagram 2 the injection voltage for the mixer is taken from the heater of the oscillator tube, at a point above the r-f choke from heater to ground. Actually the injection voltage is taken from the oscillator cathode, but capacitance between cathode and heater provides the coupling. The adjustable inductor and capacitor on the lead from oscillator grid to shorted resonant line are used for alignment or tracking of the oscillator.

Fig. 11 illustrates a method of obtaining enough variation of inductance and capacitance in an oscillator circuit to allow tuning throughout the uhf band. It is quite a problem in design to provide a wide tuning range, chiefly because there is so much stray capacitance and stray inductance in all the circuits. Such capacitance and inductance cannot be varied during tuning, and they make up such a large portion of capacitance and inductance which are resonant at ultra-high frequencies that the variable elements must have maximum possible effect.

The principle utilized in Fig. 11 is that of varying both capacitance and inductance in

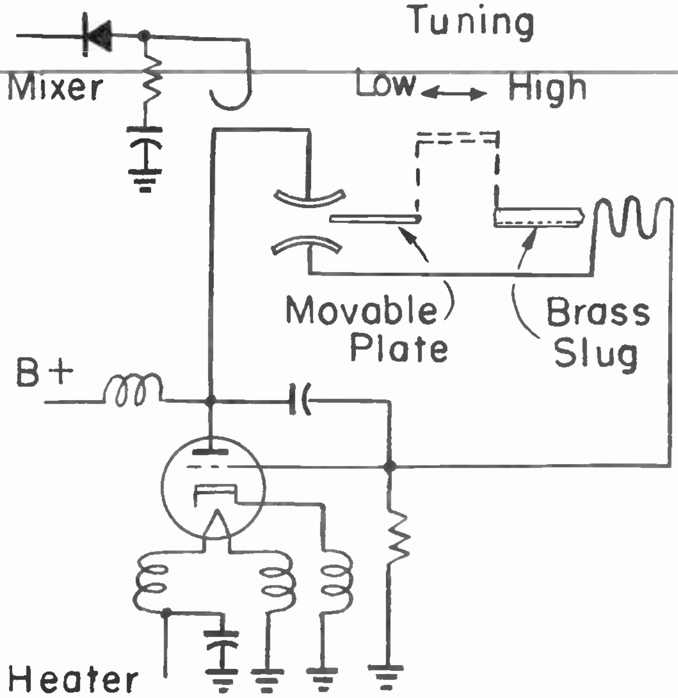

Fig. 11. A wide tuning range is obtained by varying both capacitance and inductance in the oscillator grid-plate circuit.

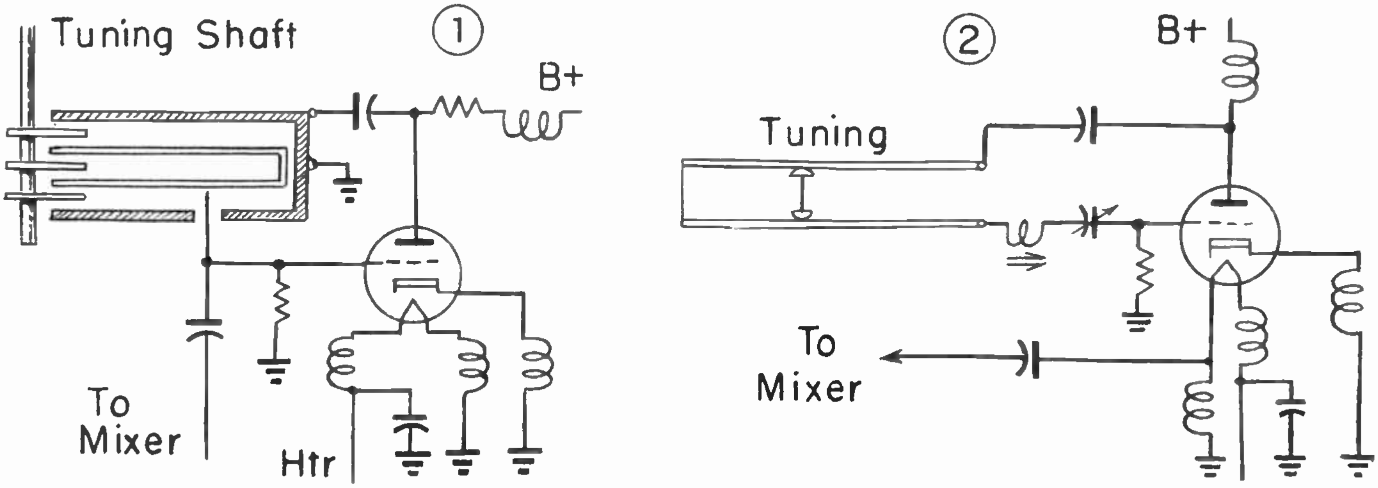

Fig. 10. Tuning circuits for uhf oscillators, and points from which injection voltages are taken.

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the plate-grid circuit. For tuning to lower frequencies the movable plate of the capacitor moves farther into mesh with the stationary plates to increase capacitance. The brass slug moves farther out of the inductor winding, thus increasing the effective inductance. You will recall that this is the effect of a non-magnetic movable core in an inductor. For tuning to higher frequencies the capacitor plate moves out, to lessen the capacitance, while the brass slug moves into the inductor winding to decrease the effective inductance.

Fig. 11 illustrates another case of taking injection voltage through a pickup loop placed near some part of the oscillator circuit. Within the shielded compartment which encloses any oscillator, all around the parts of the plate-grid circuit, are alternating magnetic or electric fields whose frequency is that of the oscillator. Any bare or insulated wire extending into the shielded compartment can pick up enough energy at the oscillator frequency to provide injection voltage for a mixer. These pickup conductors may be moved closer to oscillator circuit conductors to increase the injection voltage, or farther away to lessen the voltage.

Frequency drift of the uhf oscillator may be more troublesome than drift in vhf tuners. Frequency drift, its causes and remedies, are discussed at some length in the lesson on "Television Tuners". Drift in uhf tuners of usual construction commonly ranges from 0.15 to 0.20 of one per cent. Were total drift divided equally between top and bottom of the uhf band, with zero drift at the center, a sound intermediate which should be 41.25 mc would shift to about 42.15 mc at the low end of the band, and to about 39.50 mc at the high end.

Such changes of intermediate frequency would prevent reproduction of sound with a dual or split sound system in the receiver, but would be much less troublesome with intercarrier sound. With intercarrier sound it may be necessary to retune once or twice during the first two or three minutes after the set is turned on, while with dual sound it may take five minutes or more for reception to stabilize.

<u>OSCILLATOR HARMONIC FREQUENCIES.</u> There are several uhf tuners in which the oscillator operates at a fundamental frequency which is only half the frequency required for beating with received carrier frequencies at the mixer. The oscillator produces various harmonic frequencies at the same time. The second harmonic, or sometimes the third, is selected from the oscillator output and applied to the mixer.

For an example of using a second harmonic frequency assume that reception is on channel 39, and that the video intermediate frequency is to be 45.75 mc. At the mixer we require, from the oscillator system, a frequency equal to the sum of the video intermediate and video carrier frequencies. For channel 39 this would be 667.0 mc. The oscillator is tuned to half this frequency, which would be 333.5 mc, and furnishes also a second harmonic at the desired 667.0 mc.

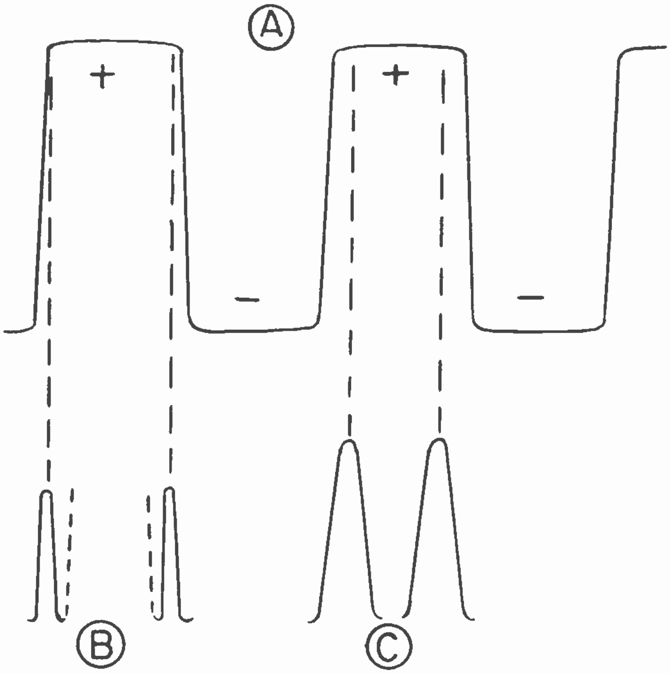

Fig. 12. A voltage or current wave with flattened peaks is made up of many harmonics in addition to the fundamental.

Any oscillator will produce frequencies which are harmonics of its fundamental because the current waveform is distorted as shown, quite exaggerated, at A of Fig. 12. Positive alternations are flattened because of saturation when the grid goes momentarily

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positive. Negative alternations are flattened by plate current cutoff.

Any waveform in which peaks of alternations are flattened is made up of a fundamental frequency and numerous higher frequencies, which are harmonics. Following is a simplified explanation of how this comes about.

In the steeply rising and falling sides of the distorted waveform, current is increasing and decreasing at the same rate as in the sine-wave alternations at B. Each of these sine waves is narrower or of less time duration than the distorted wave up above. Accordingly, the sine-wave frequency must be higher than the fundamental frequency. The waves at B would not fill in an entire distorted alternation, but a further partial fill-in would result from adding sine waves of somewhat lower frequency, as at C.

By adding together the currents of enough sine waves of different frequencies we could reproduce the flattened wave which is the actual output of the oscillator. All these added sine waves would be narrower, or of less time duration, than the distorted fundamental wave. Consequently, all the sine waves would be at frequencies higher than the fundamental, and would be harmonics. The fact is, that the oscillator output is distorted because of harmonic frequencies added to the fundamental by saturation and by plate current cutoff. The oscillator output really consists of a combination of the fundamental and numerous harmonic frequencies.

The principle just explained is employed in the uhf tuner of Fig. 13. The oscillator plate-grid circuit is tuned to the fundamental frequency. The cathode circuit, in which exists oscillator output current, is tuned to the desired harmonic frequency. This may be the second or third harmonic of the fundamental. In the tuned cathode circuit are strong current and voltage at its resonant frequency, which is the harmonic frequency desired. But all other harmonics as well as the fundamental oscillator frequency are greatly weakened. Voltage at the tuned harmonic frequency is taken through a capacitive connection to the mixer.

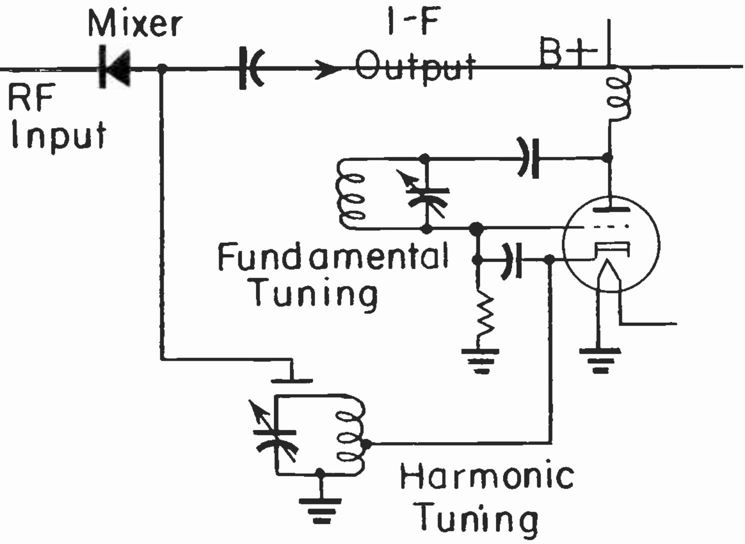

Fig. 13. An oscillator circuit which produces a fundamental frequency and also a harmonic frequency.

HARMONIC GENERATORS. If harmonic frequencies are to exist naturally in the current waveform produced by an oscillator, the oscillator circuit must be of a type which tends to produce harmonics. This is true of the Hartley circuit and most of its modifications. But Colpitts oscillator circuits and push-pull oscillators, which have certain advantages for high-frequency operation, tend to suppress harmonic frequencies and to produce an oscillatory waveform which rather closely approaches a sine wave. With these oscillators it is necessary to change the output wave to a form in which there are strong harmonics, which means a wave with flattened peaks. This is accomplished by a harmonic generator.

Fig. 14 illustrates the principle of a harmonic generator utilizing a crystal diode as a rectifier. Oscillator output voltage, of approximate sine-wave form, is applied to one side of the crystal diode. The diode allows electron flow only during alternations which make the anode positive with reference to the cathode. That is to say, the diode rectifies the oscillator output waveform and cuts off alternations or peaks of one polarity.

The other side of the crystal diode is connected to a harmonic selector circuit which is tuned to the desired harmonic frequency. This harmonic selector circuit is coupled to the mixer circuit, and furnishes

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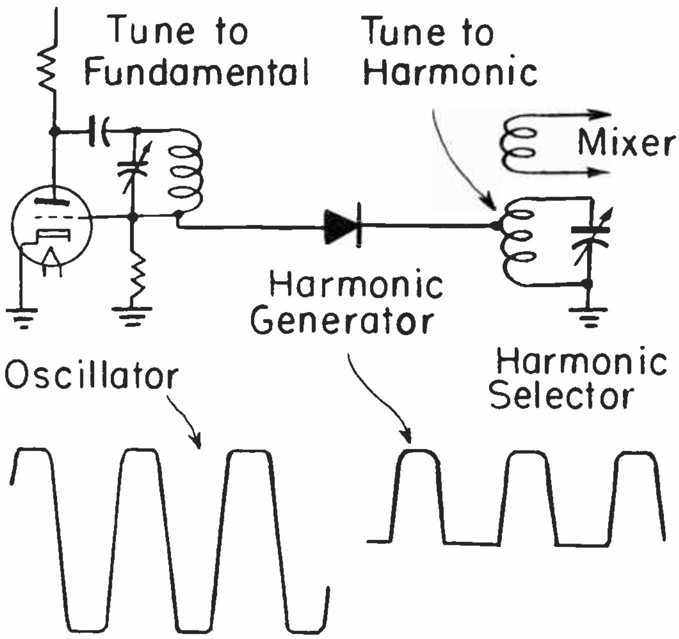

Fig. 14. A crystal diode flattens the oscillator output wave to produce harmonics which excite a tuned selector circuit.

to the mixer an oscillatory voltage whose frequency is that required for beating with received carrier frequencies.

Fig. 15 is the circuit for a push-pull oscillator from which is taken a second harmonic frequency developed by a harmonic generator crystal and selected by a tuned circuit consisting of a resonant coaxial line. The circuit in which is the harmonic generator crystal is coupled to the oscillator plate circuit by a pickup loop. One side of the harmonic generator is coupled into the harmonic selector, from which the second harmonic frequency goes to a crystal mixer along with r-f carrier frequencies.

In series between the anode of the harmonic generator crystal and ground is a biasing resistor bypassed with a small capacitor. The purpose of the biasing resistor is to maintain the anode of the crystal at an average negative potential which must be overcome by positive alternations of oscillator voltage before rectified current may flow in the crystal.

The effect of this negative bias on the crystal anode is to prevent conduction except on the positive peaks of oscillator voltage.

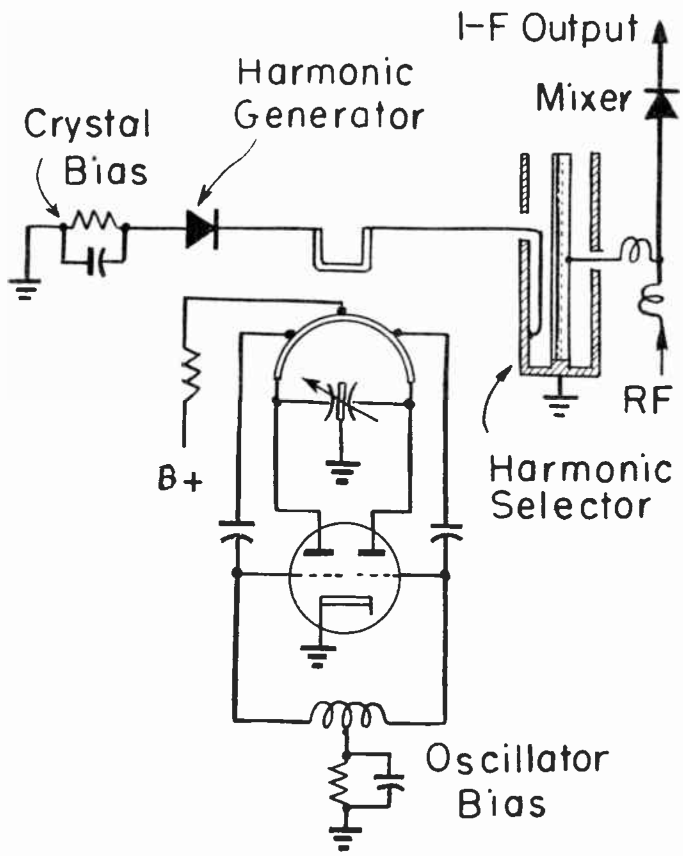

Fig. 15. A push-pull uhf oscillator with harmonic generator and selector.

Then conduction current in the harmonic generator diode consists of a series of sharp, separated pulses. The pulses shock excite the selector circuit, maintaining its oscillatory current at the tuned harmonic frequency. The value of biasing resistance depends on how the remainder of the circuit is designed, and on whether d-c voltage from the oscillator plate circuit reaches the generator crystal. In different tuners the biasing resistance may range from a few hundred ohms to several hundred thousand ohms.

Fig. 16 shows a method of using harmonic generator and selector circuits on a uhf channel strip for a turret tuner. Circuit elements and connections above the broken line are on the strip, those below are in the tuner chassis. The oscillator tube is the same one used for vhf reception. When the turret is rotated to the position carrying the uhf strip, the plate and grid of the oscillator tube are connected to an inductor which tunes the oscillator to the required fundamental frequency. This inductor may be aligned by

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as to cut off all or nearly all of the negative alternations of plate current.

Frequency multiplier systems for uhf tuning are used both for single conversion and for double conversion. For single conversion the i-f output of the uhf mixer must be at the intermediate frequencies used in the i-f section of the receiver. Most often these frequencies are 41.25 mc for sound and 45.75 mc for video. Since oscillator frequency for single conversion must be higher than received carrier frequencies, the oscillator harmonic applied to the uhf mixer must be higher than carrier frequencies in the uhf channel being received.

Fig. 18 illustrates single conversion as it might be carried out for reception of uhf channel 39 with a receiver having a turret tuner in which strips are inserted for one or more uhf channels. The receiver video intermediate frequency is assumed to be 45.75 mc. Within the broken lines are represented all the circuit elements carried by a turret strip. At each coupling or resonant circuit are shown frequencies for the video carrier, the video intermediate, and the oscillator fundamental and harmonic for reception of channel 39. The sound carrier would be 4.5 mc higher than the video carrier, and the sound intermediate would be 4.5 mc lower than the video intermediate. Strips for other uhf channels would have circuit elements resonating at frequencies suitable for each channel.

The tube which acts as r-f amplifier for vhf reception now becomes the first i-f amplifier for uhf reception, because its grid and plate circuits are tuned to 45.75 mc by inductors and capacitors on the channel strip. The tube which is a mixer for vhf reception is similarly tuned to 45.75 mc by turret strip inductors and capacitors, and becomes the second i-f amplifier for uhf reception. The vhf oscillator furnishes a fundamental frequency whose fourth harmonic is obtained by means of the harmonic generator and harmonic selector. This harmonic is applied to the uhf mixer.

The oscillator fundamental is 166.75 mc. The fourth harmonic is 667.00 mc, which is higher than the carrier frequencies of channel 39. The difference between this fourth

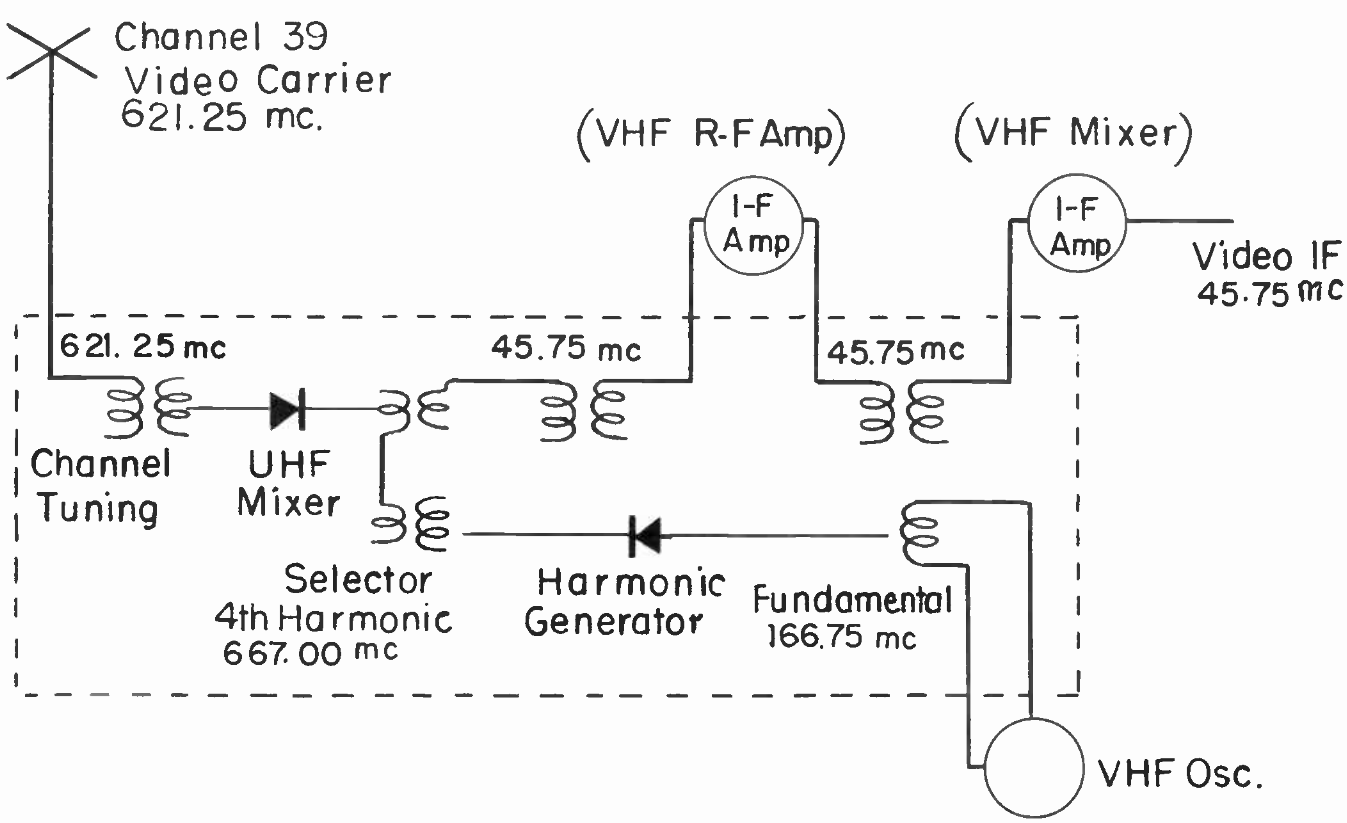

Fig. 18. Circuit elements and connections on a turret strip for single conversion.

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harmonic and the video carrier is 45.75 mc, the required video intermediate frequency.

When a frequency multiplier system is used with double conversion the conversion from uhf carrier frequencies to a first intermediate occurs in the uhf mixer. Here the uhf carrier frequencies beat with a harmonic frequency derived from the vhf oscillator by means of the harmonic generator and selector. The resulting first intermediate will be in the same general range of frequencies as vhf carriers, but will not be just the same as any vhf carrier.

Fig. 19 shows how the double conversion process may be carried out for reception of uhf channel 39 on a receiver whose video intermediate frequency is 45.75 mc. Again we assume a turret tuner on which strips for uhf channels carry the circuit elements shown within broken lines.

The oscillator fundamental frequency is 166.75 mc. The harmonic selector circuit is tuned to the third harmonic, which is 500.25 mc. Note that this frequency is lower than carrier frequencies in channel 39, as is required in the first step of a double conversion system. The difference between the video carrier and the third harmonic of the oscillator is 121.00 mc. This first intermediate frequency is applied to the grid circuit of the r-f amplifier in the tuner. This grid circuit is tuned to 121.00 mc by inductors and capacitors on the turret strip.

The plate circuit of the r-f amplifier and the grid circuit of the mixer tube likewise are tuned to 121.00 mc by inductors and capacitors on the turret strip. To the grid circuit of the mixer tube is applied also the oscillator fundamental frequency of 166.75 mc. Note that this oscillator frequency is higher than the first intermediate. The difference between the oscillator fundamental and the first intermediate is 45.75 mc. This is the second intermediate frequency, resulting from the second conversion. It is fed to the i-f amplifier section of the receiver.

The r-f amplifier tube is amplifying the first intermediate which comes from the uhf mixer, just as this tube would amplify a vhf carrier during vhf reception. The mixer

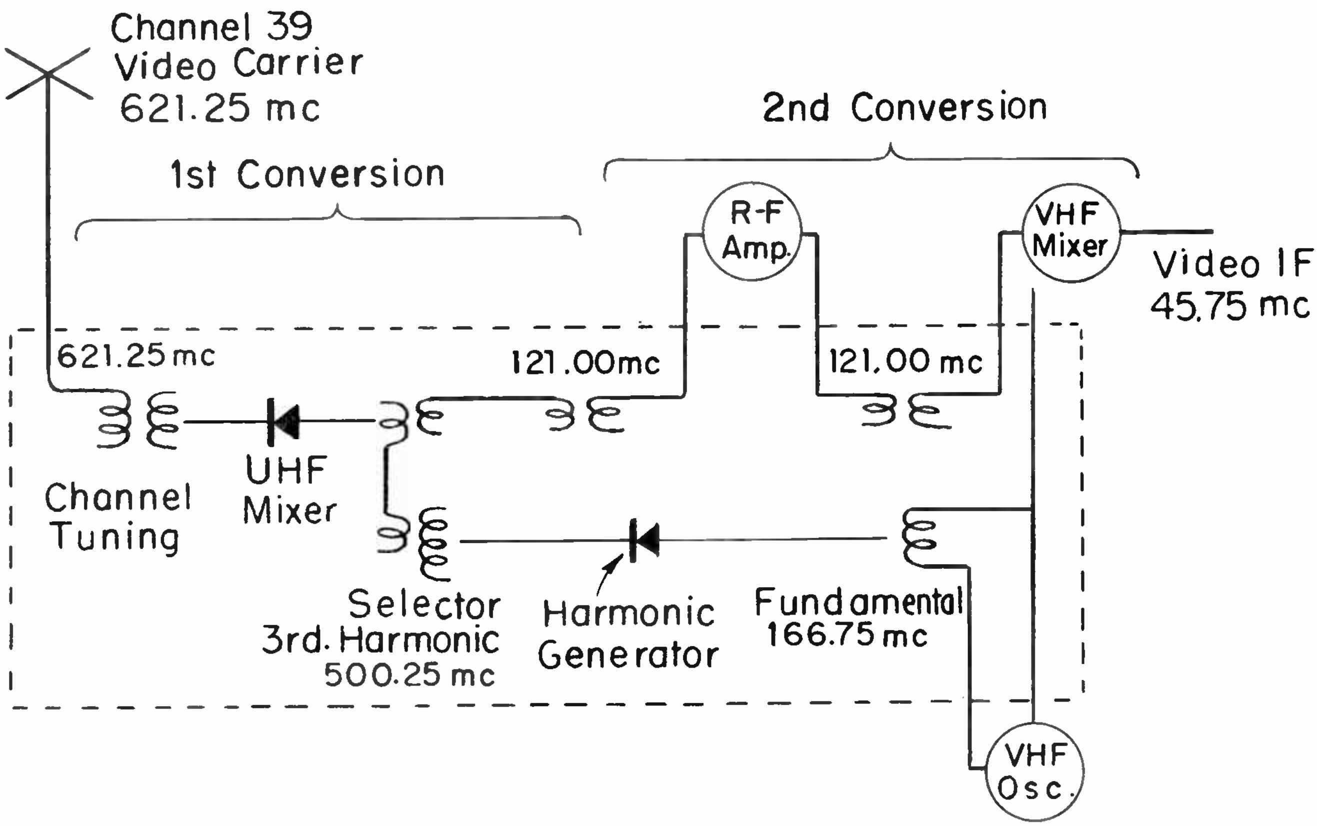

Fig. 19. Circuit elements and connections on a turret strip for double conversion.

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tube provides a conversion gain of the same order as gain during vhf reception.

Although we have used a fourth harmonic in Fig. 18 and a third harmonic in Fig. 19 to illustrate principles of single and double conversion, it would be possible to use second, third, or fourth harmonics, or even fifth and higher harmonics, for either kind of conversion. It is possible also to design these systems for any intermediate frequencies which happen to be used in the i-f section of a receiver.

As an example, supposing we have a receiver whose video intermediate frequency is 26.10 mc, and wish to receive uhf channel 39 by using the fourth harmonic of the vhf oscillator fundamental frequency. The various frequencies for double conversion would be as shown by Fig. 20.

The oscillator fundamental frequency is 129.47 mc, obtained by tuning the plate-grid circuit of the oscillator. The fourth harmonic of the oscillator frequency is 517.88 mc, obtained from the harmonic generator and selector circuits. This fourth harmonic

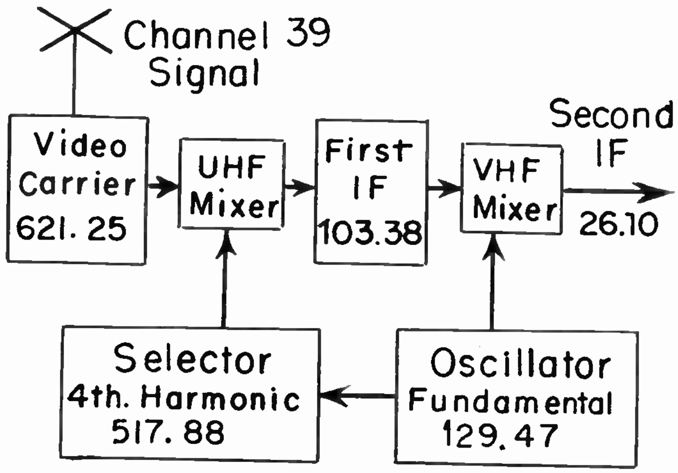

Fig. 20. Double conversion frequencies for channel 39 when the video intermediate of the receiver is to be 26.10 mc.

beats in the uhf mixer with the video carrier or 621.25 mc for channel 39. The difference frequency or first intermediate is 103.37 mc. This first intermediate is applied to the vhf mixer, along with the fundamental frequency from the oscillator. The difference, which is the second intermediate, is 26.10 mc. This is the assumed video intermediate of the receiver.

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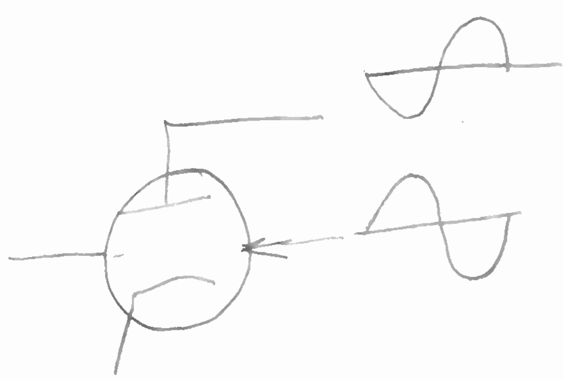

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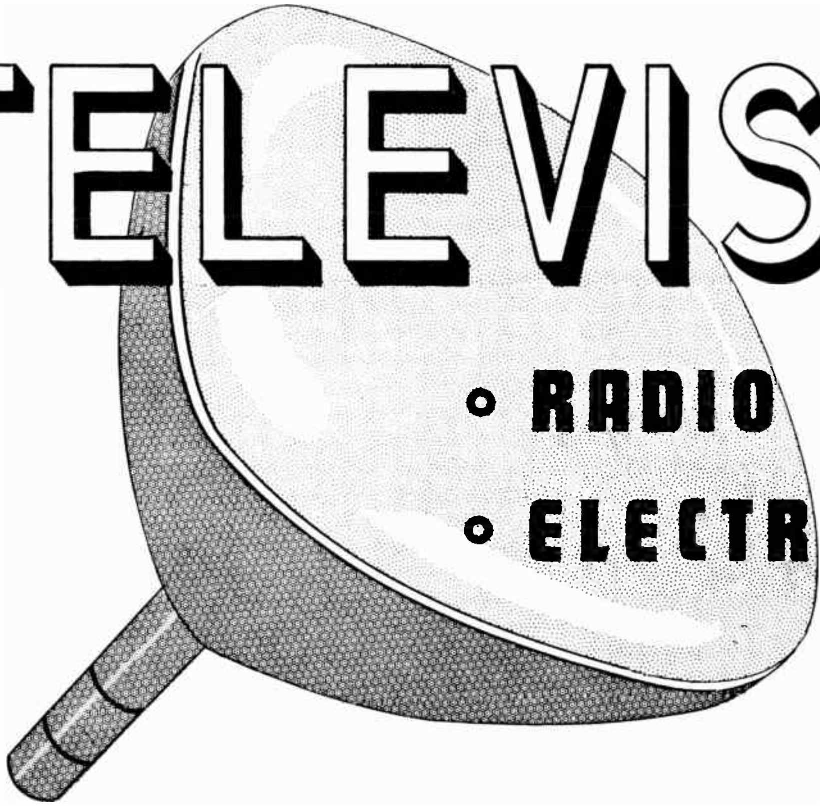

• RADIO
• ELECTRONICS

LESSON 94 — ULTRA-HIGH FREQUENCY RECEPTION — PART THREE

Coyne School

practical home training

Chicago, Illinois

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Lesson 94

ULTRA-HIGH FREQUENCY RECEPTION – PART THREE

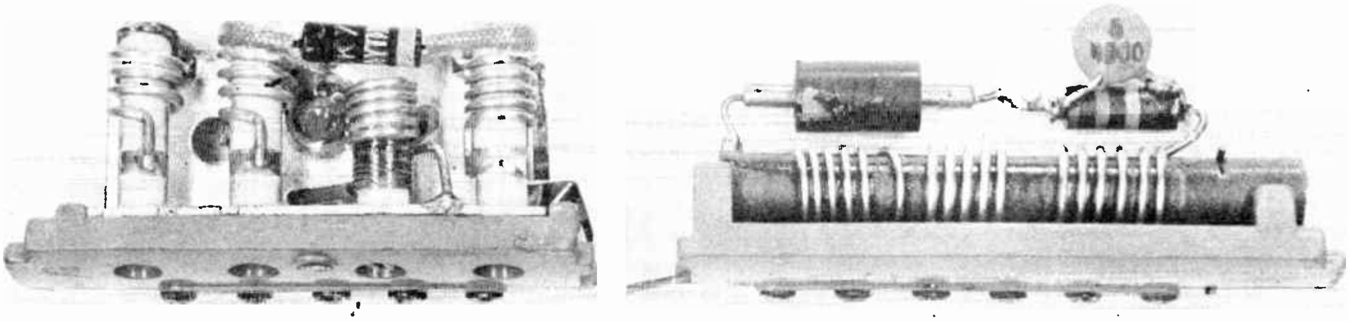

Fig. 1. Tuning inductors and capacitors, together with crystal diodes, mounted on strips for a turret tuner.

In Fig. 1 are two uhf strips which may be substituted for a pair of vhf strips on the drum of a turret tuner. The vhf strips removed, pictured by Fig. 2, are those for a channel not locally active. When the exchange has been made, a uhf channel will be received with the turret drum in the position formerly assigned to the inactive vhf channel.

The uhf strips illustrated are designed for double conversion, and for using a harmonic from the vhf oscillator in combination with a harmonic generator and selector. On the uhf strip at the left are inductors and alignment capacitors for antenna and mixer input circuits, also a crystal diode mixer, an inductor and tuning capacitor for the harmonic selector circuit, and a tuned transformer which couples the output of the uhf mixer to the r-f amplifier tube of the tuner.

On the uhf strip at the right is the harmonic selector crystal, also the resistor and bypass capacitor for biasing this crystal. In addition there are three inductors on this strip, one for the plate circuit of the r-f amplifier, another for the grid circuit of the mixer and a third for the oscillator circuit.

Referring now to the vhf strips of Fig. 2, note that the one at the left has five contact studs on what would be the outside of the strip when in place on the tuner drum. The corresponding uhf strip also has five contact studs, in the same relative positions. This left-hand vhf strip carries tuning inductors for the antenna and for the grid circuit of the r-f amplifier.

The right-hand vhf strip has six contact studs in the same positions as six studs on the uhf strip at the right in Fig. 1. This vhf strip carries three inductors, one for the plate circuit of the r-f amplifier, a second for the grid circuit of the vhf mixer, and a third for the vhf oscillator circuit.

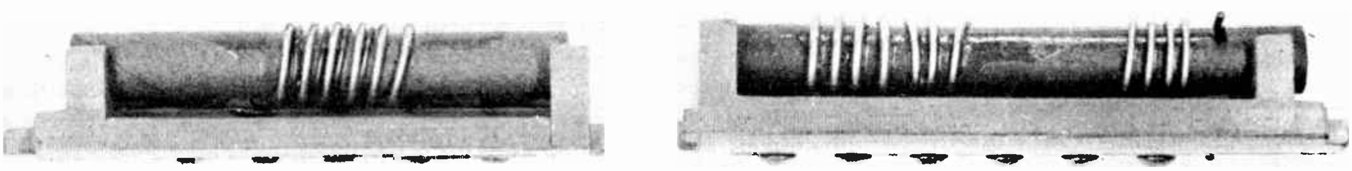

Fig. 2. These strips, for tuning one vhf channel, are replaced on the turret drum by strips for tuning one uhf channel.

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When substituting channel strips on a turret drum make sure that they will clear all parts of strips in adjacent positions. Uhf strips of the style pictured by Fig. 1 extend too far into the drum to have clearance from each other if in adjacent positions. Vhf strips must be on both sides of each uhf strip, since the vhf strips carry components small enough to leave plenty of clearance.

To make an exchange, remove the vhf strips, then insert the uhf antenna strip. While inserting the uhf oscillator strip carefully guide the small pin on this strip into the sleeve on the antenna strip. There must be good contact, and the pin must not be bent. While handling uhf strips of any kind guard against any altering of spacing between wires or of relative positions of other circuit elements.

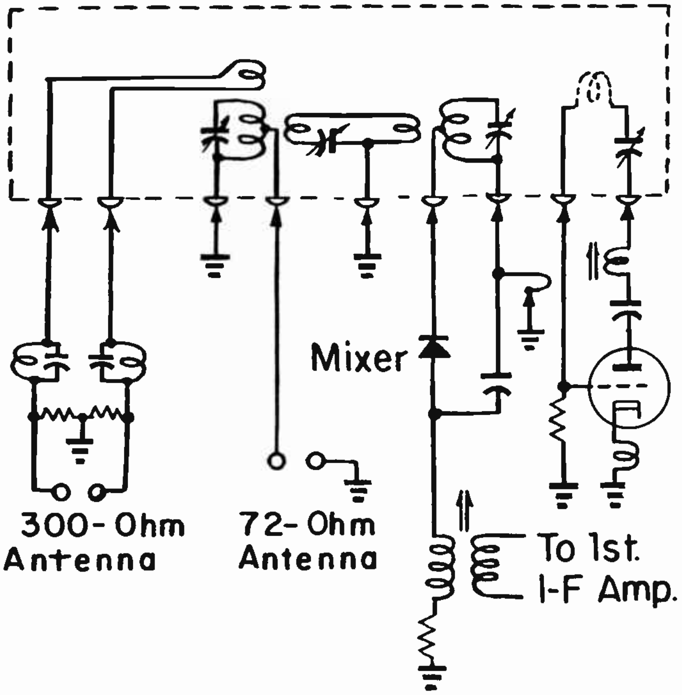

Fig. 3. Connections of a channel strip for a turret tuner in which the crystal diode mixer is within the tuner chassis.

Fig. 3 is a circuit diagram of a uhf turret strip designed for single conversion. This particular type is for insertion in any of four positions on a tuner drum having a total of 16 positions, with the other 12 positions used for vhf channels 2 through 13. Any of the additional four positions not used for uhf channels are fitted with a blank strip, which later may be removed when a uhf strip is to be inserted.

On the turret strip of Fig. 3 are separate inputs for a 300-ohm antenna and transmission line, and for a 72-ohm coaxial line. The crystal diode mixer and the triode oscillator tube are in the tuner chassis. These two are used for both uhf and vhf reception. The oscillator circuit inductor shown by broken lines is used on strips for low uhf channels but not on those for the higher channels.

Since circuit elements on the strip of Fig. 3 are different from those on vhf strips for the same tuner, the two kinds of strips do not have all their contact studs in the same relative positions. This allows making suitable connections from either kind of strip to circuits and tubes in the tuner chassis.

AN 82-CHANNEL STEP TUNER. An extension of the principle of using turret strips for a few uhf channels, along with other strips for vhf channels, is found in a turret tuner providing step tuning for all 82 television channels, 12 in the vhf bands and 70 in the uhf band.

The vhf portion of this combination unit is similar to turret tuners with which we have become familiar, having 12 pairs of drum strips for vhf channels 2 through 13. On the front of the vhf section is the added uhf tuner, also a turret type but having only eight strips. Each of these uhf strips carries a set of inductors which may be tuned by variable capacitors to any one of as many as ten uhf channels.

With the first of the uhf strips in its operating position, the variable capacitors tune the antenna-mixer selector circuits and the uhf oscillator over a range covering uhf channels 14 through 19. The second uhf strip allows tuning through channels 20 through 29. Each of the next five uhf strips allows tuning through ten additional channels, ending at channel 79. The eighth strip tunes through uhf channels 80 to 83.

Circuit elements mounted on each of the uhf strips are shown within broken lines at the top of Fig. 4. Each of two antenna-mixer

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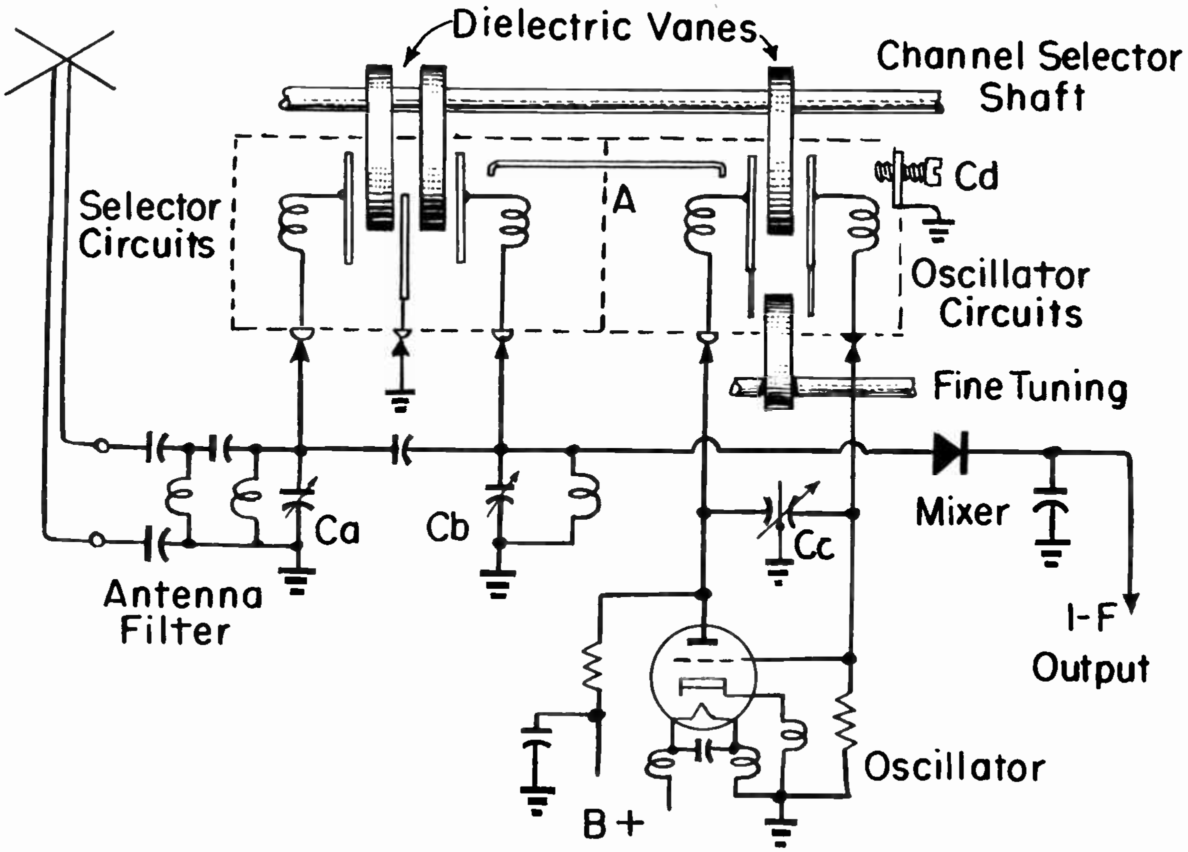

Fig. 4. Circuits of one of the uhf strips, together with elements carried on the chassis and the dielectric tuning vanes, for an 82-channel step tuner.

selector circuits consists of a small air-core coil connected at one end to a stationary capacitor plate and at the other end to a contact stud on the drum strip. A third stationary capacitor plate is grounded. Any one of the group of uhf channels handled by each strip may be tuned in by dielectric vanes which enter the spaces between stationary capacitor plates as the vanes are rotated by their shaft. Varying the capacitor dielectric area between stationary plates changes the capacitance and the resonant frequency to suit a desired uhf channel.

The oscillator circuit consists of two small coils and two stationary capacitor plates, with tuning for channels in the group by means of another dielectric vane. Fine tuning is accomplished by still another movable dielectric vane in the space between stationary capacitor plates. Oscillator injection to the mixer circuit is through the capacitances at opposite ends of a small wire where this wire comes close to an oscillator capacitor plate at one end and to a mixer capacitor plate at the other end. This wire is marked A in Fig. 4.

The dielectric vanes are not part of the drum strips but are mounted on a channel selector shaft that passes through the uhf drum. The same dielectric vanes are used for tuning all the uhf strips; the vanes pass between stationary capacitor plates of any strip which is brought into its operating position. Frequency range of each strip is determined by its coils, and by size and spacing of its stationary capacitor plates.

Capacitor Ca of Fig. 4 is an alignment trimmer for the antenna circuit. Cb is an alignment trimmer for the mixer input circuit, and Cc is a split stator alignment trimmer for the oscillator circuit. Antenna and mixer trimmer adjusters are accessible from the top of the tuner chassis. The oscillator trimmer is reached from underneath. At Cd is a screw that may be turned in to increase capacitance and lower the resonant frequency of the oscillator circuit, or out to

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decrease capacitance and raise the frequency. This screw is accessible from the front of the uhf tuner chassis. It is an alignment adjustment equivalent in effect to adjustment of slugs in oscillator coils on channel strips in many vhf tuners.

The method of channel selection is illustrated in principle by Fig. 5. Extending from the front of the combination uhf-vhf tuner is a central shaft around which are two tubular sleeves. The outer sleeve and a knob attached to it turn a shaft on which are fine tuning dielectric vanes for both the uhf and the vhf sections of the tuner. The uhf vane is the one shown in circuits of Fig. 4. The dielectric vane for vhf fine tuning is farther back on the same shaft. This vhf fine tuning vane moves between two metal capacitor plates in the vhf oscillator circuit, to accomplish fine tuning in much the same way as in other vhf turret tuners, except that neither capacitor plate is grounded in this combination tuner.

The middle sleeve and its attached knob rotate the uhf drum to bring into operating position any one of the strips on this drum. The drum is held at a selected position by a detent mechanism separate from that on the vhf drum. In one position of this middle sleeve and knob the strip for uhf channels 14 through 19 will be connected to the antenna, mixer, and oscillator circuits. The next position will bring in the strip for uhf channels 20 through 29, and each following position will bring into action the strip for another group of uhf channels.

There is a ninth position at which is no strip on the uhf drum. The drum is turned to this position for vhf reception. Note that in the vhf position of the middle sleeve and knob there will be no coils connected to the uhf oscillator, and this oscillator will be inoperative.

The central shaft extends all the way through the uhf drum, and rotates the vhf drum. This shaft and its knob are used for selecting vhf channels 2 through 13. The central shaft carries also the tuning vanes for uhf channels, so that this shaft is used not alone for vhf channel selector, but also for selection of any individual uhf channel of a group. Since the same shaft rotates both the vhf drum and the uhf tuning vanes, the detent mechanism that holds the vhf drum in position for each vhf channel also holds the tuning vanes on position for each uhf channel.

To select a vhf channel the knob for the middle sleeve is turned to its vhf position, which makes the uhf section of the tuner inoperative. Then the knob for the central shaft is turned to its position for the desired vhf channel, thereby rotating the vhf drum to the required position.

To select a uhf channel the knob for the middle sleeve is turned to the first numeral of the channel number. As an example, for channel 35 this uhf knob would be turned to its "3" position, thus bringing into action the uhf strip for channels 30 through 39. Then the knob for the central shaft would be turned

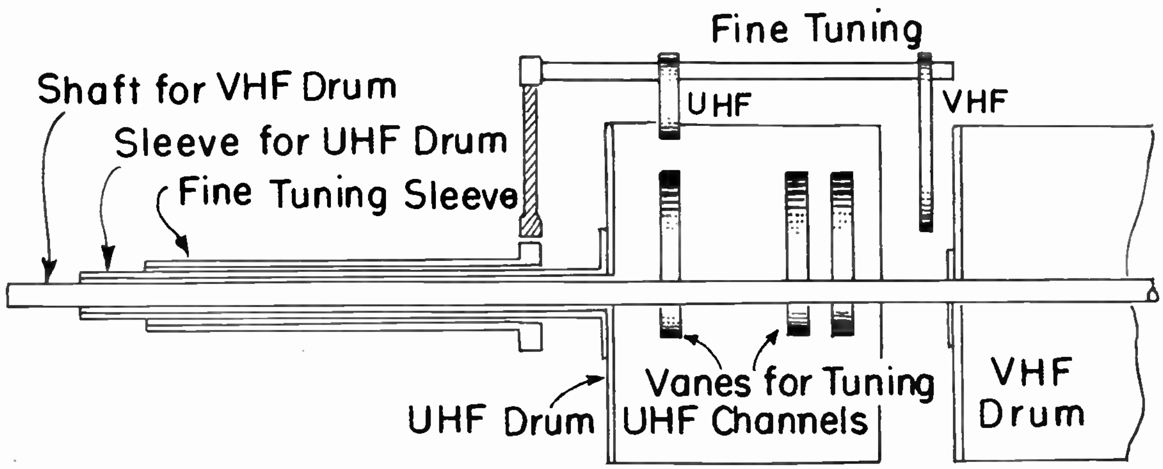

Fig. 5. Shafts and sleeves which operate the drums and the tuning vanes of the 82-channel tuner.

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to the second numeral, which in this case would be "5". This second operation would bring the uhf tuning vanes to their position for tuning channel 35 on the uhf strip that covers channels 30 through 39.

The combination tuner now being examined is a single conversion type. The tube which is a cascode r-f amplifier for vhf reception becomes a first i-f amplifier for uhf reception, the vhf mixer is changed to a second i-f amplifier, and the vhf oscillator is made inoperative. This change in the vhf section of the tuner is made by raising the spring contacts that bear on studs of the vhf drum strips, so that none of these strips for channels 2 through 13 can be active during uhf reception.

The coils for changing vhf r-f amplifier and mixer tubes to uhf i-f amplifiers are mounted on a strip of insulation which is rocked between its vhf and uhf positions by a cam mechanism on the back of the uhf section of the tuner. This changeover strip has contact studs which, in its uhf position, bear against the long spring leaves whose free ends normally rest on studs of the vhf strips. These are the springs that connect to tubes and other circuit elements in the vhf tuner section, as in other turret tuners. This action which connects the coils of the changeover strip to the springs, at the same time disconnects the springs from the vhf strips.

EXTERNAL CONVERTERS. Converters constructed as a separate unit, and designed for connection to the antenna terminals of any vhf receiver must, of course, operate on the double conversion principle. All these external converters must change the uhf carrier signals to signals at a vhf carrier frequency to which the receiver is tuned for all uhf reception. In the majority of cases the first conversion, in the converter unit, is to frequencies of vhf channels 5 or 6. Then the vhf receiver is tuned to one or the other of these channels, and there is a second conversion to the receiver intermediate frequency in the vhf tuner.

Signal output from the mixer of an external converter seldom would be so strong as signals picked up on a vhf antenna and applied to a vhf tuner. Consequently, nearly all converters include an amplifier stage between their mixer and the output connections to the vhf tuner. This amplifier stage operates at the vhf carrier frequency to which the vhf receiver must be tuned for uhf reception.

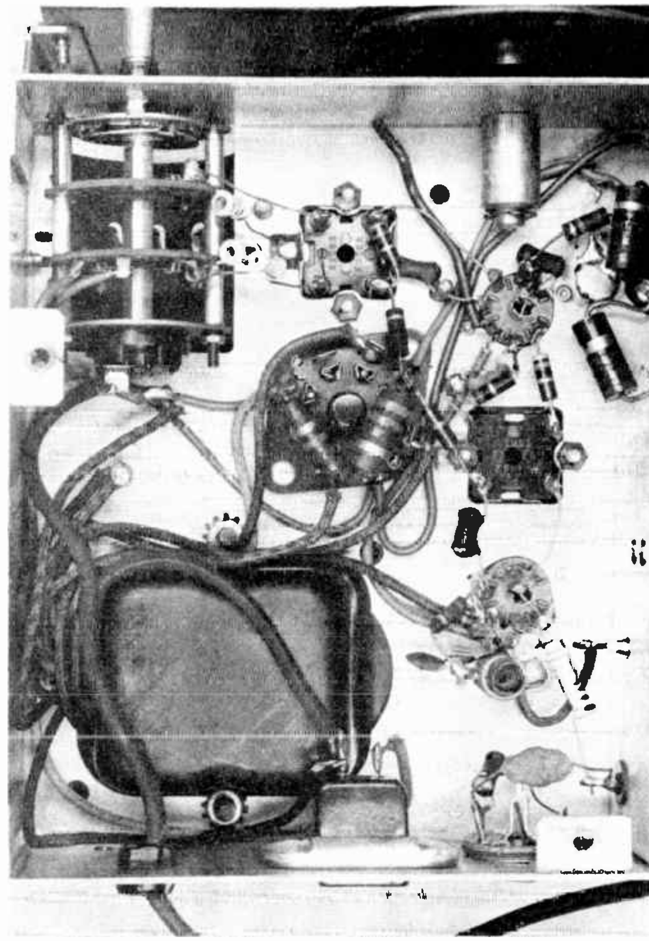

Fig. 6. Some of the under-chassis wiring of a uhf converter.

With converter output in the carrier ranges of channels 5 or 6 the amplifier in the converter will be operating at frequencies somewhere between 76 and 88 mc. These moderately high frequencies impose no great difficulties in circuit design and construction, which means that in the converter amplifier we find conventional units and wiring. Fig. 6 shows amplifier and switching connections, also part of the power supply wiring, underneath the chassis of a converter.

Most converters have their own d-c power supply for plate, screen, and biasing voltages, and for a-c current to tube heaters. Power rectifiers may be either miniature or

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GT size tubes, or may be selenium types. Half-wave rectification is common. Built-in units often obtain their d-c and a-c voltages and currents from the receiver power supply.

Amplifiers which follow the mixer in many converters are of cascode types described in the lesson on "Television Tuners", with the two sections of a twin triode connected in series for plate current. More often the triode sections are in parallel for plate currents, with the first one as a grid input amplifier and the second as a grounded grid type.

Many other types of amplifiers are used after the mixer in converters. At A of Fig. 7 are circuit connections for a twin triode whose first section is a grounded grid amplifier and whose second section is a grid input type. There are two alignment adjustments. The adjustable inductor La is effectively an impedance coupler between the crystal mixer and the cathode input of the grounded grid amplifier. Another impedance coupler, Lb, is between the plate of the first triode and the grid of the second.

The amplifier at B of Fig. 7 has two pentode tubes. The first is a triode-connected grounded grid amplifier, with plate, suppressor, and screw connected together. The second tube is a regular grid input pentode amplifier. Between the two tubes, and on the plate output of the second one, are double tuned transformers with additional adjustable capacitors for varying the degree of coupling and the pass band.

Other converter amplifiers employ only a single pentode tube. In any design the coupling between a crystal mixer and the amplifier input often is a single-tuned impedance coupler or transformer. In the output of the amplifier there is usually a two-winding transformer with separate adjusters for primary and secondary.

Adjustable transformers and couplers at the input and output of amplifiers which follow the mixer are used to align the amplifier to the vhf carrier frequency required for the tuner of the connected receiver. For instance, if the receiver is tuned to channel 5 or to channel 6 for uhf reception, the converter amplifier is aligned for the frequencies of whichever channel is to be used.

CONVERTER SWITCHING. In addition to a dial or other control for selecting uhf channels, a separate converter will have a switch for turning power on or off and for making a choice between uhf and vhf reception.

Connections on the back of a converter or on a terminal board usually are somewhat as shown by Fig. 8. The power cord of the vhf receiver is plugged into a receptacle on the converter. This receptacle is connected through the function switch to the converter power cord which, in turn, is plugged into the

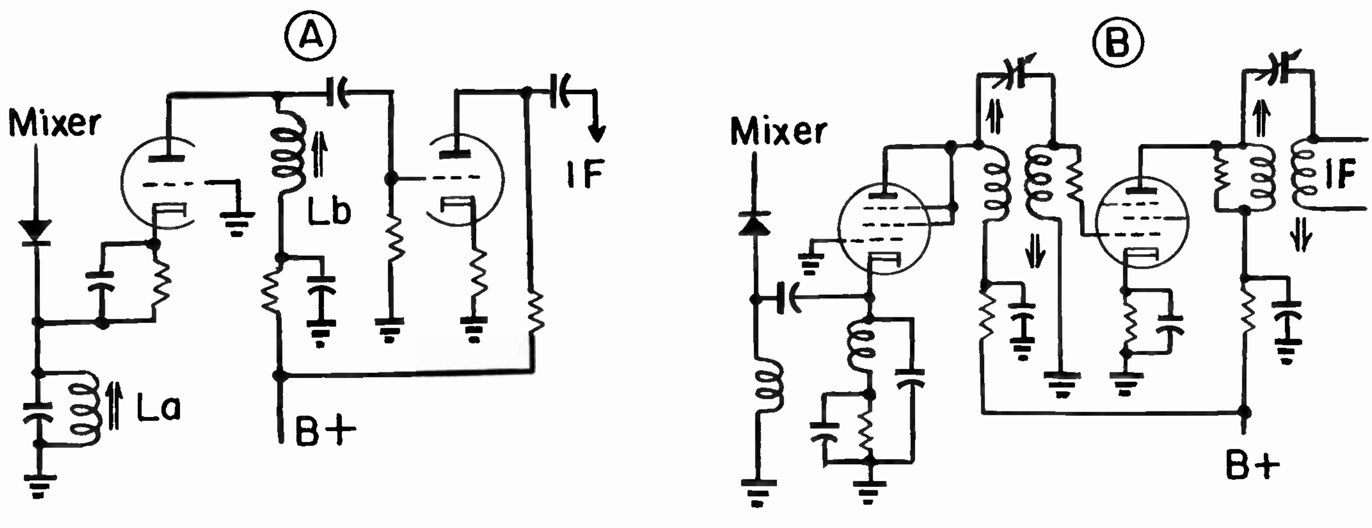

Fig. 7. Amplifiers used between the mixer and the vhf output of converters.

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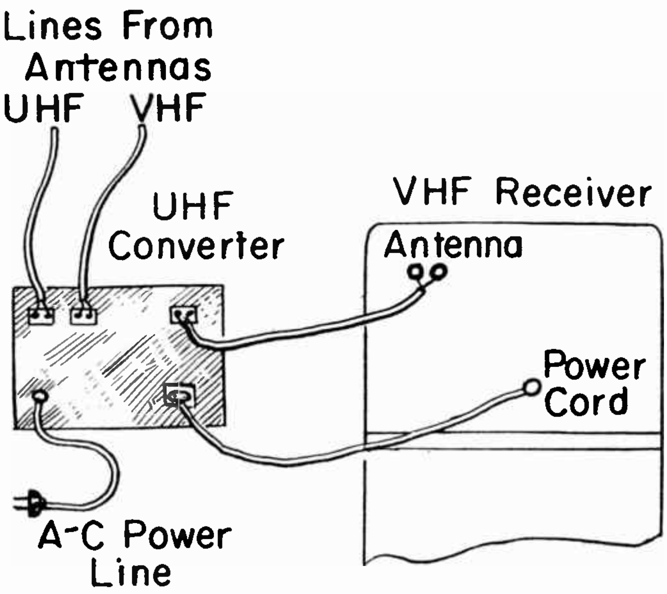

Fig. 8. Typical connections between a uhf converter and a vhf receiver.

a-c power line receptacle. Then converter and receiver may be turned on or off together, by the switch on the converter.

The transmission line from the vhf antenna is disconnected from the vhf receiver and connected to the vhf antenna terminals on the converter. Then a short piece of transmission line is run from other terminals on the converter to the antenna terminals of the receiver. With the converter switch in position for vhf reception, the vhf antenna now is connected right through the converter to the antenna terminals of the vhf receiver.

For uhf reception the converter switch disconnects the vhf antenna and connects the uhf antenna to input circuits of the converter. Signal output from the amplifier following the mixer in the converter is fed through the short piece of transmission line to the antenna terminals of the receiver. When a combination uhf-vhf antenna is used, with only a single transmission line, this line would be connected to converter terminals marked for such an antenna.

In Fig. 9 are typical switching connections for a converter in which the uhf antenna is permanently connected to the uhf input of the converter. This connection is not shown on the diagram, and is not affected by the switch. The switch consists of two wafers, or of sets of segments on front and back of a single wafer. The segments are shown in position for uhf reception.

Switch rotors and segments turn counterclockwise from the uhf position in going successively to the vhf position, then to the off position. The on-off switch, not shown by the diagram, is of the snap type commonly found on the backs of receiver volume controls and other controls. This on-off switch for line power is operated by the shaft of the selector switch.

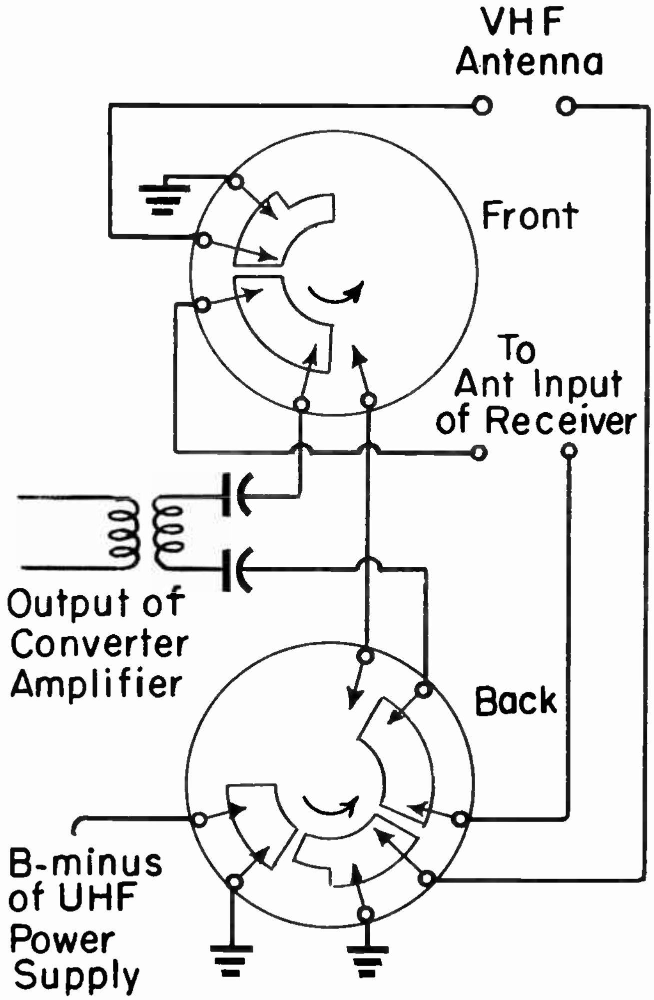

Fig. 9. Converter switching for separate uhf and vhf antennas and transmission lines.

For uhf reception the vhf antenna connections of the switch in Fig. 9 are grounded through front and back segments. Remember that the uhf antenna is permanently connected to the uhf input of the converter. The output transformer of the converter amplifier, shown on the diagram, is connected through

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front and back segments to terminals from which the short piece of transmission line ~~goes to the vhf antenna terminals on the~~ receiver. B-minus of the converter power supply transformer is grounded through one of the back segments, thus completing the ground return of d-c circuits for plates, screens, and biasing of converter tubes.

Rotating the switch one-twelfth turn counterclockwise from the position of Fig. 9 brings it to the vhf position. Ground connections are removed from the vhf antenna, and this antenna is connected through switch segments to the antenna input of the vhf receiver. The output of the converter amplifier is shorted on itself through front and back segments. B-minus of the converter power supply no longer is grounded, thus opening the d-c power circuit and removing B-voltage from converter tubes.

Another twelfth turn counterclockwise brings the switch to its off position. This opens the snap switch to remove a-c power from the converter power transformer, also from the vhf receiver when the receiver power cord connects through the converter as in Fig. 8. The uhf output of the converter remains shorted on itself. The vhf antenna remains connected to the antenna terminals of the vhf receiver. This allows the vhf receiver to be operated independently of the converter, with each unit connected through its own power cord to an a-c line receptacle.

In Fig. 10 are switching connections for a converter designed to operate from a combination uhf-vhf antenna with a single transmission line to the converter terminals. This switch, shown in its uhf position, is turned counterclockwise to the vhf position, then to the off position. The on-off power switch again is a snap type operated by the shaft of the selector switch.

The diagram shows the switch segments as connecting the combination antenna to leads which go to the uhf channel selector circuits in the converter. The output of the converter amplifier is connected to the receiver antenna terminals. One of the back segments shorts a resistor which is between the cathode of the power rectifier and the power supply filter. Shorting this resistor allows full B-voltage to converter tubes.

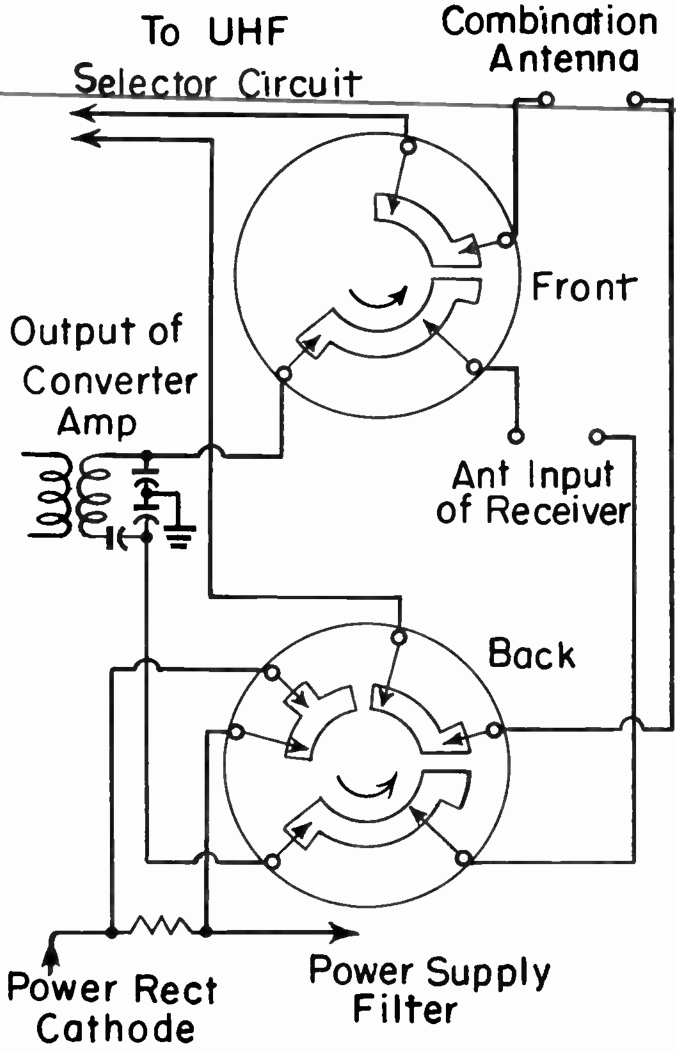

Fig. 10. Switching in a converter for a combination antenna and a single transmission line.

Moving the switch of Fig. 10 one-twelfth turn counterclockwise brings it to the vhf position. Then the combination antenna is disconnected from the converter input and is connected to the receiver antenna terminals. The uhf output of the converter is open circuited. The short is removed from the resistor in series with the power rectifier, thus dropping B-voltage on converter tubes so low as to make these tubes inoperative. In the off position each switch segment engages only one stationary contact, which has the effect of opening all circuits. The combination antenna does not remain connected to the vhf receiver.

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UHF ANTENNAS

The size of any television antenna is directly related to wavelength of signals to be received. Uhf wavelengths are so short that antennas for this frequency band are of small dimensions, and because they are small it is possible to make use of many designs which would be prohibitively large or heavy at very-high frequencies.

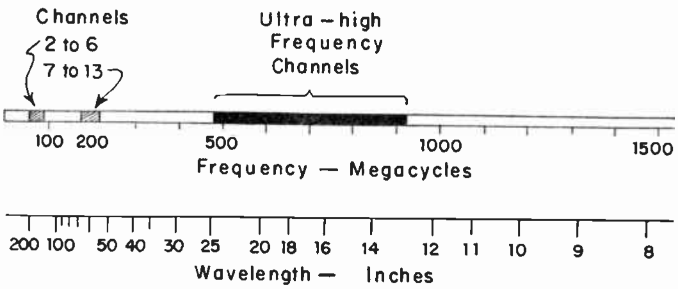

Fig. 11. Relations between wave lengths and frequencies in the several television carrier bands.

Wavelengths are related to carrier frequencies as shown by Fig. 11. In the very-high frequencies of channels 2 through 13, carrier wavelengths are between about 55 and 200 inches. In the ultra-highs the carrier waves are from about 13 to 25 inches long. Overall width of a half-wave uhf antenna cut for the middle of the band need be only about 17 inches.

For any given signal power radiated from a transmitter, the distance at which uhf signals have given strength is somewhat less than the distance at vhf signals have equal strength. Effective signal strength is further reduced by the greater losses in tuners working at ultra-high frequencies than in those for very-high frequencies.

The relatively short waves at ultra-high frequencies are reflected quite strongly from surfaces much smaller than those which may cause troublesome reflections at the lower carrier frequencies of the vhf bands. It is largely for this reason that uhf antennas should be sharply directional, and should have lease possible back response. Additional difficulties may result from the fact that objects between transmitter and receiver cause more sharply defined signal shadows than in vhf reception.

In spite of all the factors which tend to weaken uhf reception, built-in antennas may be satisfactory in localities where signals are strong. Because uhf antennas are small, a built-in type enclosed within a receiver cabinet may be of full dimensions without having to bend, coil, or otherwise deform the elements, as is necessary when getting a full-size vhf antenna into such limited space. With a built-in antenna there is, of course, no attenuation loss in a transmission line. The great objection to built-in uhf antennas is that they may pick up a great deal of noise along with signals.

When stations are to be received on only a few channels close together in the uhf band a Yagi antenna has the same advantages as for vhf reception. These advantages are high gain and sharp directional properties. If a Yagi is made with one or more dipoles of the folded type, with one dipole conductor larger than the other for broadening the band, it is possible to receive five or six adjacent channels at the low end of the uhf band. At the high end of the band these "broad-band" Yagis will cover as many as nine or ten adjacent channels.

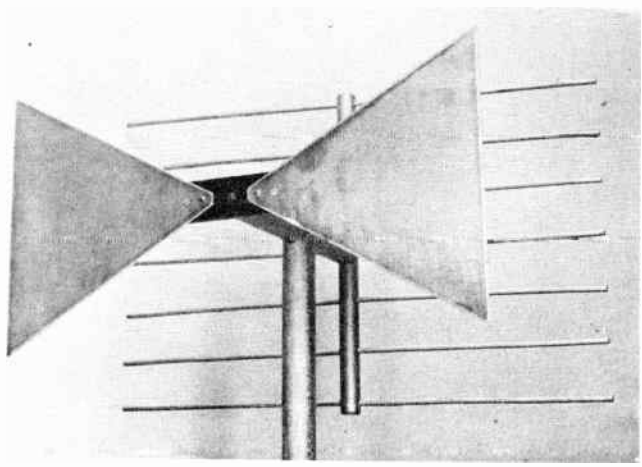

Fig. 12. A bow-tie or fan antenna for uhf reception.

A variety of antenna widely used for uhf reception, but entirely different from vhf types, is called a bow-tie, a fan, or a butterfly. The construction is illustrated by Fig. 12. The dipole elements are two triangular metal sheets mounted in a vertical plane. To the inner corners are connected the transmission line conductors. Back of the tri-

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angular elements is a reflector which, in the picture, consists of a number of metal rods mounted in a vertical plane. Reflectors often are made of open mesh metal screen instead of rods.

Making the dipole elements triangular instead of in the form of straight rods or tubes provides a solid or continuous sheet whose overall shape is like that of a conical antenna made with two or three rods or tubes fanned out from the center. The solid sheet construction increases band width to allow coverage all the way from channel 14 to channel 83.

The elements shown by the picture have angles of about 60 degrees where they come together at the center. This angle sometimes is as great as 70 degrees, and again as small as 35 to 40 degrees. Since this center angle determines total area of elements having any given overall width, the angle affects impedance at resonance. Impedance is affected also by spacing between the dipole elements and reflector.

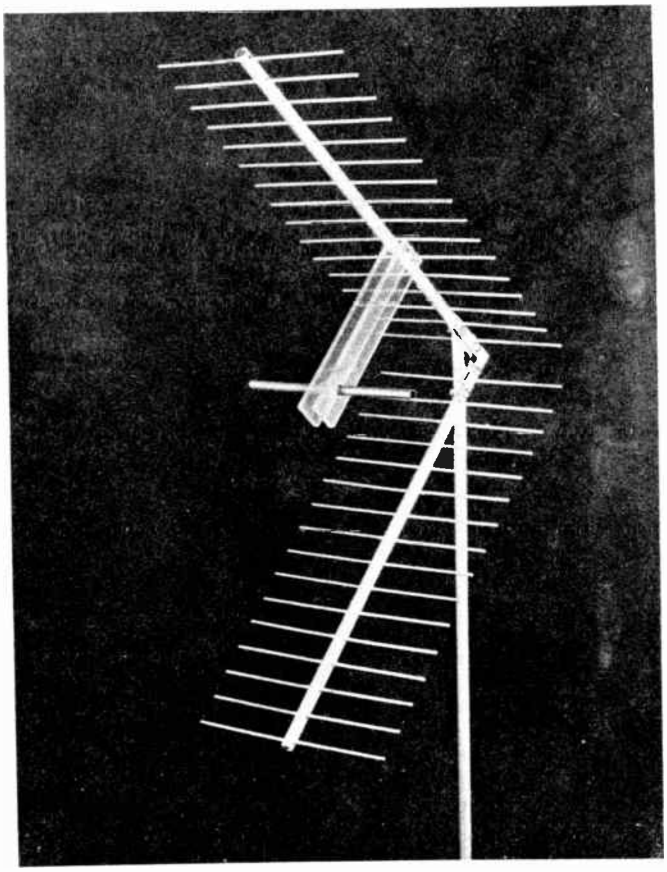

Fig. 13. A corner reflector uhf antenna.

A uhf antenna often used where gain must be greater than with a bow-tie is the corner reflector, of which one style is pictured in Fig. 13. The reflector consists of many metal rods arranged in two planes coming together at a corner behind the dipole element. The reflector rods may or may not be conductively connected together. The active element in the picture is a straight dipole. More often it is of bow-tie design with both triangular sheets bent at the same angle as the reflector corner. This is shown by Fig. 14.

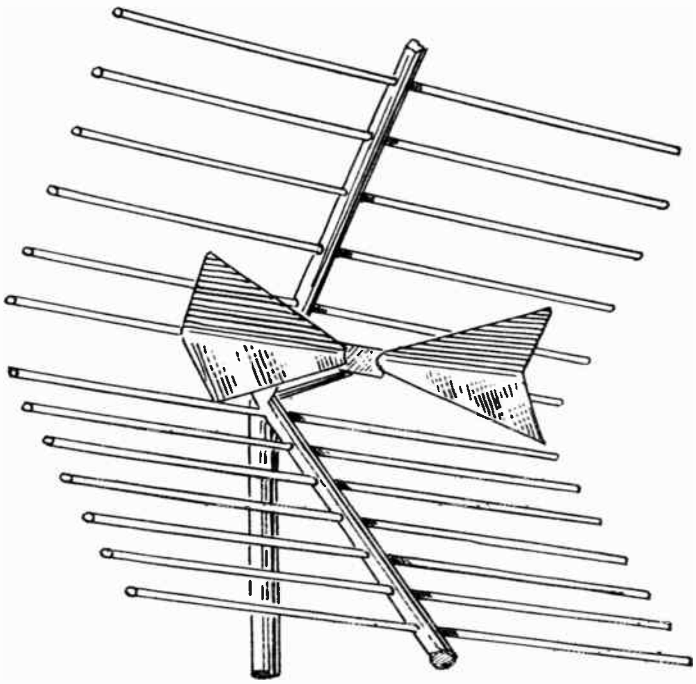

Fig. 14. A corner reflector antenna with dipole element of bow-tie shape.

Corner reflector antennas are made also with a folded dipole as the active element. To provide broad-band coverage and a desired resonant impedance one conductor of the folded dipole is much larger than the other. The larger conductor is toward the front of the antenna, with the smaller one toward the reflector corner.

Conductors which form the corner reflector do not behave electrically in the same manner as reflectors mounted behind dipole elements of other antennas. These other reflectors are of such length as to be resonant at carrier frequencies. Then reflected waves appear in the reflector, and there is reradia-

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tion of signal energy from reflector to dipole. Corner reflector conductors act as would a continuous sheet of metal. They reflect signal waves toward the dipole element just as a reflector for rays of light would reflect light waves. For this reason the length of corner reflector conductors, which is the overall side-to-side dimension of the antenna, is not at all critical.

There is no single point at which the corner reflector brings all reflected waves to a focus, but they are most concentrated along a line or plane extending directly forward from the corner. This would be a plane bisecting the corner angle.

The corner angle usually is 90 degrees, or square. A sharper angle would, in theory, increase the gain. But to realize more gain it would be necessary to increase the distance which both sides of the reflector extend forward from the corner, and to place the dipole element farther from the corner.

Bandwidth of the corner reflector antenna is great enough to include all uhf channels. The back-to-front ratio is small, there is hardly any signal pickup from either side, and very little pickup of waves coming from above or below a horizontal line.

Impedance of the corner reflector antenna would decrease rapidly were the corner angle made sharper than 90 degrees. With a plain dipole spaced about one-third wavelength from a 90-degree corner, impedance would be about 73 ohms. The impedance is increased when using either a bow-tie dipole or a folded dipole with conductors of unequal sizes.

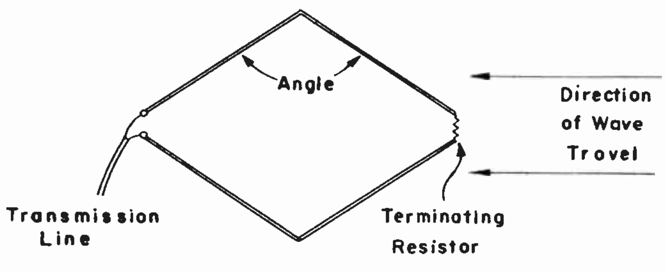

Fig. 15. The conductors of a rhombic antenna as seen from above or below.

Another type of antenna which would be too large for vhf reception, but not for uhf channels, is the rhombic. The conductor arrangement, as it appears from directly above or below the antenna, is shown by Fig. 15. There are four legs of equal lengths. Increasing the length of the legs improves the gain and makes for sharper directional effects. In practice the leg lengths usually are two to three wavelengths at the low end of the band to be covered. For the uhf band this means 50 to 75 inches. The angle marked on the diagram would be made somewhat less with shorter legs, or greater when legs are longer.

The terminating resistor is necessary to improve the back-to-front ratio of signal strength. With no resistor at this point the rhombic antenna would receive equally well from two opposite directions. This antenna has rather marked vertical directional properties; it may be tilted up or down, either to favor signals approaching on other than a horizontal line, or to reduce interference and reflections coming from above or below.

ANTENNA GAINS. Although the gain of uhf antennas depends on their type or design, it cannot be stated that some one general type will insure gain of a certain number of decibels at particular channel frequencies. Too much depends on how carefully the units have been engineered, on the quality of construction, and especially on how you install them.

In a very general way the average gains of good quality antennas of types which have been mentioned as well suited for uhf reception are as follows:

TYPE	SINGLE BAY	TWO BAYS
Bow-tie with reflector	2 to 4 db	5 to 8 db
Rhombic	5 to 10 db	8 to 12 db
Corner reflector	7 to 13 db	12 to 16 db
Yagi (best channel)	About 13 db	About 16 db

Gains always increase toward the high end of the uhf band, and there may be peaks of gain below the top of the band. The significance of rising gain, and its necessity, are explained in lessons dealing with vhf antennas.

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Gain of the bow-tie antenna rises rapidly through the lower uhf channels, then tends to level off. Gain of the rhombic type rises quite uniformly throughout the band. The corner reflector has more nearly uniform gain all through the uhf band, although there is a moderate increase from lowest to highest channels. The Yagi has quite uniform gain, but, of course, can receive only a limited number of uhf channels.

Any of the uhf antennas may be stacked for added gain and sharper directional properties. Just as with vhf antennas, two bays stacked will give two or three decibels more gain than a single similar bay. Four bays stacked will cause a further gain of two or three decibels.

Phasing connections between bays, and from an entire array to the receiver transmission line, are the same as for stacked vhf antennas. Stacking bars are run side by side when the transmission line takeoff is midway between bays. Stacking conductors are transposed between bays when the takeoff is from one or the other rather than at a center point.

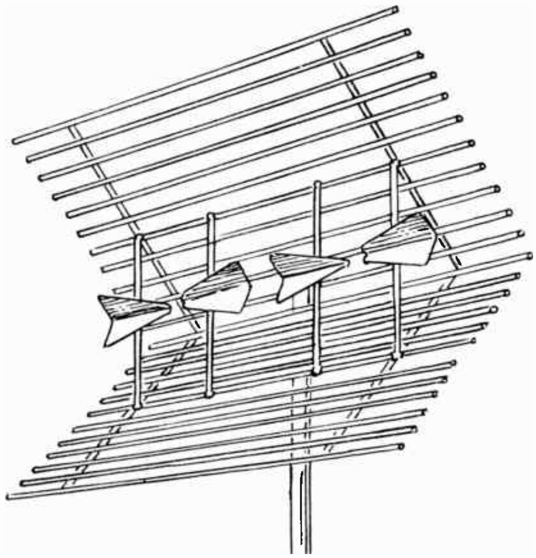

Fig. 16. Corner reflector antenna with two side-by-side dipoles.

Instead of stacking one above the other, two dipole elements may be mounted side by side in a single corner reflector structure, as in Fig. 16. Two of these twin units may be stacked vertically, giving the effect of a four-bay array. Naturally, single corner reflector antennas may be stacked vertically instead of side by side when this is more convenient.

<u>COMBINATION ANTENNAS.</u> Any style of uhf antenna and any style of vhf antenna may be mounted on the same mast and connected to the receiver through separate transmission lines. Band switching is carried out at the receiver or converter.

To avoid running two transmission lines it is possible to use a coupler which connects the uhf and vhf antennas to a single line without allowing too much interference between signals. Some coupling systems make use of only a single unit mounted close to the antennas, usually on the mast or boom. Resonant circuits in the coupler act as impedances which prevent signal energy picked up in one band from being dissipated in the antenna for the other band.

If the uhf receiver or converter has separate terminals for uhf and vhf antennas it is necessary to install a second coupler at the receiver end of the single transmission line. Uhf and vhf signals from the line are separated by this second coupler and fed to the respective uhf and vhf terminals of the receiver or converter.

The photograph of Fig. 17 shows printed circuit inductors and capacitors on a dielectric sheet for one style of antenna coupler. One picture is of the front of the sheet, the other is of the back of the same sheet. Dielectric sheets are housed in plastic covers or are molded in plastic for weather protection.

On what we may call the front of the sheet illustrated, where you can see the six coiled printed inductors, are also capacitor plates for this side of the dielectric. The opposite plates for each capacitor show on the picture of the back of the dielectric sheet.

The dielectric sheet illustrated carries circuits shown with conventional symbols on the drawing of Fig. 17. The coils and capacitors at <u>A</u> are parallel resonant and of high impedance in the uhf range. Those at <u>B</u> are parallel resonant and of high impedance in

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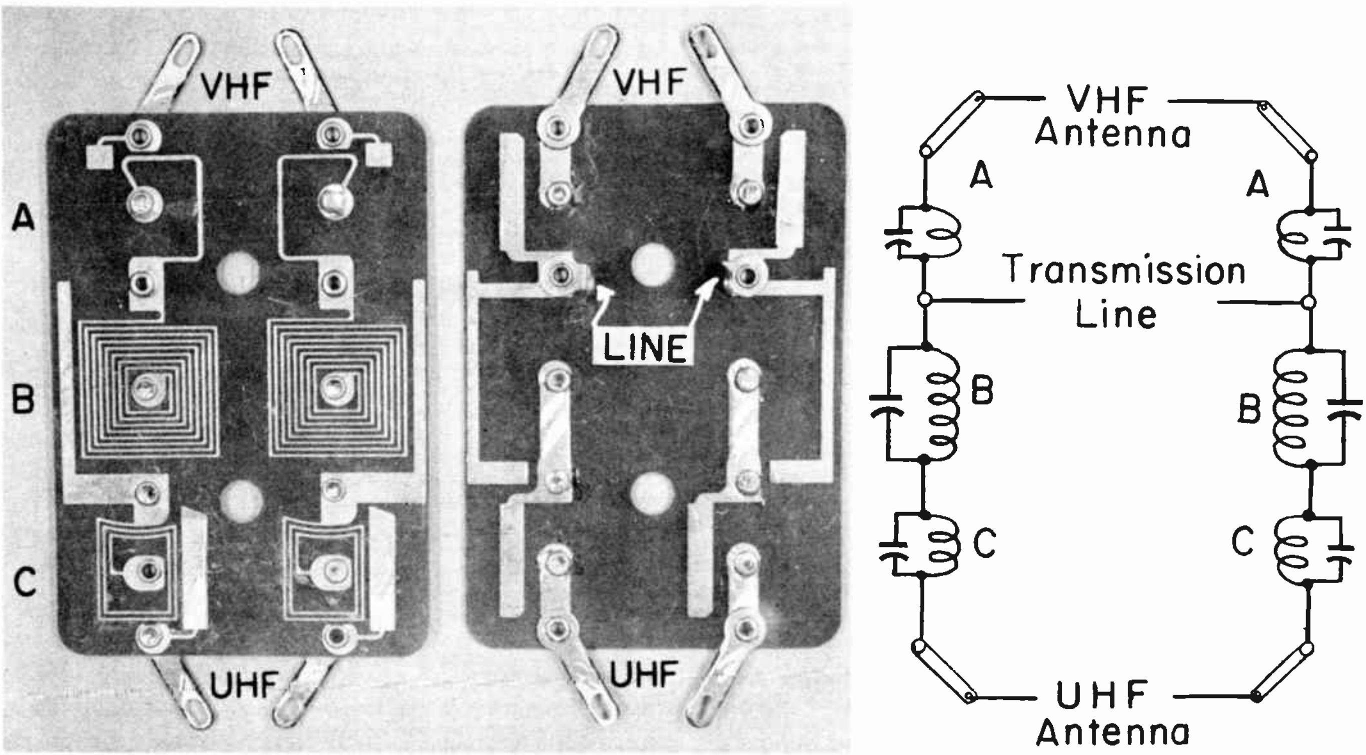

Fig. 17. A coupler for connecting uhf and vhf antennas to the same transmission line.

the low band of the vhf range, while those at C are resonant and of high impedance in the high band of the vhf range.

Vhf signals pass easily through the circuits at A, and enter the transmission line from a vhf antenna, but do not go to the uhf antenna because of high impedances at B and C. Uhf signals pass easily through circuits at C and B from the uhf antenna to the transmission line, but are kept from the vhf antenna by high impedance at A.

With a similar coupler at the receiver or converter, uhf signals pass easily through circuits at B and C to the uhf terminals. Vhf signals pass easily through circuits at A to the vhf terminals.

Other antenna and receiver couplers have different combinations of parallel resonant and series resonant circuits. In some the signals of either frequency range are shunted around antenna or receiver connections for the other range, by series resonant circuits, while high-impedance parallel resonant circuits force signals through their proper connections. Any kind of coupler introduces at least some loss of signal energy, and may not be so satisfactory as separate transmission lines in localities where signals are weak.

Some types of antennas will provide fair reception of both uhf and vhf signals on a single set of elements. They are suitable where uhf signals are rather strong, in what might be called primary reception areas, and where vhf signals are at least of moderate strength, not weak. Such combination antennas are made with various kinds of dipole elements, including folded dipoles, also the stacked-V at A of Fig. 18 and the double-V at B.

The angle included between elements of each pair in Fig. 18 is about 60 degrees. This is a good compromise for reception of both uhf and vhf signals. Narrower angles, down to 40 or 50 degrees, favor uhf signals. Wider angles, up to about 90 degrees, are better for vhf signals. Gain of V-type antennas rises almost uniformly from lowest to highest uhf channel frequencies. Forward directivity is quite sharp, but there will be quite a bit of pickup from sides and rear unless effective reflector systems are added.

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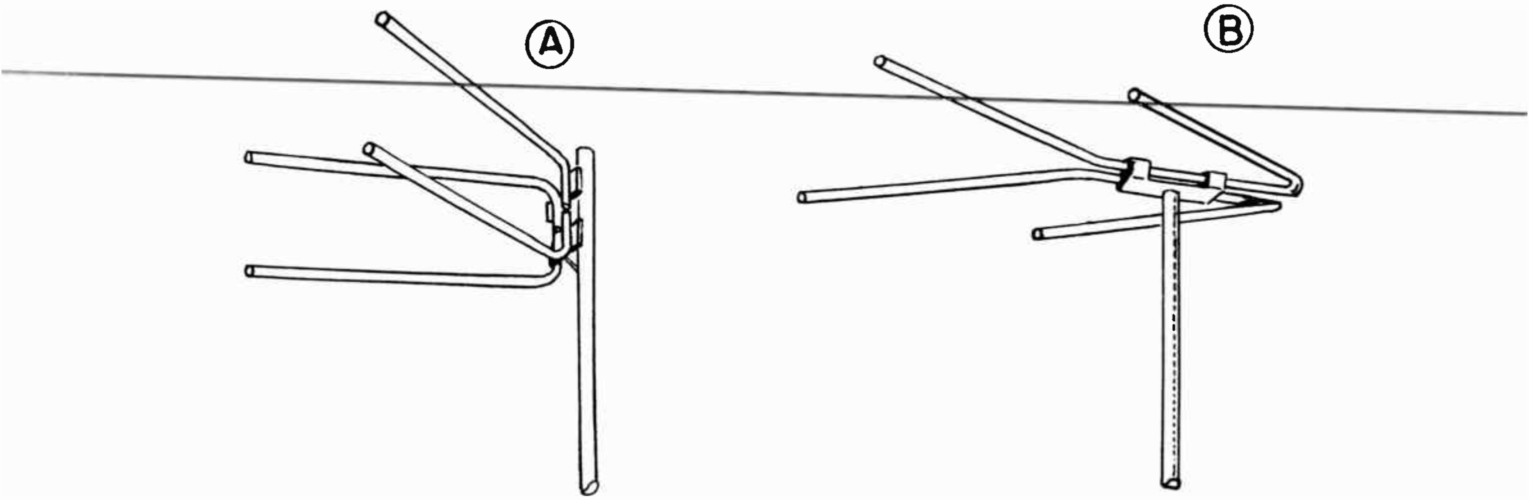

Fig. 18. V-antennas which sometimes are used for reception in both the uhf band the the vhf bands.

UHF TRANSMISSION LINES. For uhf reception the transmission line may be ribbon twin conductors, it may be tubular twin conductor, shielded two conductor, or coaxial cable. Attenuations of ribbon and tubular lines are practically equal when the lines are dry and clean. Moisture increases energy loss in both kinds of line. But, while attenuation of tubular line may increase to something like two or three times the value when dry, attenuation of the ribbon line may increase to six or seven times the dry value.

Shielded line, either coaxial or parallel conductor, is needed where strong electrical interference might be picked up by unshielded line. Attenuation of shielded line is greater than that of unshielded types when both kinds are dry, but the shielded line is unaffected by moisture. When the transmission line is wet. a low-loss shielded type will have less attenuation than any of the unshielded types.

Good quality parallel conductor air-insulated or open wire line of 300-ohm impedance has somewhat less attenuation than either flat or tubular twin conductor lines when these latter are dry. Since the air-insulated open line is little affected by surface moisture, it is a desirable type for uhf reception, Open line is, however, more affected by salt air and other corrosionforming conditions than are types in which the conductors are protected by an insulating cover.

UHF INTERFERENCE. Shielded transmission line is needed less often for uhf than for vhf reception. This is because electrical interferences of the spark and noise types have relatively little effect on ultra-high frequencies. Also, in the uhf band, there is almost no interference from industrial or medical apparatus operating in kilocycle frequency ranges.

Unless channel tuning circuits in uhf receiving apparatus have good selectivity, and rejection of frequencies outside the rather broad band intentionally covered, there may be image interference from signals in other parts of the uhf band. If your receiver uses single conversion to produce intermediates in the 40 to 46 mc range, there may be an image from signals 15 channels higher than the one to which you tune. With double conversion an image might come from signals 27 or 28 channels below the one tuned, assuming that your receiver uses carrier frequencies in channels 5 or 6 for uhf reception.

There may be excessive oscillator radiation from uhf tuners and converters when preselector and coupling circuits do not effectively attenuate oscillator frequencies. A radiating tuner or converter operating with single conversion for intermediates in the 40-46 mc range may cause interference for receivers tuned seven or eight channels lower. With double conversion the oscillator interference could affect receivers tuned 14 channels higher, again assuming the use of carrier frequencies in channels 5 or 6 for uhf reception.

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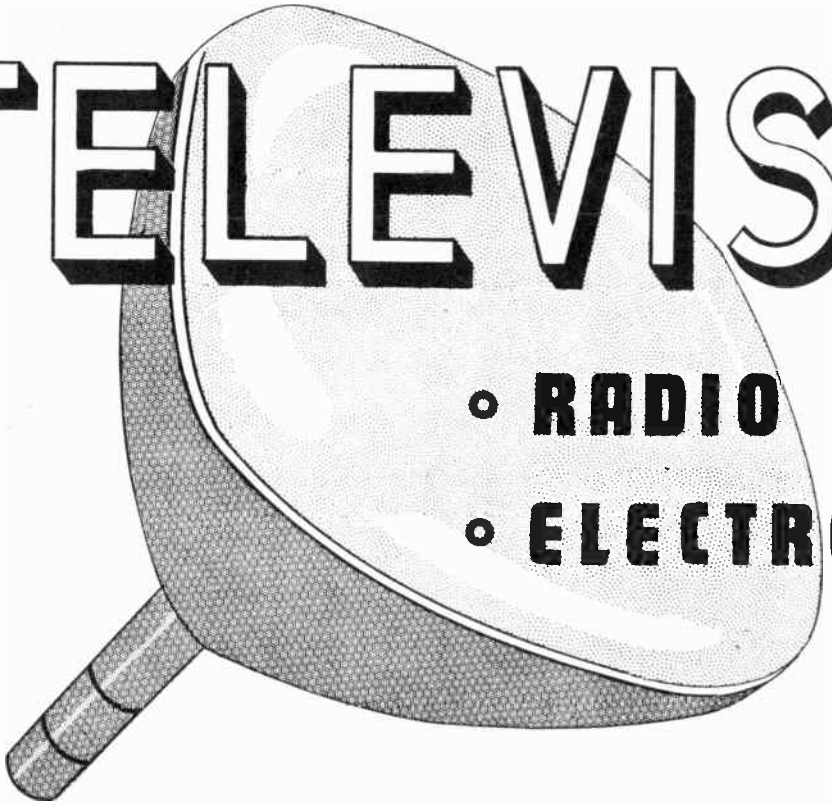

- RADIO
- ELECTRONICS

LESSON 95 — ULTRA-HIGH FREQUENCY RECEPTION — PART FOUR

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Lesson 95

ULTRA-HIGH FREQUENCY RECEPTION — PART FOUR

When an ultra-high frequency receiver or converter gives unsatisfactory performance it is wise to commence looking for trouble in the antenna and transmission line. Orientation of the uhf antenna is important, because uhf carrier waves travel more nearly straight lines than waves at lower frequencies, and because uhf antennas usually are more sharply directional than vhf types.

The higher a uhf antenna is mounted the greater will be average strength of received signals. After the mast or mounting has been arranged for greatest practicable elevation, moving the antenna up or down by only a foot or two may change signal strength in a ratio as great as three or four to one. This is because uhf carrier waves are only one or two feet long, and because direct and reflected waves coming from the same general direction may oppose at some levels and add their strengths at others.

Shifting a uhf antenna sideways a foot or two may cause as much variation of signal strength as similar changes of elevation. All this makes it necessary to choose the exact location with care when maximum signal strength is needed.

Many uhf antennas have sharp vertical directivity. Then strength of received signals will change as the boom is tilted slightly up or down, or, with a corner reflector, with upward or downward tilt of an imaginary line through the center of the dipole element and the corner between reflector planes. Such tilting may be called azimuth adjustment.

The uhf antenna should be rigidly supported or well guyed to prevent swaying by winds, since this would alter the horizontal position and cause signals to vary. U-bolts and other clamping devices on the mast and boom must be so tight that winds cannot turn the antenna to change its orientation.

Unshielded transmission lines require careful installation. Separate uhf and vhf lines should be spaced apart six inches or more all the way from antenna to receiver. A uhf transmission line should come no closer than about six inches to any objects or surfaces along its path, which calls for long standoffs. Standoffs perferably are of types having minimum metal around the line, especially when a great many must be used. If the line must be fastened otherwise than by standoff insulators, use plastic or electrical tape, not friction tape.

If the uhf transmission line is of hollow tubular construction be sure it is dry when installed and be sure to seal both the antenna end and the receiver end. Some tubular style lines have their interior space filled with dielectric material, which makes sealing unnecessary.

Some kinds of lightning arresters may partially short circuit uhf signals, or may upset the impedance matching, or may unbalance the conductors of a twin line. Such troubles result from excessive capacitance in plastic housings within which the gaps are between metal pieces of large surface area, or sometimes from certain types of resistance elements which are across the gap to dissipate static charges. When judging the suitability of a lightning arrester, watch reproduced pictures with and without the arrester connected to the transmission line.

The uhf transmission line should have no sharp bends or kinks anywhere, nor should there be any loops. This applies all the way from antenna to tuner, including the short length of line from terminals on a cabinet or chassis to the tuner input.

Here is a check list of the more common antenna and transmission line troubles.

Line too close to chassis metal, or to any metal between antenna and receiver.

Kinks, sharp bends, or loops anywhere along the line.

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Moisture on a ribbon line, or an unsealed hollow tubular line.

Line terminal connections loose or corroded. Soldered joints are best.

Antenna dipole tubing, rods, or plates loose or rusted where contacts should be good.

Broken insulators at the antenna.

When possible, temporarily cut out parts which may cause trouble. An example is observing reception with a lightning arrester disconnected. As another example, try connecting the uhf transmission line directly to the channel selector side of a high-pass filter which carries the regular antenna terminals for the tuner.

TROUBLE SHOOTING METHODS. If the antenna and transmission line are in good condition and properly installed, trouble may be in the uhf tuner or converter, or it may be in portions of the receiver used for both uhf and vhf reception. With any double conversion system, either a combination tuner or a converter, good reception of vhf signals means there is no trouble in the vhf tuner or in circuits beyond this tuner. Then the fault must be in the uhf tuner or converter. If the same kind of trouble appears on both uhf and vhf channels, the fault is not in the double conversion uhf tuner or converter, so must be in the vhf tuner or beyond.

Should trouble be indicated in the vhf tuner or beyond, correct it before making further checks of the uhf tuner or converter. Since vhf carrier signals may be much stronger than uhf signals, make sure that the vhf tuner has plenty of gain on weak vhf signals, so it may perform well on weak uhf signals.

With a single conversion system, good reception of vhf signals means only that no trouble exists in portions of the tuner used for vhf signals. Then poor uhf reception may indicate either of two things: First, there may be trouble in the portion of the vhf tuner which changes the r-f amplifier and mixer to i-f amplifiers for uhf reception. Second, there may be trouble in the uhf tuner itself, in the portion of the apparatus that converts carrier signals to i-f signals.

If a uhf converter is used, the quickest check is to substitute another converter known to be in good condition. Make sure that the i-f output of the substitute converter suits the channel to which the receiver is tuned for uhf reception. If the new converter allows good reception, the fault is in the original converter.

Paragraphs which follow list troubles most likely to cause difficulties in uhf reception. Detailed instructions for making some of the suggested tests are given later in this lesson.

Uhf Tuner Or Converter Trouble. Should trouble be localized in the uhf tuner or converter, make the following routine checks.

Measure d-c plate and grid bias voltages on all tubes, also on screens of i-f amplifiers in the uhf section of the apparatus.

Try new tubes or tubes known to be good.

Try a new or good crystal diode mixer, also a harmonic generator crystal if one is used.

Look for loose or corroded solder joints.

Look for resistors which appear to have been overheated, and if any are found, determine the cause of heating.

Examine decoupling and bypass capacitors for shorts, opens, or wrong values.

Examine decoupling chokes for opens or accidental grounds.

Wrong Channel Number. If the number of a uhf channel actually received is not close to the dial number, the cause usually is in the uhf oscillator circuit, although the dial pointer may have slipped on its drive cord or shaft. See that the oscillator tube or its shield are not tilted to bring tube elements too close to shield metal. Check oscillator alignment adjustment, also uhf fine tuning if it is adjustable.

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Covers of shielded compartments containing oscillator circuits, or containing antenna and mixer tuning elements may be loose or missing. Plates of uhf tuning capacitors may be incorrectly bent.

Pictures Weak Or Noisy. Troubles especially likely to cause pictures to be weak, filled with snow, or otherwise "noisy" include the following.

Uhf tubes pins making poor contacts in sockets.

Tube shields loose.

Crystal diode mixer defective.

Contacts of tuner switches or of function switches loose or dirty.

Rotor shafts of uhf tuning capacitors making poor contact to ground metal.

Decoupling chokes shorted or grounded.

Oscillator injection incorrect; check current in the crystal diode mixer, also positions of pickup loops or wires.

Poor alignment of antenna and mixer preselector circuits in a uhf tuner or converter, or in the vhf tuner when double conversion is used.

Failure of the uhf tuner or converter circuits to track well at some points in the range of uhf carriers. This is a type of alignment fault.

UHF WIRING. When looking at service diagrams of uhf circuits remember that conventional symbols for inductors do not necessarily represent coils of wire, they may indicate straight conductors of any kind, or conductors with small loops.

Neither do capacitor symbols always indicate any of the forms encountered in vhf circuits. Uhf capacitors may be any pieces of metal separated by any kinds of dielectric. Adjustable capacitors often consist of screws inside a dielectric form, on the outside of which is an inductor. One plate of a fixed capacitor may be metal deposited on the outside of dielectric material which coats one end of an inductor. The inductor acts as the other plate. A fixed capacitor may be nothing more than a small stud pressed into dielectric which separates two inductors to be coupled.

All conductors in the high sides of resonant or tuned circuits must be considered as inductors at ultra-high frequencies. Base pins for grid, plate, or cathode of a tube act as inductors. Where inductance and its reactance are not wanted, or should be small, shortening of leads is all-important. Components of grid and plate circuits usually are very close to socket lugs, or soldered directly to the lugs to eliminate additional leads. You can see such construction in Fig. 1.

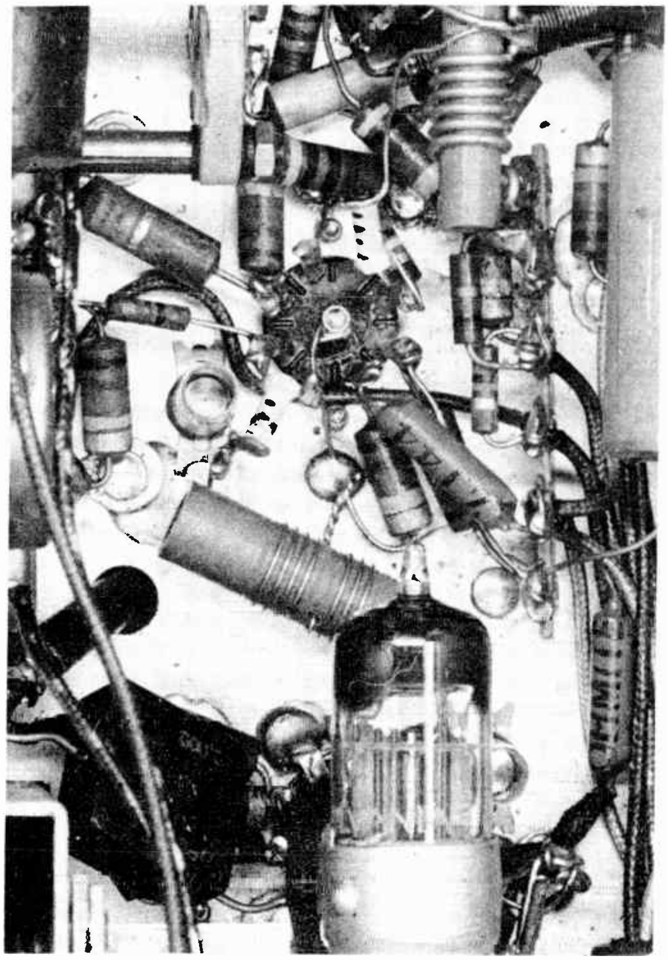

Fig. 1. Circuit components are close together and leads are short or absent around the sockets of tubes operating at ultra-high frequencies.

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To reduce stray capacitances and energy losses, tube sockets are of ceramic or plastic materials having small dielectric constants and small r-f losses. Sockets must hold tube base pins securely, and tube shields must be held rigidly in one position. All dielectric supports are placed, so far as possible, where r-f fields are relatively weak.

All plate and grid circuits must be isolated from circuits for B-supply, d-c biasing, and heater current by voltage dropping resistors or by r-f chokes, with decoupling capacitors connected close to the high side of the resistors or chokes. R-f returns from grid and plate to cathode are made through capacitors close to socket lugs. These returns should not pass through any conductor common to both, but should connect to one side of bypass capacitors whose other sides go to a common point and to the cathode.

Resistors in uhf circuits always are carbon or composition types, to avoid the inductance of wire wound types. Resistors inside of which are large metal fastenings for pigtails may have appreciable capacitance between these pieces of metal.

Decoupling capacitors for uhf circuits are small ceramics in values from 100 to 500 mmf. Reactance of 100 mmf capacitance is no more than 3½ ohms anywhere in the uhf carrier range, and of 500 mmf is less than an ohm.

Replacements of any components in uhf circuits should be made only with units of the same size and shape, as well as of the same electrical characteristics. Do not alter the lengths of any leads, nor rearrange any of the leads or any of the small parts such as resistors and capacitors which are in or connected to resonant circuits.

OSCILLATION TESTS. The easiest check of oscillator tube operation is measurement of d-c grid voltage with a VTVM. Connect the high side prod of the meter to the grid lug of the oscillator socket and the common lead to ground. The reading should be almost anything between 2 and 8 volts while the tube oscillates, but only a small fraction of a volt when there is no oscillation. Connections are shown by Fig. 2.

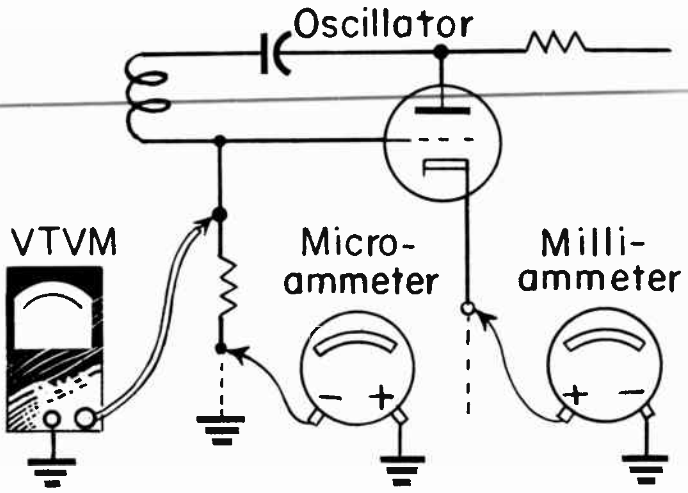

Fig. 2. Three ways of determining whether an oscillator tube actually oscillates.

To experiment with this test for oscillation keep the d-c prod of the VTVM on the grid lug of the oscillator socket. Bare only the tip of any piece of insulated wire, to prevent shorts, and touch the bare tip to the grid lug. This will stop oscillation and cause the VTVM reading to drop if the tube was oscillating.

Oscillator grid current may be measured, as shown also in Fig. 2, by opening a connection at the grounded end of the oscillator grid resistor and inserting a microammeter of about 500-microampere range. Cathode current may be measured with a milliammeter of about 50-ma range connected in series with the oscillator cathode. Grid current and cathode current should drop to low values when oscillation is stopped, and should rise when oscillation takes place.

OSCILLATOR INJECTION TESTS. Measurement of d-c current flowing in a crystal diode mixer provides a check of oscillator operation, of oscillator injection voltage, and of crystal condition, all at the same time. Crystal current should vary with changes of injection voltage, with the operating frequency, with the type of crystal and with its condition.

A few of the many methods of measuring mixer current are shown by Fig. 3. In diagram A the path for d-c mixer current extends from ground through r-f choke La, through the crystal, the primary of the i-f

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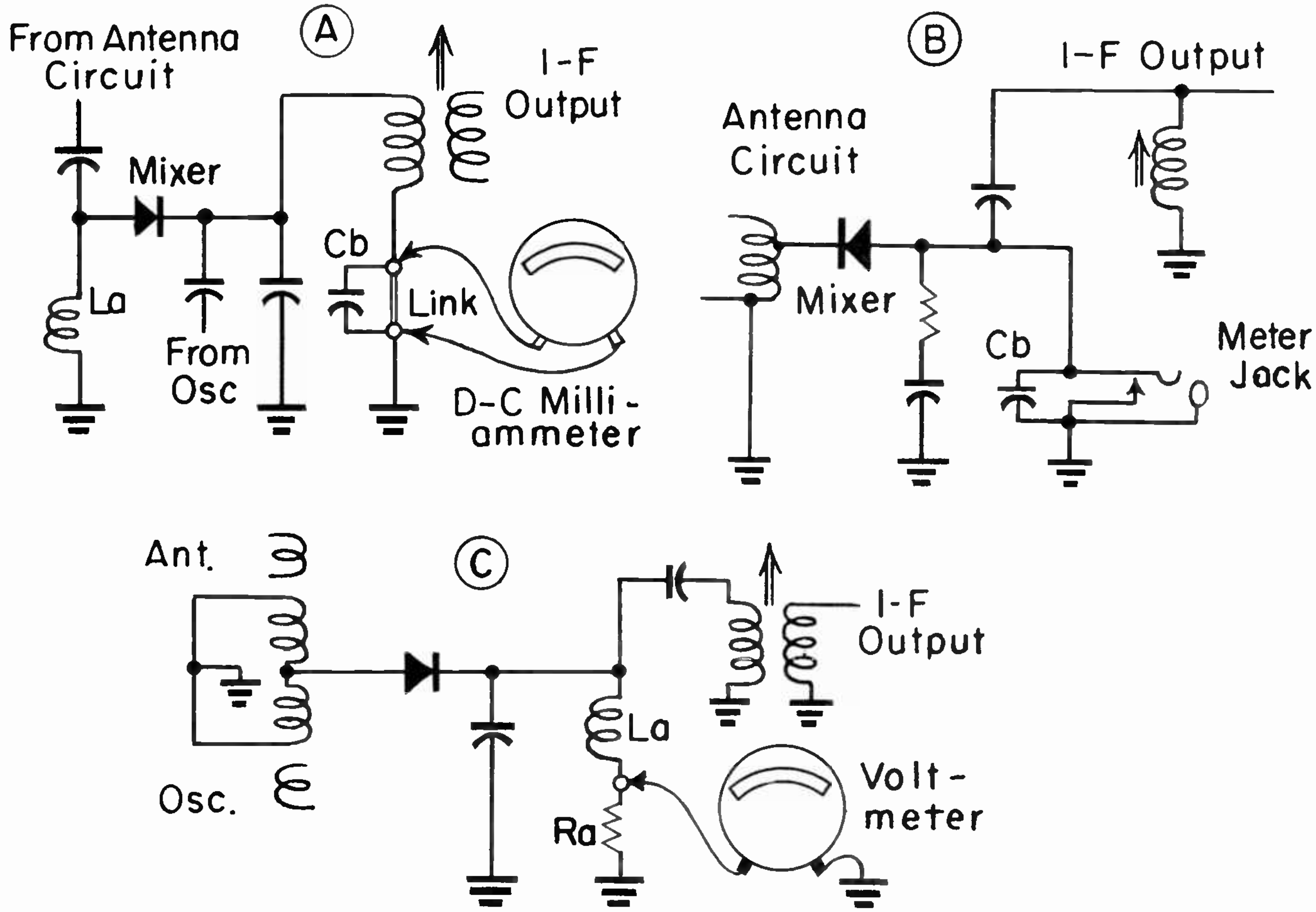

Fig. 3. Connections for measuring d-c current in uhf crystal mixers.

transformer, a link connection, and back to ground. With the link temporarily opened, a d-c milliammeter is connected in its place. The meter will be bypassed by capacitor Cb, usually of about 500 mmf.

At B the path for d-c mixer current passes through a closed circuit jack. Insertion of a plug connects in series with the mixer circuit a milliammeter attached to the plug. Again there is a bypass capacitor at Cb.

In diagram C the d-c current in the mixer circuit flows through resistor Ra, which is in series between r-f choke La and ground. With a low range d-c voltmeter connected across Ra, indicated voltage will be proportional to drop across the resistor, and to d-c current in the mixer.

To determine the method of meter connection, if any method is provided, follow the conductive path for direct current in the crystal, either on a service diagram or in the tuning unit itself. This d-c path usually begins and ends at ground.

Crystal mixer current will vary widely as the tuner or converter is tuned through the uhf carrier range, but always there will be current provided the oscillator is furnishing injection voltage and the crystal, with its circuit, is in good condition. Maximum current may be something like 2 ma, or may be several times this value. Correct current or current limits for any one tuning unit can be learned only from service instructions.

CRYSTAL MIXER TESTS. If faulty reception or no reception persists after determining that the oscillator tube is operating, and you have no specific instructions for checking d-c current in the mixer, try replacing the crystal with a new one or with one known to be good in this kind of service. Replacement with the original type is desirable, although types 1N72, 1N82, and some

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others usually may be interchanged. Measuring forward and back resistance of a mixer crystal with an ohmmeter seldom will give a reliable indication as to whether the crystal will operate satisfactorily.

When a defective crystal has been replaced with a good one it may be necessary to realign the mixer input circuit and possibly the antenna selector circuit in order to obtain best possible performance. However, if the new crystal restores satisfactory performance with the original alignment it is not advisable to attempt further improvement unless you have suitable apparatus, and experience in such work.

For a crystal diode to provide best mixer action the diode should operate at the bend of its characteristic curve where forward current undergoes sharpest change for a given change of applied voltage. That is, the crystal should be made to work as an effective rectifier in cutting off current alternations of one polarity as sharply as possible.

Good rectifying action of the mixer crystal sometimes is aided by providing a positive bias of a quarter- to a half-volt on its anode. The crystal may be self-biased as at A of Fig. 4, with a resistor and bypass capacitor between crystal and ground. Self-bias voltage will vary with channel tuning. Another method of biasing is from voltage divider resistors in a B-plus line, as in diagram B. This kind of bias is not altered by channel tuning. Crystal bias may be measured with a VTVM set for measurement of positive d-c voltage, with the prod connected on the anode side of the crystal.

UHF SIGNAL GENERATORS. Other than instruments regularly used for servicing vhf tuners and receivers the only special types required for work on uhf tuners and converters are a uhf sweep generator and uhf marker generator, separate or combined. These instruments must tune to ultra-high carrier and oscillator frequencies. At points following the output of the uhf mixer all signal frequencies of double conversion systems are in the vhf carrier range, and for single conversion are in the range of receiver intermediates. This makes it possible, beyond the uhf mixer, to use the same instruments as for uhf servicing.

Some uhf sweep and marker generators provide fundamental frequencies throughout a range from about 400 to 950 mc. Others provide fundamentals for the low end, and harmonic frequencies for the high end of this range. Still other uhf generators operate with beat frequencies which are the sum of two lower frequencies. In all designs the generator tuning dials are marked with the ultra-high frequencies, and often with uhf channel numbers.

Uhf sweep generators provide sweep widths as great as 50 to 60 mc, or even greater. These wide sweeps are essential

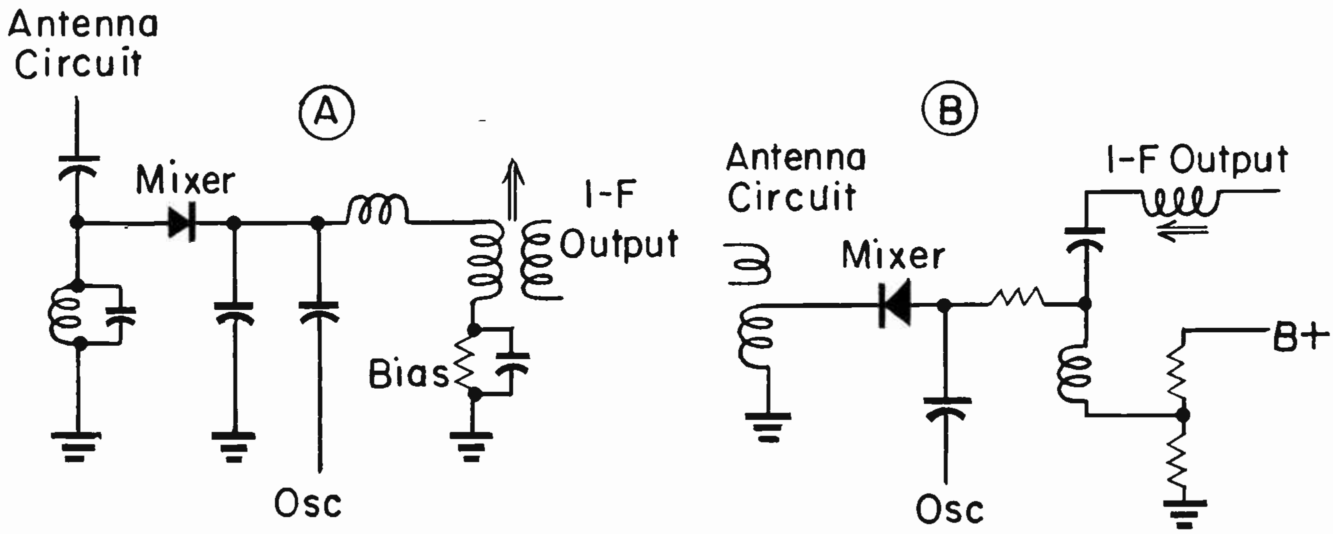

Fig. 4. Mixer crystals may be self-biased or biased from a voltage divider.

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when checking response of channel selector circuits between antenna and mixer input. Pass bands of these circuits are much broader than those of vhf tuner circuits serving similar purposes. Sweep widths up to at least 15 or 20 mc are desirable also for checking i-f amplifier circuits immediately following the mixer.

TEST SETUPS. Output cables of uhf signal generators should be coaxial types, as short as possible. For connections to antenna input terminals of uhf tuners and converters the sweep generator cable must have proper impedance matching termination. Even though cables are shielded types they should not run parallel with one another, and should be reasonably well separated all along their lengths.

Should frequency response curves appear definitely wrong, the fault may be misalignment, but is just as likely to result from a poor setup for testing. Connections which bond and ground the chasses and housings of receivers, converters, and test instruments may be too few or poorly placed. Often you can separate test leads for input and output, or can avoid parallel leads and crossovers by shifting the relative positions of instruments.

Long cables used without suitable impedance matching pads may develop standing waves at some frequencies. The setup should be considered satisfactory only when laying your hand on chasses, housings, and cables causes no change in shape of the response curve. With correct impedance matching there should be no standing waves.

OSCILLOSCOPE CONNECTIONS. Fig. 5 shows points at which the vertical input of the oscilloscope might be connected for uhf alignment. Wherever signals are at ultra-high, very-high, or intermediate frequencies, before demodulation by a mixer or a video detector, it is necessary to use a detector probe. Only at the output of a mixer and at points beyond a video detector is it possible to use a plain prod.

It would, of course, be desirable to observe a frequency response at the mixer input (point 1) since here we would have the pass band for channel selector circuits be-

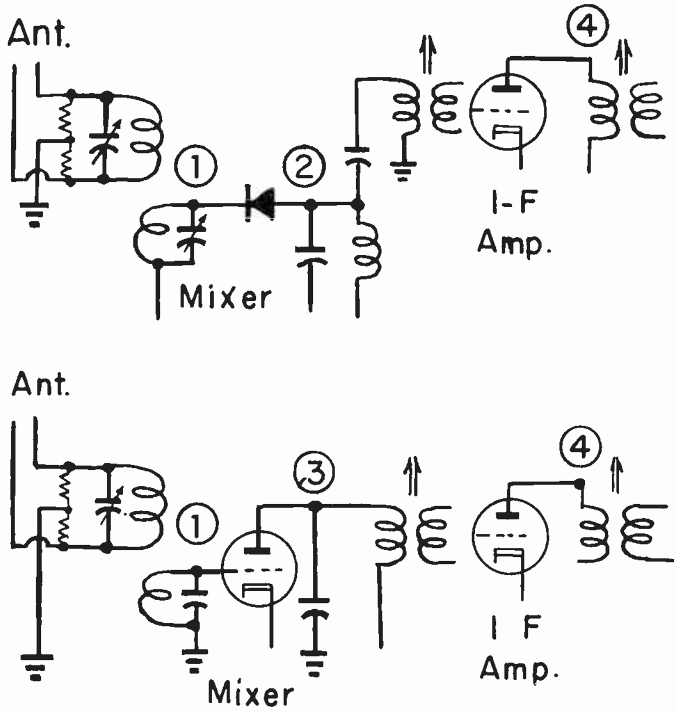

Fig. 5. Some of the points at which the vertical input of an oscilloscope might be connected for observing frequency responses.

tween antenna and mixer. A detector probe would be needed. We would encounter a serious difficulty when there is no r-f amplifier tube between antenna and mixer, for then a probe could not pick up enough energy for an oscilloscope trace without completely detuning the selector circuits. Even with an r-f amplifier tube between antenna and mixer, signal energy still would be small and the scope would have to have high vertical sensitivity. This response and others are compared in Fig. 6.

No detector probe would be needed at the output of a mixer. With single conversion this output would be at an intermediate frequency, and with double conversion it would be at a frequency in the vhf carrier range. But at the output of a crystal diode mixer (point 2) the signal would be even weaker than at the input, and there would be little chance of obtaining a frequency response. At the output of a mixer tube (point 3) a response trace could be observed were the scope highly sensitive. Any such response would be affected by a tuned coupling following the mixer.

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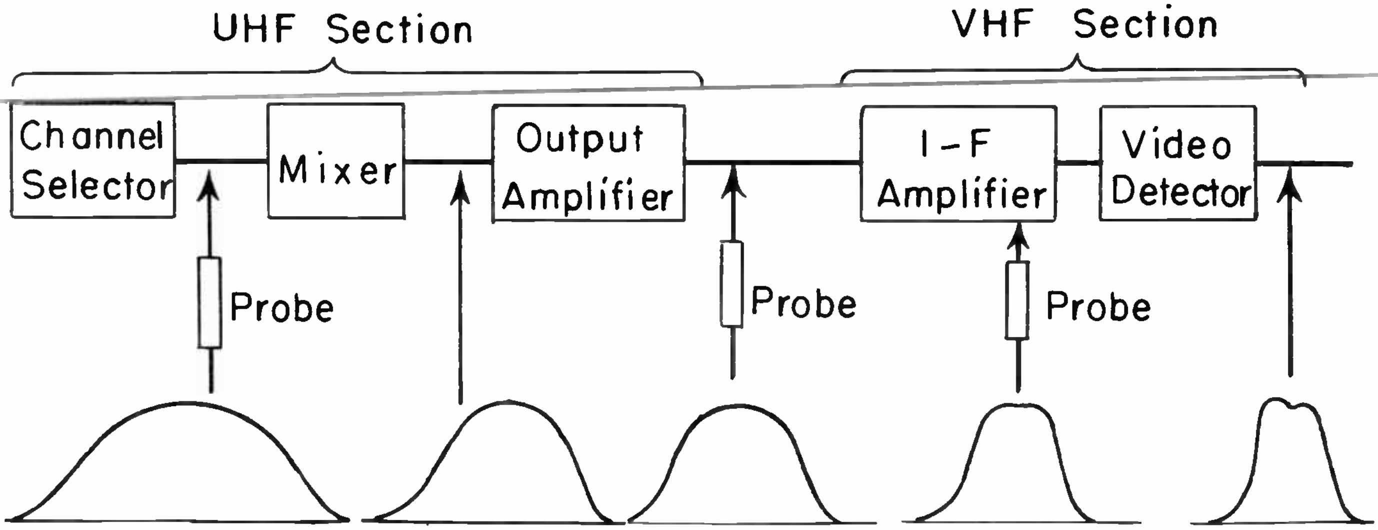

Fig. 6. The shape of response curves, and what they indicate, depends on the point in the receiving system from which they are obtained.

At the output of any i-f amplifier (point 4) a detector probe would be needed. From a converter there would be a vhf signal, fairly strong but requiring a high-frequency detector probe. At the lower frequency output of the i-f amplifier in a single conversion system there should be no difficulty in obtaining a frequency response with an ordinary detector probe.

The output of any i-f amplifier would not show the frequency response of the uhf tuning circuits. It would show only the pass band of the i-f couplers, because these couplers would be between the sweep generator and oscilloscope. This is true also when taking responses from any i-f amplifier stages in the vhf receiver.

At the video detector load in the vhf receiver there would be no difficulty in obtaining a strong frequency response without a detector probe, and with a scope of only moderate sensitivity. But here the response would be only that of the i-f amplifier section of the vhf receiver, and would give little indication of response from the uhf tuner or i-f amplifier.

If the scope is to be connected to the video detector load, or anywhere between this load and the picture tube signal input, the i-f amplifier section of the vhf receiver should be in good alignment. This alignment should be checked before making any adjustments in the tuner sections.

I-F ALIGNMENT IN UHF TUNER OR CONVERTER. The i-f amplifier in the uhf section of the receiving apparatus must be aligned so that its response takes in all the frequencies to be delivered to following sections. With single conversion this response need cover only a little more than the range of receiver intermediate frequencies, or only the range of a 6-mc channel. This i-f response should be quite similar in form to that fed from the vhf mixer to the i-f amplifier section of any vhf receiver.

With double conversion the i-f response of the uhf section will be at very-high frequencies, and must extend below and above the range of frequencies to be fed into the vhf tuner. For example, with a uhf converter requiring that the vhf receiver be tuned either to channel 5 or to channel 6, output of the uhf i-f amplifier must extend through both channels, or at least from 76 to 88 mc.

Fig. 7 shows what might be approximate relations of pass bands or frequency responses for uhf channel selector circuits, for the i-f amplifier of the uhf tuner or converter, and for the i-f amplifier of the vhf receiver.

To align the uhf i-f amplifier of a tuner or converter the output of an ordinary vhf

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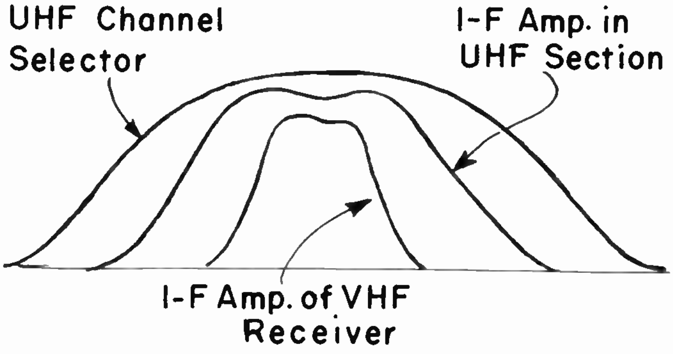

Fig. 7. Responses become progressively narrower as we move away from the uhf antenna and toward the video detector.

sweep generator should be fed to the i-f amplifier input while the scope is connected through a detector probe to the amplifier output. Since it is the response of the amplifier which is to be examined, and if necessary corrected by alignment, the input and output transformers or couplers must be included between the sweep generator and oscilloscope. This is shown in a general way at A of Fig. 8. Set the channel selector dial of the tuner or converter at any point well removed from any locally active uhf channel.

Adjust the center frequency of the sweep to correspond with the desired frequency of the i-f amplifier. This will be the receiver intermediate frequency with single conversion systems, or a very-high frequency with double conversion.

The sweep output is connected through a blocking capacitor C to the primary of a transformer or to the high side of an impedance coupler between the uhf mixer and the i-f amplifier tube. Excessive capacitance added to the amplifier input circuit will change the response frequencies, and may add peaks which would not exist during normal operation. To check for such effects try various values of blocking capacitance, say from 1,000 mmf down to as little as 5 mmf. The response curve will become lower with smaller capacitances. But if a smaller capacitance removes secondary peaks or radically alters the tilt of the response, that smaller capacitance must be used. Greater blocking capacitance is allowing too much cable capacitance to affect the tuned input circuit, and is preventing a true response.

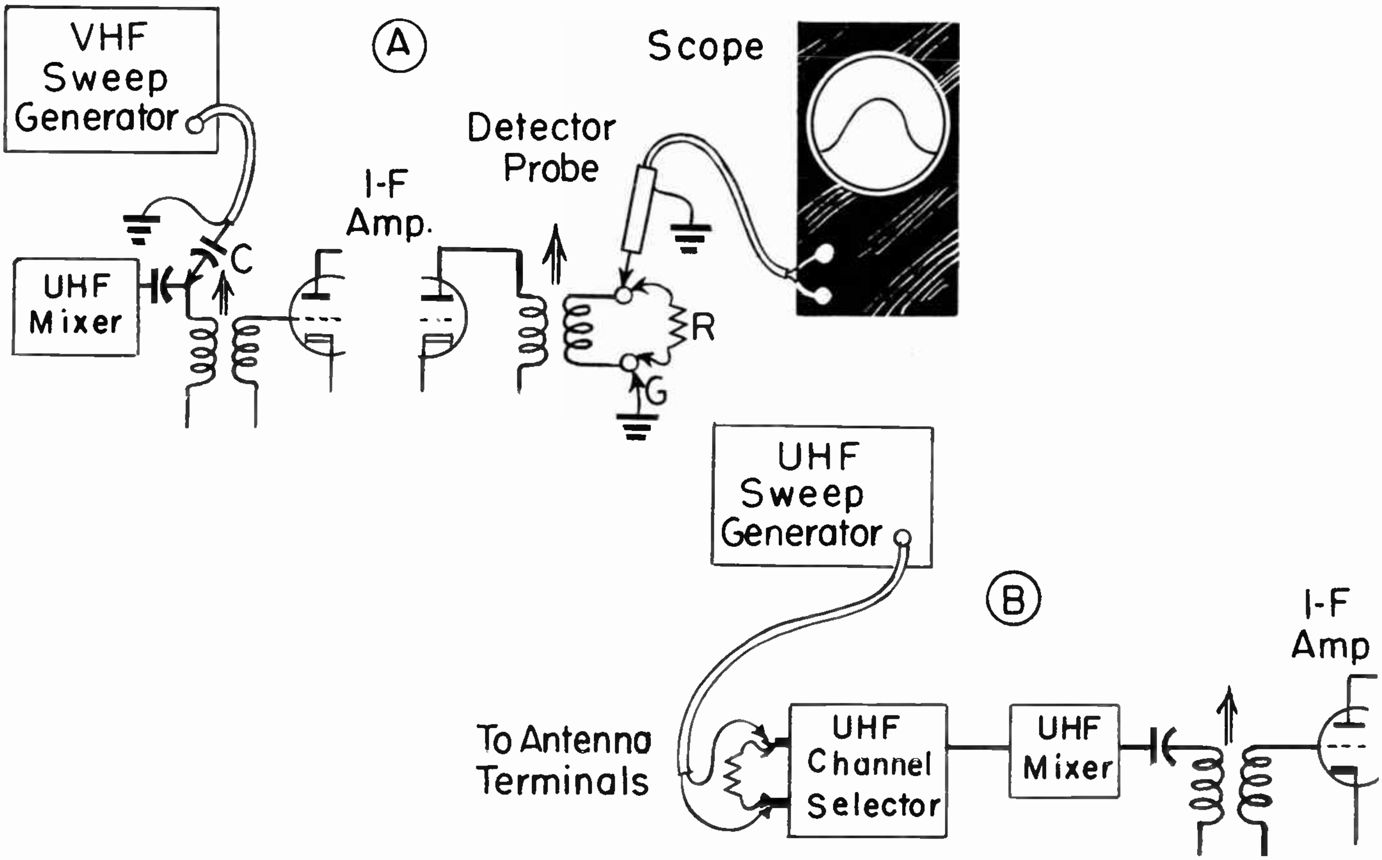

Fig. 8. Connections of sweep generator and oscilloscope for aligning the i-f amplifier in a uhf tuner or converter.

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It is possible also to connect a uhf sweep generator to the uhf antenna terminals of the tuner or converter while aligning the i-f amplifier in the uhf section. This is shown at B of Fig. 8. Now both the center frequency of the sweep and the dial of the tuner or converter must be set for the same uhf channel. With the connection at B the sweep output cable should have a termination that matches input impedance of the tuner or converter, which usually is 300 ohms. If you have no properly terminated cable, connect between the uhf antenna terminals a fixed resistor of 300 to 500 ohms, then connect a plain cable to the terminals.

Output of the i-f amplifier in the uhf section is from the secondary of a transformer whose primary is in the amplifier plate circuit, as on diagram A of Fig. 8. With single conversion the output point would be at the connection from the uhf section to the vhf section of a combination tuner, or to the i-f amplifier section of the receiver. With double conversion the uhf i-f output would be at the connection to the antenna input of the vhf tuner.

The detector probe may have only small input capacitance. Otherwise the probe capacitance will so detune the i-f output coupling as to prevent production of a true response curve. Probe capacitance may be limited, if necessary, by connecting in series a fixed capacitor of 3 to 10 mmf. It would be a good idea to observe the effect of such a series capacitor on response frequency and curve shape.

Across the output terminals of the uhf i-f output transformer, wherever they may be located, connect a fixed resistor R of a value approximately that of the circuit or line normally connected to the output terminals. Resistance somewhere between 300 and 5,000 ohms usually allows maximum height of the response curve. Connect the detector probe and its ground lead across this resistor. Try an additional ground connection, G, on the end of the resistor opposite the probe. This often allows a higher response curve.

Some converters, also some double-conversion uhf tuners, have provision for tuning their output only to one or the other of several vhf channels. A desired channel may be selected by aligning the transformer which is in the plate circuit of the i-f amplifier of the uhf section. Most such alignments are made with movable cores in the transformer inductors, but some are made be switching an auxiliary capacitor or inductor into the transformer circuit for a lower vhf channel, and by cutting it out for a higher channel.

As a rule it is possible to select a given vhf channel by aligning only the output transformer on the uhf i-f amplifier. The input transformer or impedance coupler may have a pass band broad enough to include at least two adjacent vhf channels. There are other designs in which both the input and output couplings must be aligned for selection of a certain vhf channel. In any case, if the input coupling is adjustable, its alignment may result in a much higher response on a selected vhf channel range.

Naturally, with double conversion the vhf tuner should be properly aligned on the channel to be used for uhf reception. This is especially necessary when an adjacent vhf channel is active. Were channel 6 used for uhf reception, misalignment on this channel might allow interference from sound or video on active channel 5, or when using channel 5 for uhf reception there might be interference from an active channel 6. Should interference appear, realign both vhf channels which may be involved.

It may be possible to improve uhf performance by realigning a vhf tuner on the channel used only for uhf reception. It may help to narrow the pass band, and thereby increase the gain. Such realignment must be checked by actual performance on transmitted signals, not only by observation of frequency response.

CHECKING UHF ALIGNMENT. After obtaining a frequency response curve anywhere in the uhf band, on any channel, it is advisable to follow the response all the way to the top and bottom of the band. Do this by simultaneously changing the center frequency of the sweep generator and the channel selector of the uhf tuner or converter to keep the response curve on the screen of the scope.

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Height or amplitude of the response curve will rise or fall at various frequencies, due to variations of gains and attenuations in the uhf section of the receiving apparatus. There should be no material change in shape of the response, nor should it disappear completely at any frequencies - unless there are dead spots in the uhf circuits at some frequencies.

While tuning the sweep generator and receiver or converter through the uhf carrier range it is quite likely that one or more false response curves may appear. Sometimes, as the regular response is moving to the right or left on the screen of the scope, another curve will move in the opposite direction. Such false response curves are caused by beating of oscillator voltages or by harmonics. Voltages from the swept oscillator in the generator may beat with voltage from a uhf oscillator, or even with that from the oscillator in a vhf tuner when double conversion is used.

ALIGNING UHF CIRCUITS. Between antenna input and mixer of the uhf section of a tuner or converter are several resonant circuits which may require alignment. These circuits are as follows.

1. Uhf Channel Selector. Usually there are two tuned circuits, one for the antenna and another for the mixer input. Alignment of these circuits affects the uhf pass band, also the tilt of a response curve, just as does alignment of equivalent circuits in a vhf tuner.

2. Antenna To Mixer Coupling. This coupling may or may not be adjustable. If the coupling can be varied, its effect is to change width and amplitude of the pass band. There will be a wider response with less amplitude, or narrower response with increased amplitude. Effects of coupling adjustment are much the same as that of an equivalent adjustment between r-f plate and mixer grid in a vhf tuner. Fig. 9 shows alignment adjuster screws for two preselector circuits and their coupling.

3. Oscillator Alignment. Aligning the uhf oscillator circuit serves to "track" the oscillator frequency with that of the antenna and mixer circuits. The purpose is to make all these circuits resonant at frequencies appropriate for the same channel at the same time, as the circuits are tuned together by the uhf channel selector knob or dial. This is the same effect as of adjusting oscillator frequency in a vhf tuner.

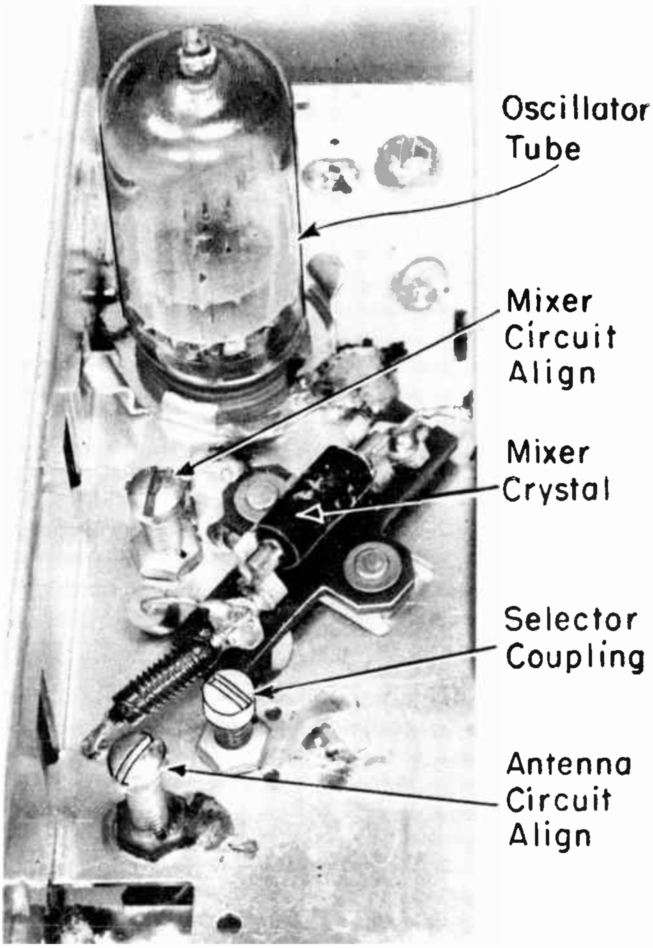

Fig. 9. Preselector adjustments on a uhf tuning chassis.

In Fig. 10 the cover has been removed from a shielded compartment in which is the bottom of a uhf oscillator socket. Inside this compartment is an adjuster screw for oscillator alignment. The head of the screw is accessible through an opening in one side of the shield.

4. Harmonic Selector Alignment. In any uhf receiving system which tunes uhf channels with the help of harmonic frequencies from a vhf oscillator there will be a harmonic selector circuit. The effect of harmonic selector tuning is similar to that of aligning a separate uhf oscillator.

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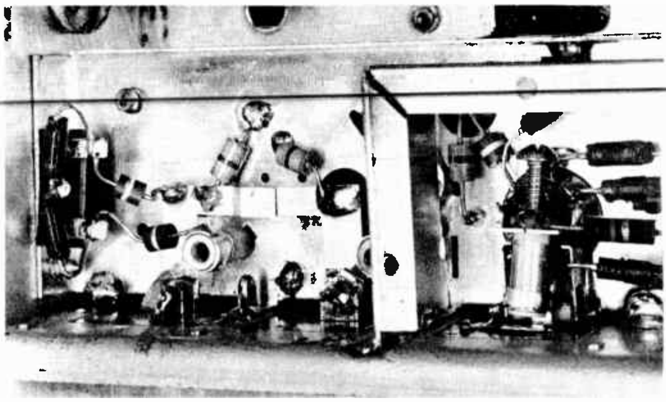

Fig. 10. The cover is removed from the oscillator shield compartment to expose an alignment adjuster.

For any of the four alignments mentioned the oscilloscope may be connected to the video detector load or anywhere between this load and the signal input to the picture tube. The frequency response then will be only that of the receiver i-f amplifier section, although this response may be affected by alignment in a preceding uhf tuner or converter.

With double conversion systems the scope might be connected on either the grid side or the plate side of the vhf mixer, as when aligning a vhf tuner. The response would be that of the vhf tuner, as it might be limited or otherwise affected by alignment of the preceding uhf converter or tuner section. With the scope on the mixer output, or anywhere beyond the video detector, no detector probe would be needed on the vertical input.

When the i-f amplifier in the uhf section of a combination tuner or in a converter has been aligned with its output through a detector probe to the scope, the probe may remain there for alignment of all four uhf circuits mentioned in preceding numbered paragraphs. The frequency response would be that of the uhf i-f amplifier which, of course, would be affected by alignment of uhf antenna and mixer input circuits.

For alignment of all the uhf circuits the uhf sweep generator is connected to the uhf antenna terminals, as at B of Fig. 8, and is operated at uhf channel frequencies.

Alignment adjusters for uhf antenna and mixer input circuits were described when we examined the construction of these circuits. There may be movable cores for varying the tuning inductances, but more often the alignment is made with variable capacitors. One capacitor plate often is a screw or slug which may be moved within a dielectric tube, around the outside of which is metal forming the second plate of the capacitor.

There may be only one adjustment for tuning the antenna circuit and one more for tuning the mixer input. In some designs there are two adjustments on each of these circuits, one for the low end of the uhf band and another for the high end.

Don't forget that connection of the scope to the output of the uhf i-f amplifier, to a vhf mixer, or to a video detector load will not yield the true response curve of the uhf antenna and mixer preselector circuits. The curve will show only the response of circuits immediately ahead of the scope connection.

As a consequence, alignment of uhf preselector circuits can be made only for maximum amplitude, proper band width, and desired shaping of the curve traced on the scope. When uhf antenna and mixer output alignment is carried out in this manner there is little or no danger of interference from other uhf channels, for the reason that uhf channel allocations in any one district are too far apart in frequency for this to happen.

It is frequency of the uhf oscillator, or resonant frequency of a harmonic selector, that really determines which one of a number of adjacent uhf channels will be received at any dial setting. This is because the oscillator circuit tunes sharply to one frequency, while antenna and mixer circuits tune broadly to a range of frequencies which may include several channels. Thus, with any alignment of antenna and mixer input circuits, adjustment of oscillator frequency will bring in any one of a group of adjacent uhf channels.

There may be one or several adjustments for uhf oscillator frequency, depending on the kind of tuner or converter with which you are working. Adjusters may be tubular variable capacitors, they may be movable cores in inductors, or both kinds may be used.

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An oscillator alignment adjuster which affects all channels would be one connected across the oscillator tuning inductor. This inductor may be a coil, a resonant line, or some other variety used in uhf circuits. Its adjustment would compensate for slight differences between oscillator tubes, when making replacements.

Another oscillator adjuster may be in series with the grid. Sometimes there is only a capacitor in this position, or there may be an adjustable capacitor and adjustable inductor in series. The inductor would have greater effect at the lower channels of the uhf band, while capacitor adjustment would be more effective at the higher channels.

On turret tuners having individual positions for each uhf channel, or for small groups of uhf channels, there are adjustable cores inside the oscillator tuning inductors on the drum strips. These core adjustments are used in the same manner as similar adjustments in vhf turret tuners.

After the uhf channel selector and oscillator circuits have been aligned on some one channel, the number of this channel should be compared with the number indicated by the tuning dial. The dial number can be brought into agreement with that of the aligned channel if the pointer is a friction fit on its shaft, if the pointer will slide on its drive cord, or by any other means which is evident upon inspection. Final adjustment of pointer position should be made during actual reception of one or more uhf programs.

UHF ALIGNMENT WITH VHF SIGNAL GENERATORS. Some of the service type sweep and marker generators designed for vhf alignment will produce uhf frequency response curves and markers on the oscilloscope. The trick is to use harmonics of fundamental generator frequencies to reach uhf carrier frequency ranges. Although it is possible to use harmonics from vhf sweep and marker generators, there are many difficulties and many chances of working with false responses and incorrect marker pips.

One difficulty is that generators of good quality seldom will deliver harmonics higher than the third, or at most the fourth, of sufficient strength to produce an oscilloscope curve. With some instruments even a second harmonic is very weak. The highest uhf carriers, at about 900 mc, can be reached by the fourth harmonic of a 225-mc fundamental. If a sweep generator operates on fundamentals up to this limit, and if the fourth harmonic is strong enough, the generator could be used. Were only the third harmonic strong enough to produce an oscilloscope curve, the generator would have to tune to fundamentals as high as 300 mc.

Another major difficulty when using harmonic frequencies is that there may be too many response curves, some of which are merely confusing rather than being useful. This results from too many oscillators operating at the same time. First of all, the sweep generator will contain one oscillator operating at a fixed frequency and another at swept frequencies. The uhf tuner will have at least one oscillator, and for double conversion there will be also a vhf oscillator.

Often there is enough leakage or enough interaction of signal fields for the fundamentals of some of these oscillators to beat together, thus forming many sum and difference frequencies. In addition, all the oscillators produce not only the harmonic frequencies we want, but many others at the same time. Any of these harmonics may beat with fundamentals or with one another:

As an example, the swept oscillator of the sweep generator may beat with the uhf oscillator, or some of their harmonics may beat together. Because one of the frequencies and its harmonics are being swept, resulting traces may look like frequency responses. Yet the false responses will not be at multiples of sweep generator dial readings, and they cannot be identified as corresponding to any particular harmonic frequencies.

If the sweep generator is tuned to a fundamental center frequency in the i-f range of the vhf receiver there may be strong response traces, but they are not useful. With double conversion there will be other false responses if the sweep is tuned to a fundamental center frequency in the range of very-high frequencies produced by the first

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conversion, such as carrier frequencies of vhf channels 5 or 6 in the case of many converters.

When using harmonics from a sweep generator the width of sweep, in megacycles, is multiplied along with the range of swept frequencies. To illustrate, if the sweep generator width control is set for 10 mc, and you use the second harmonic of the center frequency, the effective width of sweep will be 20 mc. On the third harmonic the effective sweep width would be 30 mc, and so on. Response curves will appear abnormally narrow on the screen of the scope, but when checked with markers the responses will be found to have normal pass bands in relation to frequencies. This effective increase of sweep width is an advantage because, as mentioned before, pass bands of uhf tuned circuits nearly always are much broader than those of vhf tuner circuits.

Harmonic frequencies from vhf marker generators will produce pips on a uhf frequency response, and frequencies may thus be identified if you can be sure of the harmonic which produces the pip. The marker generator should tune to fundamentals at least as high as 150 mc, so that no harmonic higher than the sixth will be needed for covering the entire range of uhf carriers. Many good quality marker generators will not produce fairly strong harmonics higher than the second or third.

Frequency of a harmonic producing a marker pip is equal to the generator dial reading multiplied by the number of the harmonic. There is no direct method for determining the number of a harmonic, unless you know the range of sweep frequencies producing the response and thus can tell the number of the only marker harmonic that could fall in this range. This method is not wholly dependable, because marker pips may be caused by harmonics from oscillators other than in the marker generator.

As an experiment, a uhf tuner was adjusted for reception at a center frequency of 560 mc. A marker generator was tuned through fundamental frequencies from 80 to 280 mc. There appeared six correct pips, at 560 mc. These pips were produced by harmonics from the seventh, on an 80-mc fundamental, to the second harmonic, on a 280-mc fundamental. But in addition, pips appeared with the marker generator tuned to six other frequencies, none of which were simple fractions, or sub-harmonics, of 560 mc.

If a pip is produced by a harmonic of a frequency indicated on the dial of the generator, the pip and the response curve will behave as outlined in the three tests which follow. Otherwise the pip cannot be depended upon as indicating any useful harmonic frequency. Correct behaviors are illustrated by Fig. 11.

<u>1. Change the center frequency of the sweep generator.</u>

The response should move across the scope screen, and the pip should remain in

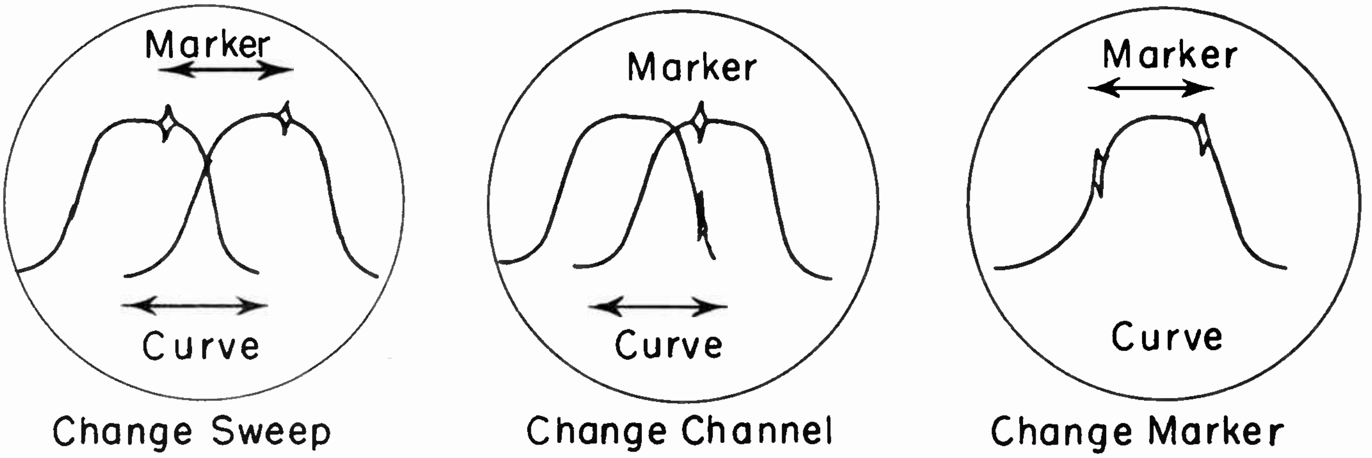

Fig. 11. How markers and response curves should behave with changes of sweep frequency, of channel frequency, and of marker generator frequency.

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the same position on the curve. The pip should move with the curve. This is because changing the range of swept frequencies is not altering the frequencies at which there are certain gains on the response, and these gain points must remain at frequencies identified by marker pips.

2. Change the channel tuning of the uhf tuner or converter.

The response should move across the scope screen, but the marker pip should remain at the same position from left to right on the scope screen. The marker pip should not move with the curve. This is because varying the uhf tuning, as to some other channel, alters the frequencies at all points on the response. The altered frequencies will be shown when the marker pip remains stationary while the curve moves.

3. Change the tuning of the marker generator.

The response curve should remain stationary on the scope screen, but the marker pips should move across the curve, and, of course, will move across the scope screen at the same time. This is because the only thing which should change with tuning of the generator is the frequency of the marker pip.

When using marker harmonics you must avoid the same fundamentals as when using sweep harmonics. Do not tune the marker generator to a fundamental within the i-f range of the receiver, nor within the range of an i-f amplifier in a uhf tuner or converter. With double conversion systems do not tune the marker to a fundamental within the range of frequencies resulting from the first conversion.

These things to avoid have been described only in relation to fundamental tuning of marker and sweep generators. If these generators have strong harmonics other than those needed for responses and markers, some of these other harmonics can cause false indications. Then matters become really complicated.

For satisfactory accuracy of marker pips produced by harmonics, the generator must have accuracy of a high order on fundamentals. Consider the following example.

Assume that we use the fourth harmonic of 140 mc to identify 560 mc on a uhf response curve. If accuracy is one per cent on the fundamental it will be of this same percentage on harmonics. One per cent of the fundamental, 140 mc, is 1.4 mc. But one per cent of the 560-mc harmonic is 5.6 mc, which is nearly the width of a whole uhf channel. To have the marker correct within 1.4 mc at 560 mc its accuracy would have to be 1/4 of one per cent. Such accuracy is obtained only with crystal control or with crystal calibration at closely spaced intervals in the tuning range of the marker generator.

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COYNE ELECTRICAL SCHOOL

Television Home Training Division

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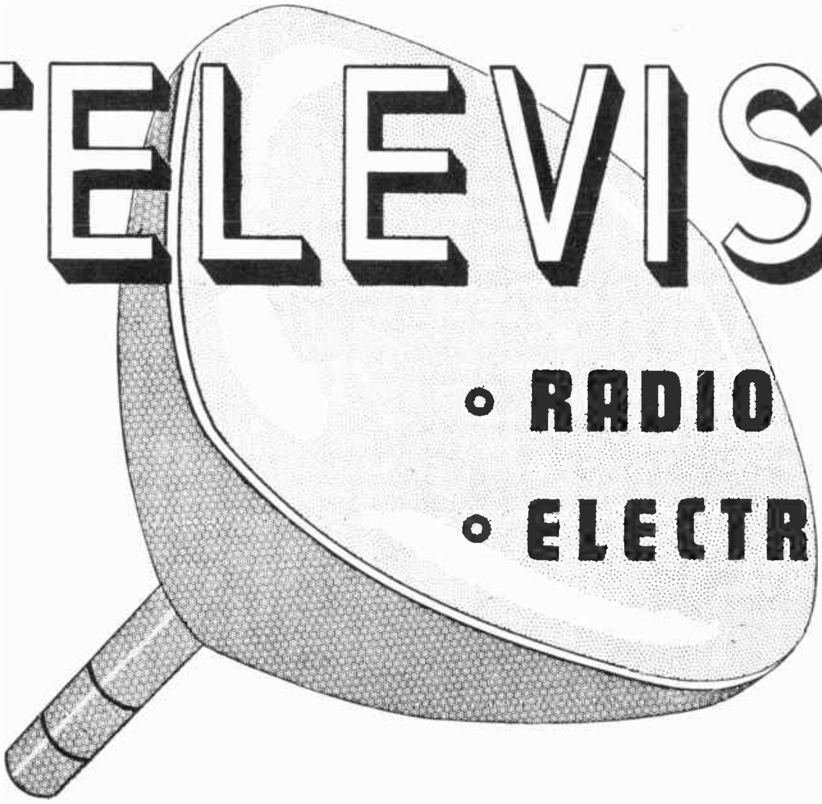

TELEVISION

• RADIO

• ELECTRONICS

LESSON 96 — COLOR TELEVISION — PART ONE

Coyne School

practical home training

Chicago, Illinois

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Lesson 96

COLOR TELEVISION — PART ONE

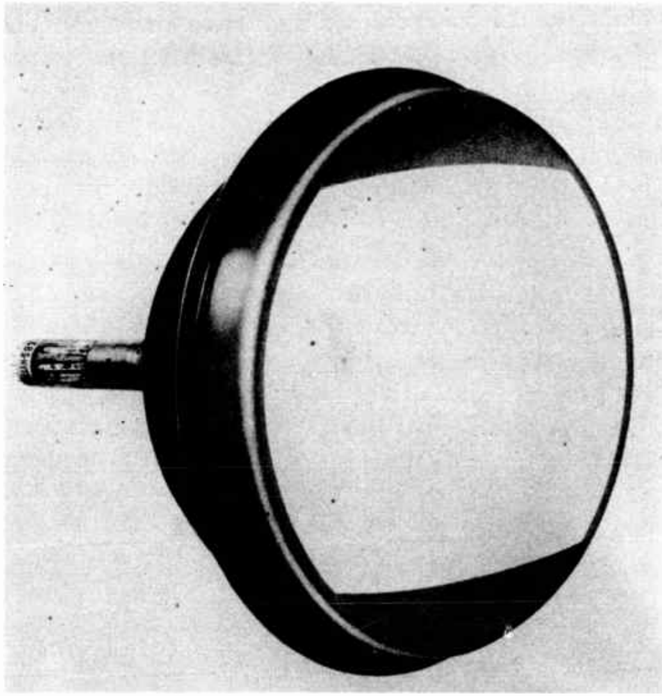

Fig. 1. A CBS-Hytron color picture tube.

Years of research and experiment were required to bring color television to its present highly satisfactory state. Difficulties and problems which beset the early methods were removed or solved upon adoption of the standard composite signal devised by the National Television System Committee, whose name is abbreviated "NTSC". All color broadcasts are of the NTSC signal, and all that follows in these lessons deals with transmission, reception and reproduction of this signal.

This standardized system allows broadcasting of color television in the same six-megacycle channels used for black-and-white transmission at both very-high and ultra-high carrier frequencies. Many methods proposed earlier would have required wider channels, and a special band of carrier frequencies for color.

The NTSC signal allows all of the millions of present black-and-white receivers to reproduce color broadcasts, although the reproduction is in black-and-white, not in color. This would not have been possible with other systems; color pictures could have been reproduced in no form at all except by color receivers. Also, color receivers designed in accordance with the NTSC system will reproduce all black-and-white broadcasts in black and white.

PRIMARY COLORS. In printing and in photography, pictures which appear to have every imaginable color consist actually of only three "primary" colors that blend together in your eyes to form all the others. Color television pictures consist similarly of only three primary colors. On the screen of the color picture tube are formed red, green, and blue pictures, either at the same time or in such rapid succession as to give the impression of a single full-color picture.

The color receiver and its picture tube can reproduce only the three primary colors and their limitless combinations, or, can reproduce black lines and areas where the phosphors are not excited by an electron beam. Yet, when receiving a black-and-white broadcast, the color picture tube can show pictures in shades of gray and in black and white, just as would a black-and-white receiver.

It is possible to reproduce white and gray on the color picture tube because the primary red, green, and blue may be so proportioned that color disappears, and we have the visual impression of white light. Then, for shades of gray, it is necessary only to reduce the intensity of the electron beam, in the same way that grays are formed on a black-and-white picture tube. This is the principle utilized for black-and-white reproduction on a color receiver.

To understand how signal voltages corresponding to color images are formed at the color camera circuits, and how these signals eventually produce colored pictures at the receiver, we first should become acquainted

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with a few facts relating to color and to light in general. Let's begin with something familiar.

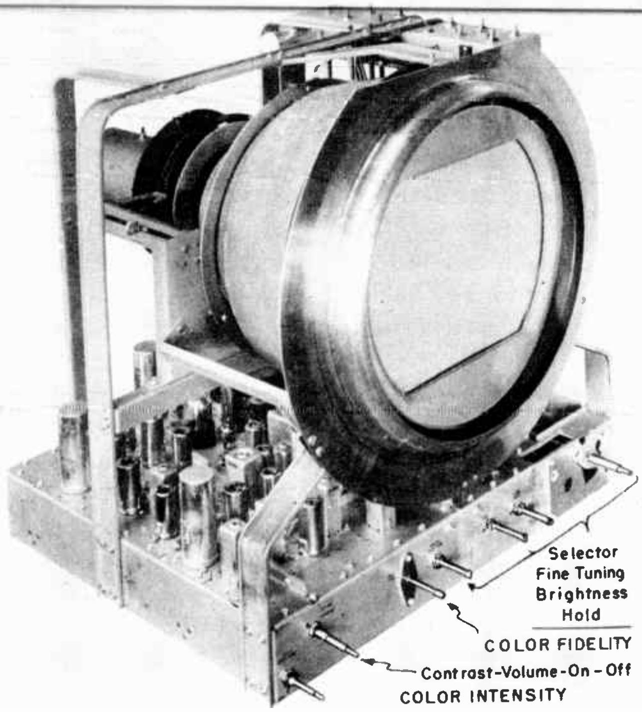

Fig. 2. The only additional operating controls for color are those marked Color Intensity and Color Fidelity on this early model of an Admiral receiver.

Probably you have described some object as having "all colors of the rainbow". When looking at a rainbow you do see all the pure colors. Around the outside is deepest red. Then, in order, are orange, yellow, green, and on the inside is blue. There are no sharp divisions. Each color merges gradually into those in either side.

It takes white light, as from the sun, to form a rainbow. No other kind of light would do. Orange light might give an orange bow, and green light a green bow, but the other colors would be missing. White light contains all the pure colors. Rain drops in the sky refract the white light and split it into all the colors from red to blue. Were all these colors put back together, the result would be white light.

The difference between colors is in wavelengths of light which produce in our eyes the various color sensations. Light is a form of radiant energy which, like radio waves, travels through space. Wavelengths in white light range from about 1/36000 inch

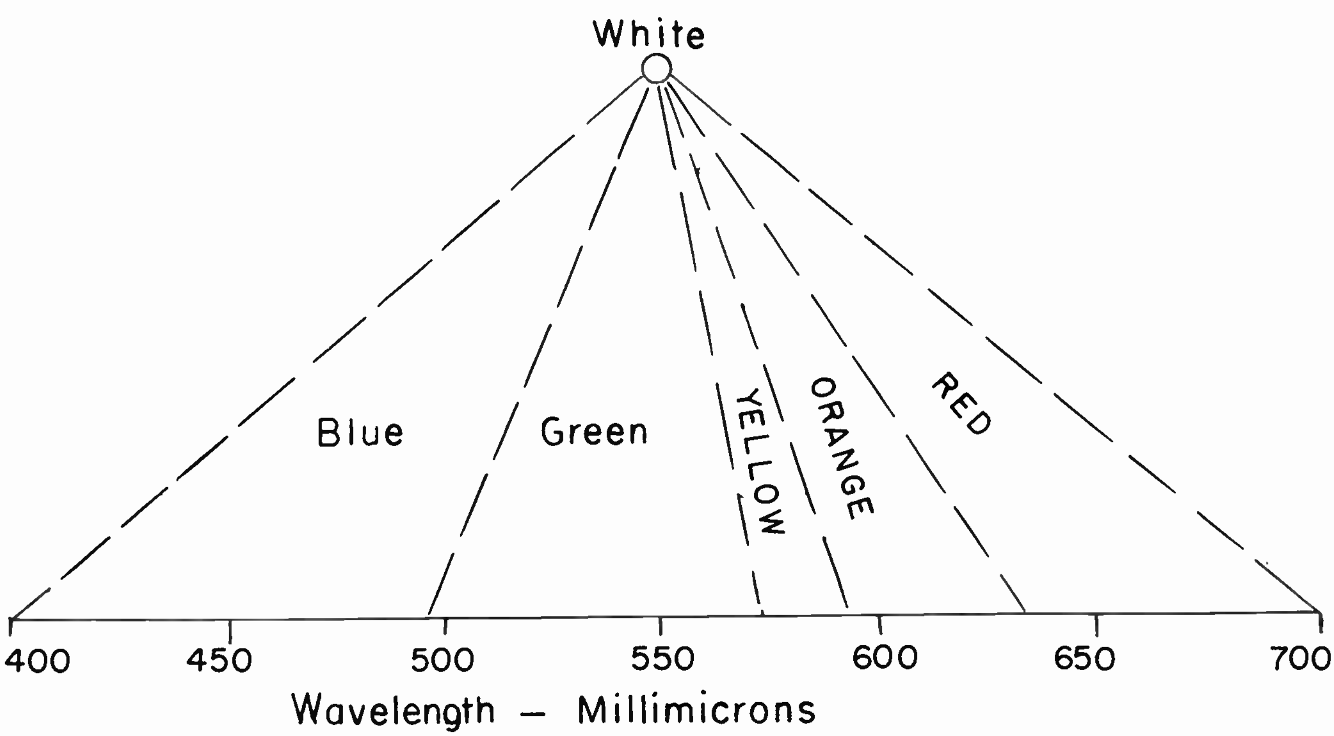

Fig. 3. White light is a mixture of all wavelengths in the visible spectrum.

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to 1/63000 inch, which corresponds to frequencies all the way from about 750 million megacycles to 430 million megacycles per second.

Splitting white light into colors divides it into certain bands of wavelengths, somewhat as shown by Fig. 3. Here we are not specifying wavelengths in fractions of an inch, which are inconvenient to use, but in the commonly employed unit called the millimicron. One millimicron is equal to one billionth of a meter. The range of visible radiation or visible wavelengths goes from about 400 millimicrons in the blue to about 700 millimicrons at the red. This range is the visible spectrum.

When white light falls on some object which you see as having green coloring, maybe the leaf of a plant, that object is reflecting wavelengths of about 490 to 575 millimicrons. It is absorbing and dissipating the radiant energy at other wavelengths. Your eyes receive only the energy in the reflected green wavelengths, and the leaf appears green.

Color is all in your eyes. It is just a visual sensation which we describe by names such as red, green, or yellow. The sensation is the same whether radiant waves are reflected from an object on which light is falling, or whether the waves come to your eyes from the illuminated phosphors in a color picture tube.

As mentioned before, all the color bands of the visible spectrum may be combined to give the sensation of white light. But if only two of the color bands are combined, the results may be rather peculiar.

At A in Fig. 4 only green and red wavelengths are reaching the eye of an observer. He doesn't see these two colors, instead he sees the color we call yellow. The sensation of yellow can be produced by mixing the wavelengths corresponding to green and red, although no truly yellow wavelengths are in the mixture.

At B the eye of the observer is reached by a combination of blue and green. The resulting color sensation is cyan, which

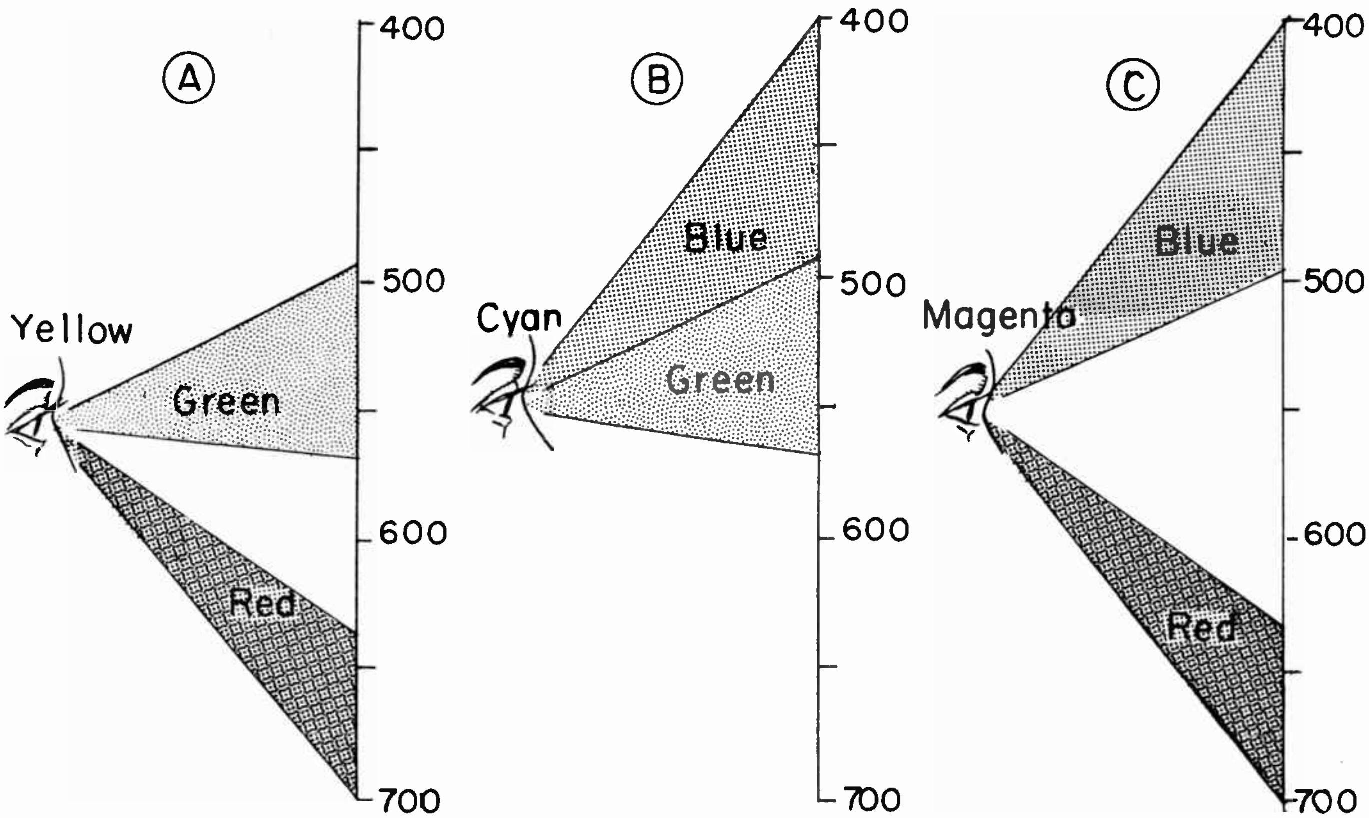

Fig. 4. Wavelengths for two color bands combine in the eye of an observer to give the sensation of a third, different, color.

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most people would call bluish-green. At C the visual sensation results from a mixture of blue and red wavelengths. The result is magenta, which you might describe as purplish-red. These and all other color sensations may be produced by mixing red, green, and blue lights of suitable relative intensities.

Of course, to produce any particular color sensation it is necessary to mix rather exact proportions and definite wavelengths from the red, green, and blue bands. If we select just the right bands of red, green, and blue, and combine them in certain definite strengths, it is possible to imitate every pure color of the visible spectrum as well as all the impure colors, like brown, which are not in the spectrum.

The bands of red, green, and blue wavelengths ideally suited for mixing and reproduction of television pictures in full color are called the television primary colors. There is a red primary, a green primary, and a blue primary. These are all we need.

The three primaries are produced at the color television camera. You may learn how a televised scene appears in the three parts of the camera by looking through colored glass or transparent colored plastic at anything having a variety of colors. If possible, use three pieces of glass or plastic, one red, another green, and the third blue. Do your viewing in daylight.

When you look through the red glass, everything that is red, orange, or yellow or strongly tinged with these colors, appears red. Everything that is green or blue, or strongly tinged with green or blue, appears decidedly dark. In your eyes is formed a red image.

Next, look through the green glass. Now the greens appear strong, yellows become yellowish-green, and blues appear as blue-greens. But reds and oranges become very dark. A green image of the scene is being formed in your eyes.

Upon looking through the blue glass you see a blue image. All the blues appear strong. Greens take on a bluish cast, yellows become somewhat greenish, but orange and red become dark.

One type of color television camera, whose principle is illustrated by Fig. 5, has three light-sensitive tubes, image orthicons such as used for black-and-white televising. There are mirrors which allow some colors to pass through while reflecting others to one side, and there are transparent color filters. One camera tube sees a blue image, another sees a green image, and the third sees a red image of the scene being televised. Another type of color camera has only one light-sensitive tube. It looks through a whirling disc in which are red, green, and blue filters, and sees red, green, and blue images in rapid succession.

The blue image formed on the light-sensitive surface in the camera tube or tubes causes an output voltage proportional to strength or brilliance of blues in the tele-

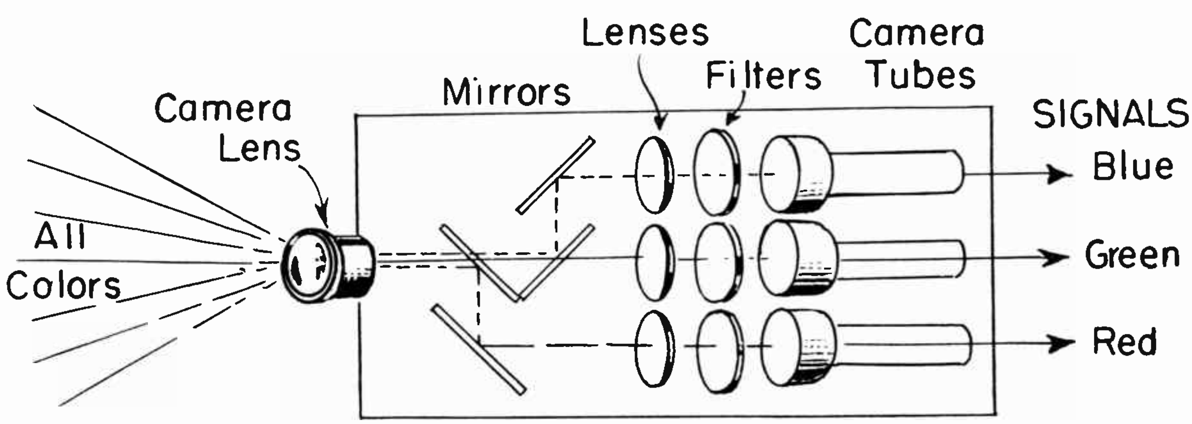

Fig. 5. How a color camera separates all the colors of a scene into the three primary bands.

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vised scene. The green image causes a separate output voltage proportional to strength of the greens. The red image causes a third output voltage proportional to strength of reds in the scene. Now, in effect, all colors of the televised scene have been changed into three voltages, which are the red primary voltage, the green primary voltage, and the blue primary voltage.

After a great deal of electronic maneuvering these three voltages for the three primary colors will arrive at the picture tube in a receiver, and will control the electron beam or beams.

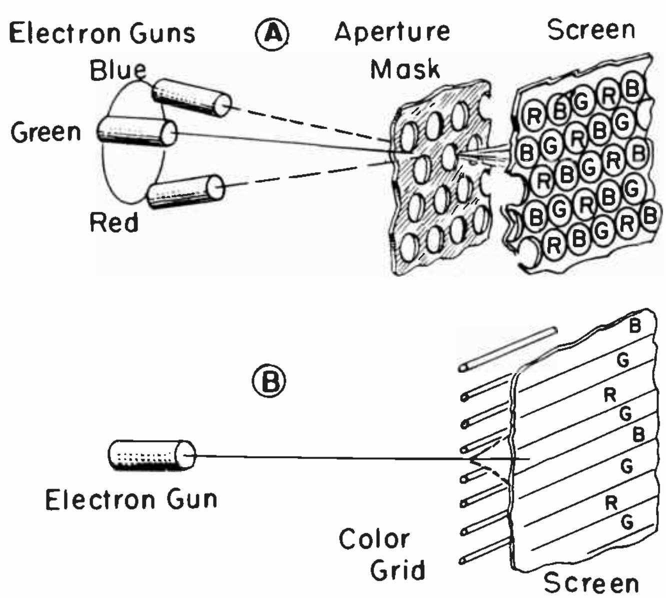

Fig. 6. Elementary principles of a three-gun color picture tube and of a single-gun tube.

COLOR PICTURE TUBES. At A in Fig. 6 is illustrated the basic principle of a color picture tube in which are separate electron guns for each of the primary colors. On the inside of the viewing screen are hundreds of thousands of tiny phosphor dots in groups. Each group consists of one dot which emits red light, another which emits green light, and a third which emits blue light.

Behind the screen is an aperture mask with openings through which beams from the three guns pass to the phosphor dots. The guns, the mask openings, and the dots are in such relative positions that the beam from the red gun can reach only red phosphor dots, the green beam can reach only green phosphor dots, and the blue beam can reach only blue phosphor dots.

In the three-gun picture tube, all three color images appear continually, all at the same time. The color dots are so close together and so small that the three primaries blend to reproduce televised scenes in full color.

The principle of a single-gun color tube is shown at B of Fig. 6. The screen phosphors are in the form of very narrow horizontal strips, with the primary color emissions arranged as on the diagram. Immediately back of the screen is a color grid consisting of very fine horizontal wires which may be electrically charged.

With the grid wires uncharged, the electron beam goes straight through to a green phosphor. Charging adjacent wires in opposite polarities focuses the single beam away from a green phosphor and onto a red strip. Reversing the polarities of the grid wires focuses the beam onto a blue strip.

In the single-gun tube the pictures in the three primary colors are formed in such rapid succession that persistence of vision blends them into all colors of a televised scene.

REPRODUCING COLORS. When the color camera scans any area which is wholly red only the red phosphor is excited. Likewise, only green or blue phosphors are excited for areas wholly green or wholly blue. For a yellow area both the red and the green voltages come through, because the sensation of yellow results from mixing red and green. Both phosphors are excited, and you see that portion of the scene as yellow. Every other color is similarly produced by exciting one, two, or all three of the color phosphors as may be required.

Supposing a scanned area of the original scene is white, how does it come through? We know that white consists of all colors, of all visible wavelengths of light. To reproduce white it is necessary only to excite all three phosphors in the correct degrees, and the result gives the sensation of white light.

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What about black? We need only drop the intensity of the electron beam or beams to the black level or below. Then there is no light, and absence of light is black.

How does the color picture tube show the difference between vivid red and pink or light red, or between any strong color and a lighter shade of the same color? This may be answered by asking another question. If you had some paint of intense red color and needed pale red, what would you do? Naturally, you would mix in some white paint. In color television we do something equivalent to make any color lighter, we mix in some white.

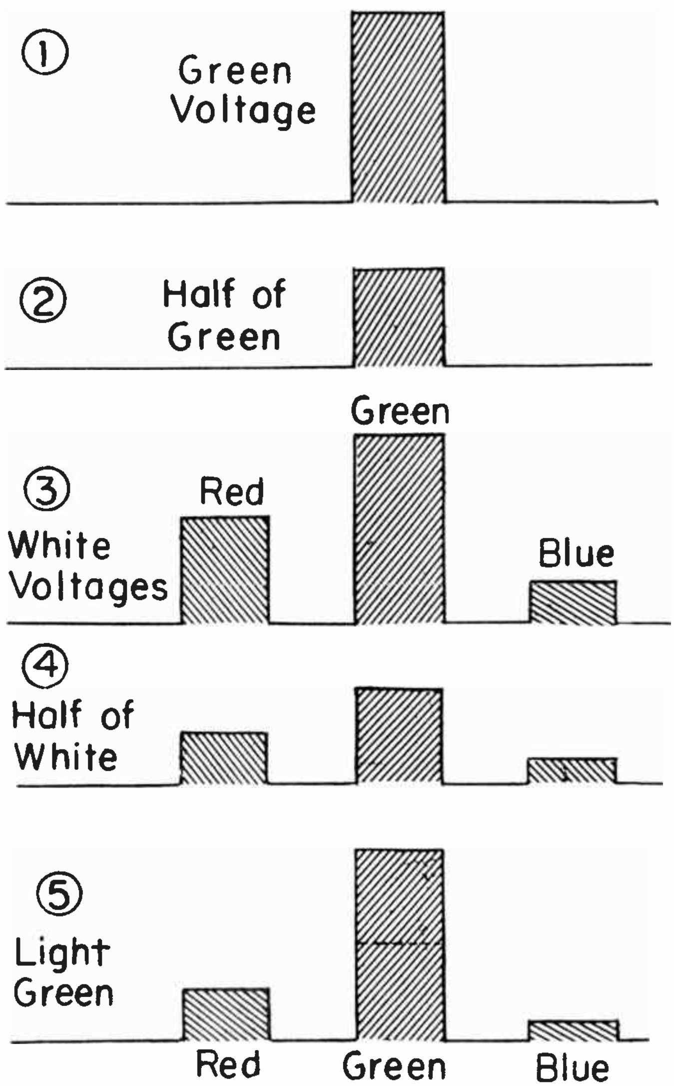

Fig. 7. To obtain light green we mix half the green voltage with half of the three primary voltages which combine for white.

Let's say we want a light green, a mixture of about half green and half white. To get the green half we take half of the voltage that results from a green image in the color camera. This is shown at 1 and 2 of Fig. 7. The only way to produce white in color television is to take such proportions of red, green, and blue as will cause the sensation of white when mixed together. These are shown at 3. In the present case we want only half white, so, as at 4, we take only half of the voltages for red, green, and blue signals.

Now let's see what has been accomplished. There is only half the red voltage. There is half of the green voltage, as required for desired proportion of white, but there is also the second half of the green voltage to form our predominant color, which is to be green. Finally, there is half of the red voltage, as required for the white which is to dilute the predominant green. The result, shown at 5, is a combination of half the red signal voltage, two halves or the whole of the green voltage, and half of the blue voltage. We see a light green color.

Should we wish a still lighter green it could be formed by taking less of the green voltage, and still more of the combination of red, green, and blue voltages which represent white. A green not so light could be made with less of the white combination and more of the green voltage. Any other colors may be similarly be made lighter than the primary.

Supposing the color called lilac is to be reproduced. Lilac is a combination of three parts blue, one part red, and two white. For lavender we would need eight parts of blue, one of red, and about seven of white. The color called brown requires a mixture of red and yellow. We have no yellow primary, so would form this color by mixing red and green. Then we would have quite a lot of red and some green. Because brown is a dark color, intensity of the electron beam or beams would be reduced to a rather low value. Reducing beam intensity will darken any color.

Fortunately, all this mixing of primaries is done automatically, first by the color camera and associated circuits, second by

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reversing the whole process in receiver circuits.

HUE. There is a single word that describes the property we have been calling color. That word is hue. If the color of an object is red it is of red hue, if the color is orange it is of orange hue, and so on.

Hue tells how a wavelength, a band of wavelengths, or any mixture of visible wavelengths affects our eyes. We might specify hues in terms of wavelength, but ordinarily we use the common names such as blue, red, yellow, and all the rest.

A good definition of the word hue says it tells how a color differs from gray of the same brightness. The idea is illustrated by Fig. 8. Gray is made up of all wavelengths or all colors, because gray really is white of less than maximum brightness. The colors or wavelengths which produce gray are distributed from red to blue, just as for white.

If some wavelengths are absent you no longer see gray, but instead see whatever color or hue is produced by the mixture of wavelengths that remain. This is why we may say that hue described the manner in which wavelength distribution differs from the distribution in gray, or white, light.

SATURATION. Earlier we made red paint lighter by mixing in some white. This reduced the "saturation" without changing the hue. The hue remained red. Saturation is a measure of how much white is mixed in with any hue.

You might start out with some intense, strong, vivid hue. The saturation would be 100 per cent. The color or hue, of 100 per cent saturation, might be one of our primaries, red, green or blue, or it might be any other color or hue.

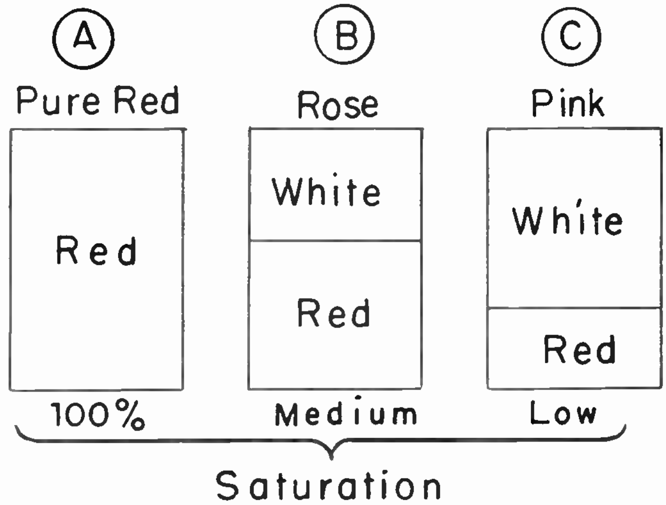

Fig. 9. Saturation depends on the extent to which a hue is diluted with white light.

Commencing with a red hue of 100 per cent saturation, A of Fig. 9, then mixing with it a certain amount of white, at B, could produce a rose color. This rose would actually be red of medium saturation. With still more white, at C, the color might change to what you would call pink, or a pastel shade of red. This would be a red hue of low saturation.

Some authorities use the word chroma as meaning the same as saturation, without

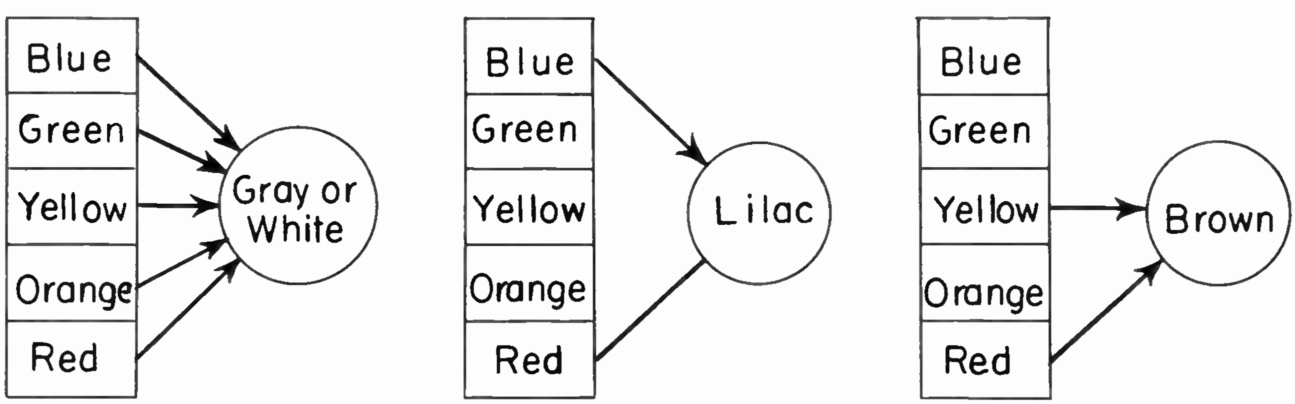

Fig. 8. A hue results from using only a few of the color bands which would produce gray, or white.

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reference to hue. Chroma then relates to how much white is mixed with any hue, but ~~not to changes of hue. Others use the word~~ chroma as referring to the total effect of hue and saturation together. Then chroma describes all the characteristics of a color which result from wavelengths, also from proportions of white.

CHROMINANCE. In color television practice we ordinarily use the word chrominance when referring to any combination of hue and saturation which determines the properties of a color. It is chrominance that distinguishes a colored picture from a black-and-white picture of the same scene. In a black-and-white picture there are only whites, blacks, and various shades of gray. If we retain whites, blacks, and grays, but add hues of various saturations, we have added chrominance and have a picture in color.

As we shall learn, a color TV receiver responds to two signals which are transmitted simultaneously. One is the black-and-white or "monochrome" signal that varies illumination and puts shadings into pictures. The other is the chrominance signal that adds color in the form of hue and saturation.

The terms black-and-white and monochrome are used in television as meaning the same thing, or as referring to pictures which are without color and formed only by black, white, and intermediate grays. Neither name is strictly correct. A monochrome picture would be one formed by any single hue in varying degrees of saturation and brightness. A black-and-white picture would lack intermediate grays. A correct name for a shaded picture free from color would be achromatic. But we shall use the terms black-and-white and monochrome, because only photographers and artists would know what we mean by achromatic pictures.

LUMINANCE OR BRIGHTNESS. With a black-and-white or monochrome TV receiver the pictures are formed by variations of light and shade, actually by variations of brightness at different points on the screen. Variations of brightness result from changes of electron beam intensity. These changes, in turn, result from continual alteration of grid-cathode voltage due to the picture signal.

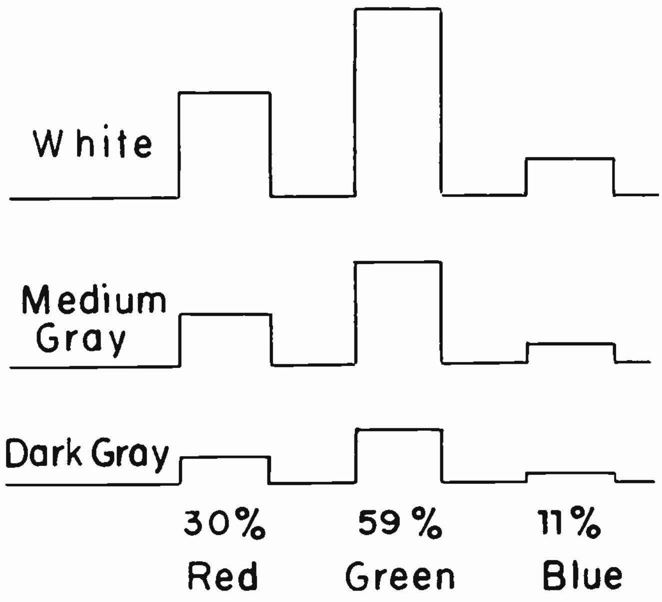

Fig. 10. Proportions of primary colors remain the same for luminance giving white or any shade of gray.

In color TV we have the equivalent of the monochrome signal, but we call it the luminance signal or sometimes the brightness signal. The luminance signal is a combination of red, green, and blue voltages of such proportions as give the sensation of white. Such a signal is represented at the top of Fig. 10. If proportions remain unchanged, but signal strength is reduced, we obtain shades of gray, as at the center and bottom. It is thus that lights and shadows are produced to form picture outlines.

The effect of the luminance signal in color TV is the same as that of the picture signal in monochrome TV. Either signal will produce blacks, grays, and whites on the picture tube screen. Although the luminance signal is made up of a certain combination of red, green, and blue voltages, it produces no color effects because red, green, and blue always are in proportions which form white or gray when mixed.

The word luminance, as used in color TV, means practically the same as brightness. Luminance is a measure of how much light is emitted from a given area of the picture tube screen, and brightness is a

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measure of the same thing. With zero brightness or zero luminance the screen would be dark. Maximum brightness or maximum luminance would make the screen brilliantly white. Intermediate values of brightness or luminance would produce various shades of gray.

If we have chrominance, in addition to luminance, there still will be all variations of shading as caused by varying strength of the luminance signal, but shading will be in colors which are brighter or less bright. In some certain case the luminance signal, by itself, might produce a rather dark gray. At the same time the chrominance signal might produce a reddish-yellow hue of low saturation. On the screen of the color picture tube we would see a darkened reddish-yellow of low saturation, which would be called brown.

It may be easier to comprehend the difference between luminance and chrominance by looking through any piece of colored glass at a sheet of white paper which is illuminated. Strength of illumination on the paper represents luminance or brightness. With a bright light there will be high luminance, and with a dim light there will be low luminance.

Hue and saturation, which together are chrominance, are determined by the color of the glass, not by strength of illumination. With a strong light on the paper there will be a certain chrominance effect combined with high luminance. With a dim light there will be the same chrominance effect, but with low luminance.

LUMINANCE SIGNAL. Variations of brightness which produce black, white, and grays on the color picture tube result from the luminance signal. With only this signal, and in the complete absence of the chrominance signal, there would be black-and-white pictures.

The luminance signal in the NTSC system is formed at the transmitter by taking certain fractions of the red, green, and blue

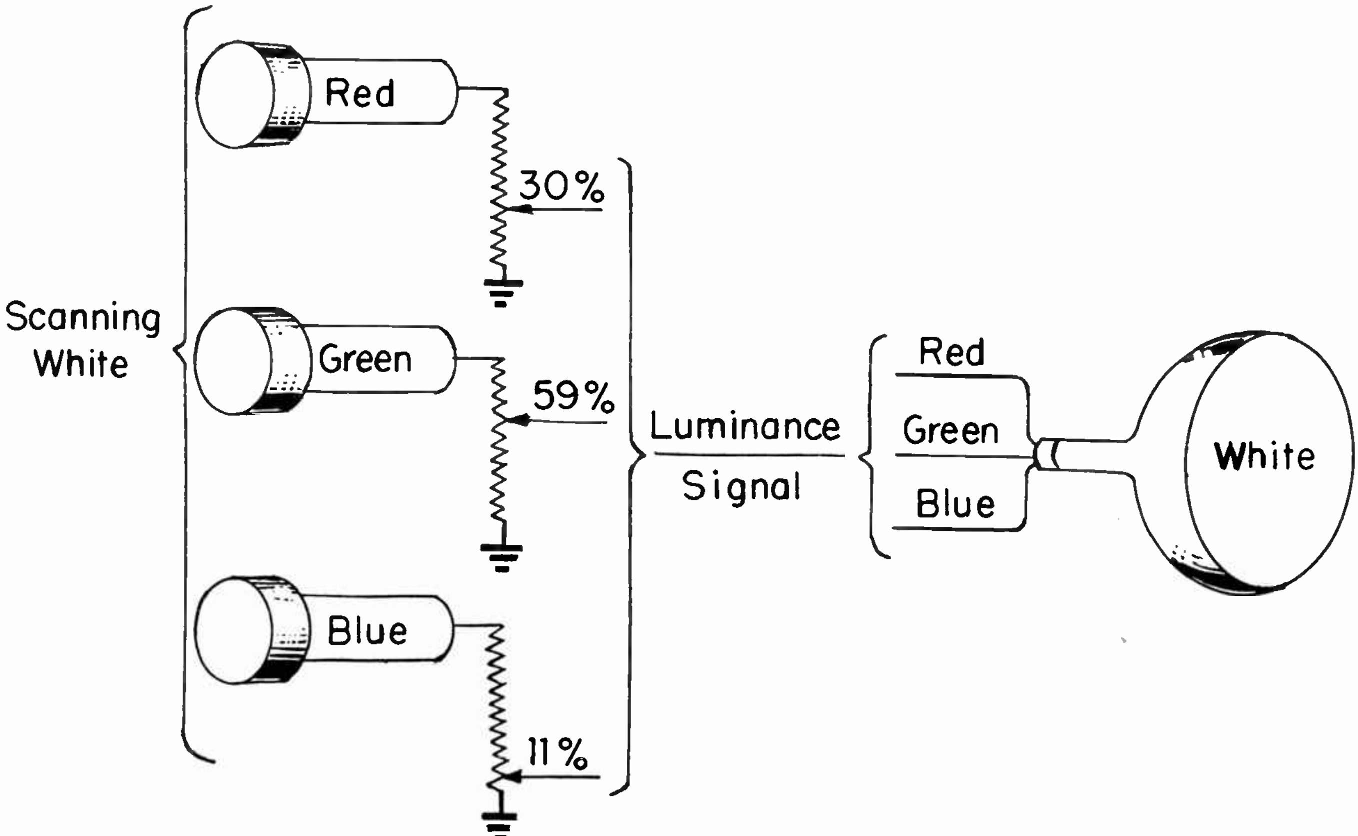

Fig. 11. The luminance signal voltage is a combination of certain percentages of output voltages from the red, green, and blue camera tubes.

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output voltages from the color camera. This is shown in principle by Fig. 11. These fractions are 0.30, or 30%, of the red voltage, 0.59 or 59% of the green voltage, and only 0.11 or 11% of the blue voltage. This combination of color voltages, which is the luminance signal, amplitude modulates the TV carrier.

After demodulation of the carrier in the receiver, the luminance signal voltages, in proportions just mentioned, act in the electron gun or guns of the color picture tube. When there is only the luminance signal, intensity of the electron beam acting on the red phosphor would be determined solely by the red luminance voltage. Intensity of the beam acting on the green phosphor would be determined by the green luminance voltage, and the blue luminance voltage would determine beam intensity on the blue phosphor.

Were white being scanned at the camera, the three phosphors would emit red, green, and blue lights in such proportions as to form white. You would not see the separate primary colors, but only the same effects as on the screen of a black-and-white receiver.

To form shades of gray, and black where needed, intensities of the beams and brightness of the three phosphors would go up and down together. Pictures would have no coloring, because we assume there is no chrominance signal.

The luminance or brightness signal often is called the Y-signal, especially in circuit diagrams. Voltage corresponding to the luminance signal maybe shown by the symbol E_Y (E sub-Y). Still another name for the luminance signal is monochrome signal.

COMPATIBILITY. The NTSC television system is a compatible system because it allows reception in all the ways illustrated by Fig. 12. A color receiver will, of course, produce a color picture from a color transmission signal. But, without any readjustments whatever, a black-and-white set will produce a monochrome picture from the color signal.

A color receiver operating on a monochrome signal will produce a monochrome picture, because there is no chrominance signal to be received. And, naturally, the black-and-white receiver will produce a monochrome picture from a monochrome signal.

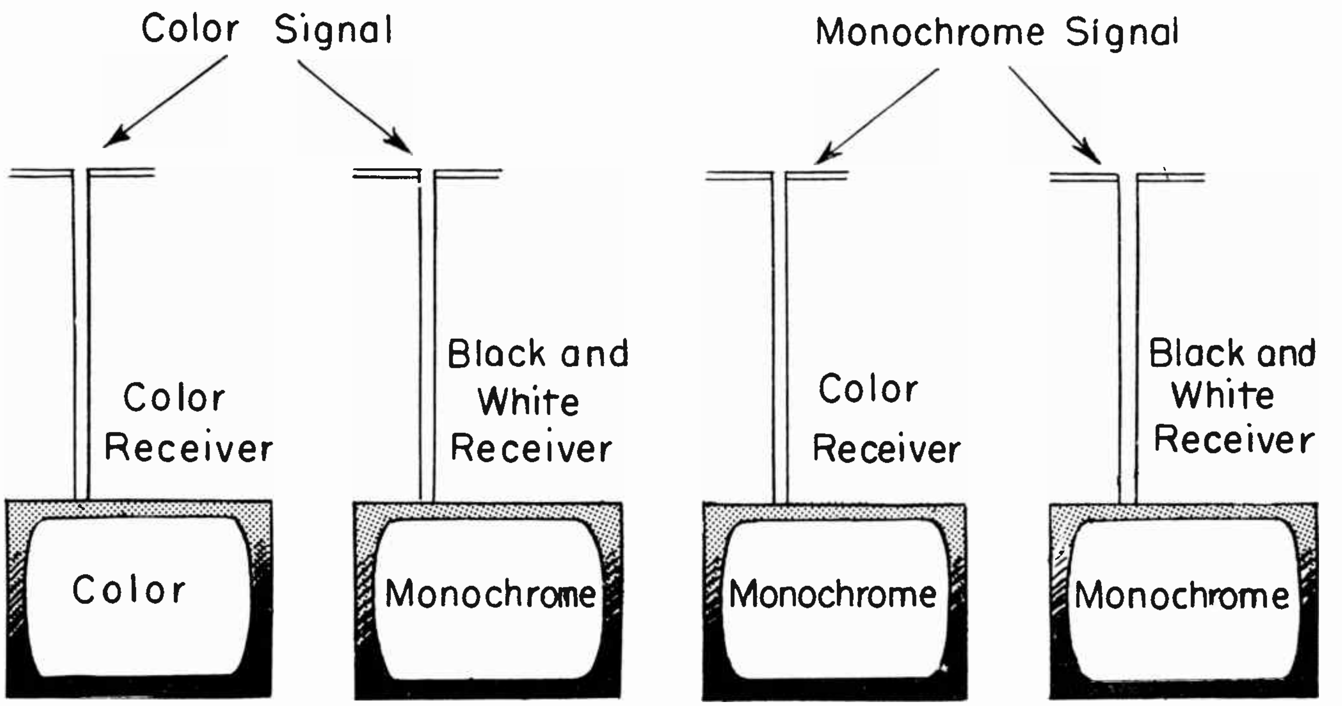

Fig. 12. The NTSC system of color television is a compatible system.

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Although the luminance signal will produce black-and-white pictures entirely free from color, we must not lose sight of the fact that this signal is made up of certain proportions of red, green, and blue voltages. It is the definite proportions of these voltages which combine for white and for gray tones.

Should the three color voltages forming the luminance signal become of wrong proportions, the effect in a black-and-white receiver will be pictures of poor quality. Wrong proportions of these color voltages will unbalance the relations required for white and grays in a color receiver. Then colors may appear in pictures from a monochrome signal. Good monochrome pictures may be as difficult to produce on a color set as color pictures.

When all circuits are working as they should, and all adjustments are correct, pictures on a black-and-white set receiving a color signal will be as good as when receiving a monochrome signal, although there may appear to be somewhat less contrast and "snap" than in pictures from a monochrome signal. Usually this is due to the fact that studio lighting for color telecasts may be flatter and may cause fewer shadows than lighting for black-and-white telecasts. When the color signal is reproduced by a color receiver, contrast appears better than in monochrome pictures, because different colors make objects stand out more distinctly than in monochrome pictures.

Since the luminance or brightness signal is a combination of voltages corresponding to all three primary colors, it must be taken into account when using the chrominance signal that some color information already is present. The chrominance signal must be a "color difference" signal, consisting of voltages which are differences between primary color values in the luminance signal and those required to bring out hues and saturations which color reproduced pictures.

I-SIGNAL AND Q-SIGNAL. The chrominance signal is formed by combining two color signals. One, called the I-signal, is represented at the top of Fig. 13. There is a positive voltage equal to 60% of the red

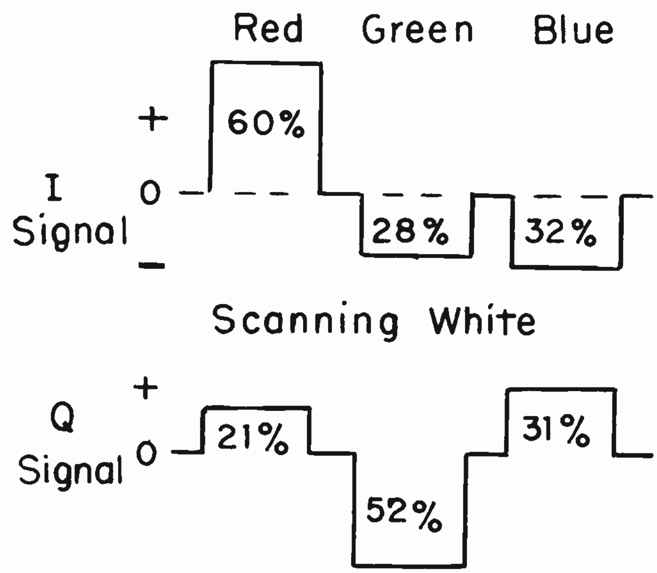

Fig. 13. How the I-signal and the Q-signal, for chrominance, are formed from certain percentages of the color camera voltages.

camera output, a negative voltage equal to 28% of the green camera output, and another negative voltage equal to 32% of the blue camera output.

Supposing the camera is scanning an area of pure white. Since white is made up of the three primaries, camera output voltages will be of equal strengths for red, green, and blue - because the color camera is designed to work this way. Now the positive voltage equal to 60% (red) is balanced by the two negative voltages of 28% (green) and of 32% (blue), whose sum is 60% negative. Positive and negative voltages of the I-signal balance out, and there is no I-signal. Remember, this disappearance of the I-signal happens only while scanning pure white, or gray.

The other color signal, called the Q-signal, is represented at the bottom of Fig. 13. Here we have two positive voltages, one equal to 21% of the red camera output and another equal to 31% of the blue camera output. The sum is 52% positive. The third voltage in the Q-signal is 52% of the green camera output, but this is a negative voltage. Now we have, in the complete Q-signal, 52% of positive and 52% of negative. While white or gray is being scanned, these positive and negative voltages will cancel and the Q-signal will disappear.

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While scanning white or gray, both the I-signal and the Q-signal disappear. Because it is these two that form the transmitted chrominance signal, there won't be any chrominance signal for white or gray areas of an image. Then the luminance signal will be left to act alone, and will transmit white and all gray tones.

Supposing now that the camera is scanning areas which are not pure white, but have hue and saturation as well as brightness. Percentages of camera outputs that go into the I- and Q-signals won't change. But the red, green, and blue output voltages themselves will change. Consequently, actual color voltages corresponding to the several percentages will change accordingly.

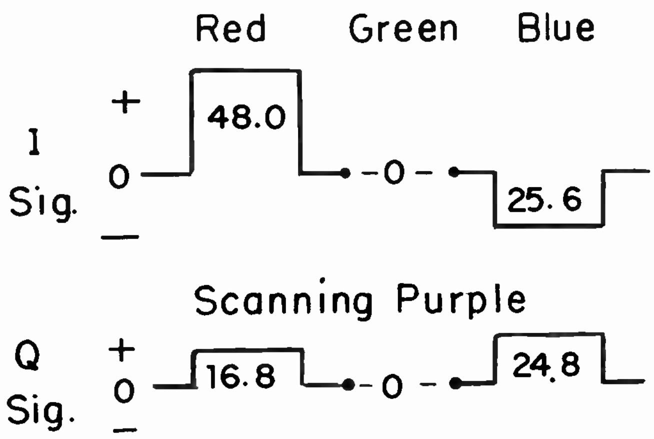

Fig. 14. Voltages of the I- and Q-signals which, together, would result in a color reproduction of purple.

To illustrate: Assume that a purple object is being scanned. What happens is shown by Fig. 14. Purple is a combination of red and blue, with no green. Relative camera outputs, in millivolts or any other unit, might be 80 of red, 80 of blue, and 0 of green. The I- and Q-signals would be formed thus:

	CAMERA OUTPUT	I-SIGNAL Per Cent	Units	Q-SIGNAL Per Cent	Units
RED	80	+ 60%	+ 48.0	+ 21%	+ 16.8
GREEN	0	- 28%	0	- 52%	0
BLUE	80	- 32%	- 25.6	+ 31%	+ 24.8

Actual units of voltage going into the I- and Q-signals are not numerically the same as the percentages, because we are not scanning white or gray, and because camera outputs now correspond to the hue and saturation in a color.

These I- and Q-signals which result from certain combinations of primary color voltages eventually may be used at the receiver to produce the same combinations of color voltages, and such illuminations of the phosphors as cause the visual sensation of purple.

At first glance we might assume that the + 48.0 voltage units of red in the I-signal would combine with + 16.8 units of red in the Q-signal for a total of + 64.8 units of red. It might seem also that - 25.6 units of blue in the I-signal would combine with + 24.8 units of blue in the Q-signal, with a net result of only - 0.8 unit of blue for production of purple. Obviously, these assumptions must be wrong, for there would be eighty-one times as much red as blue. The resulting hue would be practically pure red, certainly not purple.

To find where we are wrong it will be necessary to examine a number of factors which affect formation of the I- and Q-signals and affect the manner in which these signals combine to form the complete chrominance signal. To begin this line of investigation we shall get acquainted with the color carrier.

COLOR CARRIER. The I-signal and the Q-signal amplitude-modulate a voltage called the color carrier or the subcarrier. This color carrier is a sine-wave voltage at constant frequency of 3.579545 mc per second. For convenience we shall hereafter refer to this frequency as its approximate value of 3.58 mc. The modulation process is illustrated by Fig. 15.

The space carrier for whatever television channel is being used is amplitude modulated by the chrominance signal or Y-signal. The Y-signal covers a frequency range from about 60 cycles to 4 mc per second, and in this range acts like the regular video or picture signals for black-and-white transmission.

There is also TV carrier modulation for horizontal and vertical sync pulses and for blanking. Now, along with all these other

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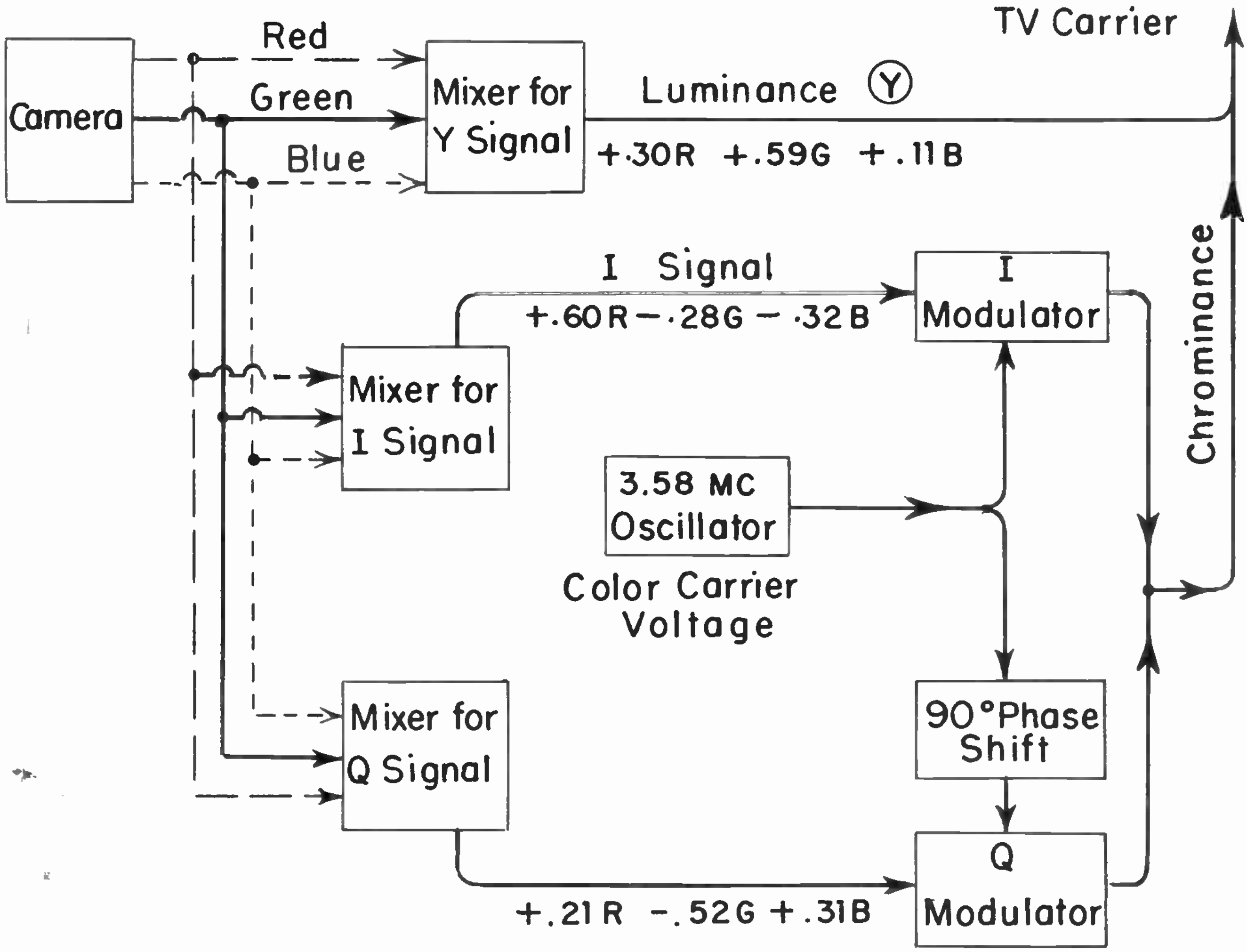

Fig. 15. How the color carrier is modulated at the transmitter to form the chrominance signal.

modulations, we shall add chrominance modulation or add the color modulation.

The I-signal is formed by mixing voltages from the outputs of red, green, and blue cameras. This signal goes to the I-modulator, where it modulates the 3.58-mc color carrier.

The Q-signal is formed similarly by voltages taken from the three cameras. The Q-signal goes to the Q-modulator, but this modulator does not receive a voltage directly from the 3.58-mc oscillator.

The 3.58-mc color carrier voltage is generated in the master oscillator, which is part of the transmitter. Part of the color carrier voltage goes from the oscillator to the I-modulator, where it is modulated by the I-signal.

The remainder of the color carrier voltage from the 3.58-mc oscillator goes to a phase shifting circuit at whose output is a voltage lagging the original oscillator voltage by 90 electrical degrees or a quarter-cycle, but still at a frequency of 3.58 mc. This lagging 3.58-mc voltage goes to the Q-modulator, where it is modulated by the Q-signal.

The two modulated color carrier voltages combine to form the chrominance signal. The chrominance signal modulates the TV space carrier; it is not radiated through space by itself, as is the separate television sound signal, but is merely additional modulation on the space carrier.

The I-signal now exists as modulation on a 3.58-mc voltage which is in phase with voltage from the master oscillator. This

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In-phase relation is the reason for calling the associated color signal the I-signal, and the associated modulator the I-modulator.

In the chrominance signal we have the original Q-signal as modulation on a 3.58-mc voltage which is a Quarter-cycle out of phase with the master oscillator voltage, or is in Quadrature with the oscillator voltage. This is the reason for using the names Q-signal and Q-modulator.

Whenever we speak of phase relations of the I-signal, the Q-signal, and the complete chrominance signal, the phase of the master oscillator voltage is our reference. When mentioning a signal as being of a certain phase, measured in electrical degrees, that measurement is with respect to master oscillator voltage as being of zero degrees, or as being the reference phase.

For simplicity of explanation we have assumed, in Fig. 15, that the I-signal is in phase with master oscillator voltage, and that the Q-signal is 90 degrees out of phase with oscillator voltage. These relations are shown at A of Fig. 16.

In the NTSC method of color transmission the phase relations actually are as shown at B. The I-signal is made to lag the reference voltage by 57°. Since the I- and Q-signals always remain separated in phase by 90°, the Q-signal now lags the reference voltage by the sum of 57° plus 90°, or by 147°

Both the I-signal and the Q-signal go into the same circuits before they modulate the space carrier or TV channel carrier. Inasmuch as two voltages or currents cannot exist independently in a single circuit or single conductor, the I- and Q-signals must combine into a single resultant voltage or current, which is the chrominance signal.

Voltages resulting from combination of two alternating voltages are illustrated by Fig. 17. Only positive alternations are

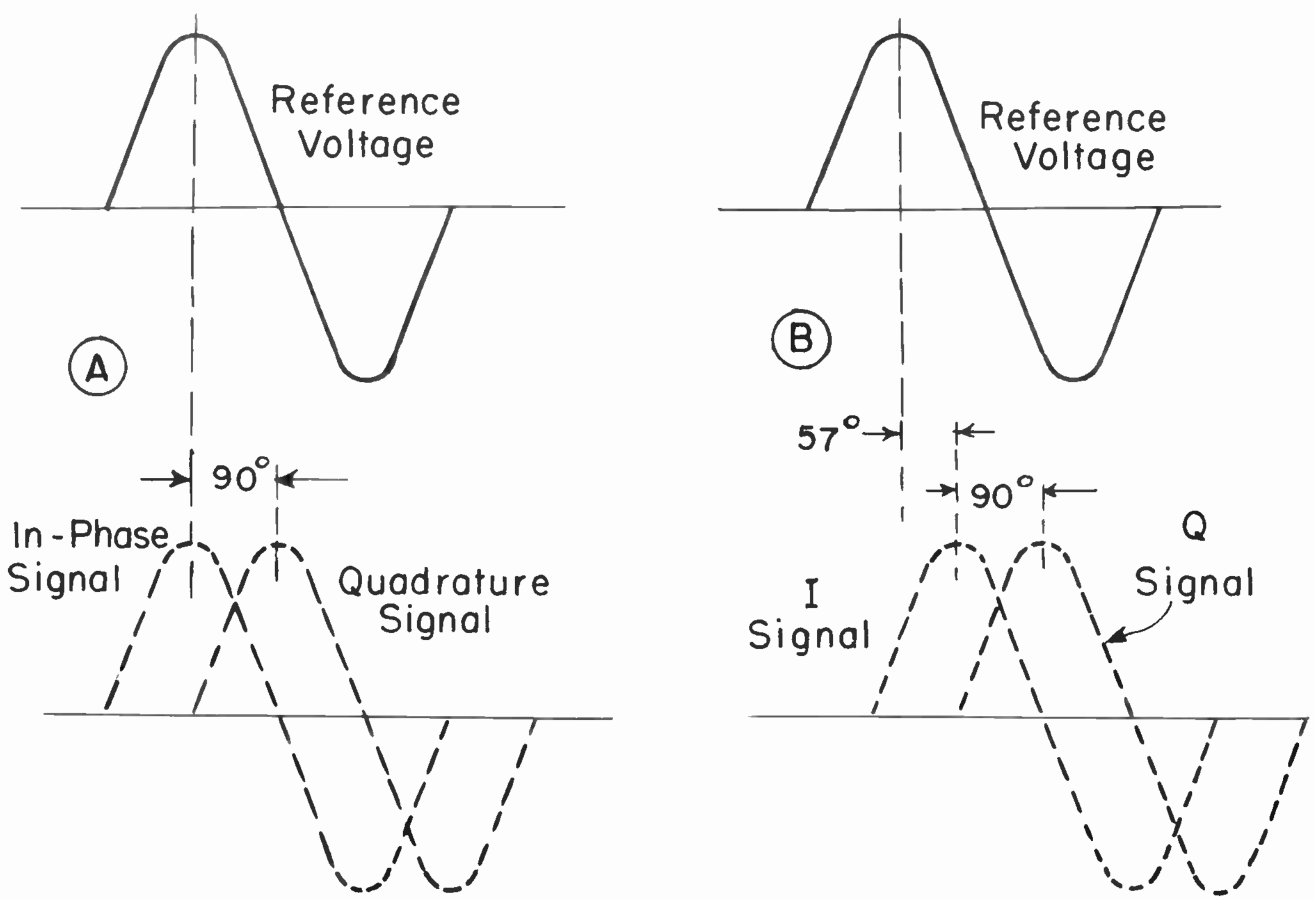

Fig. 16. The I- and Q-signals as represented by sine-wave diagrams.

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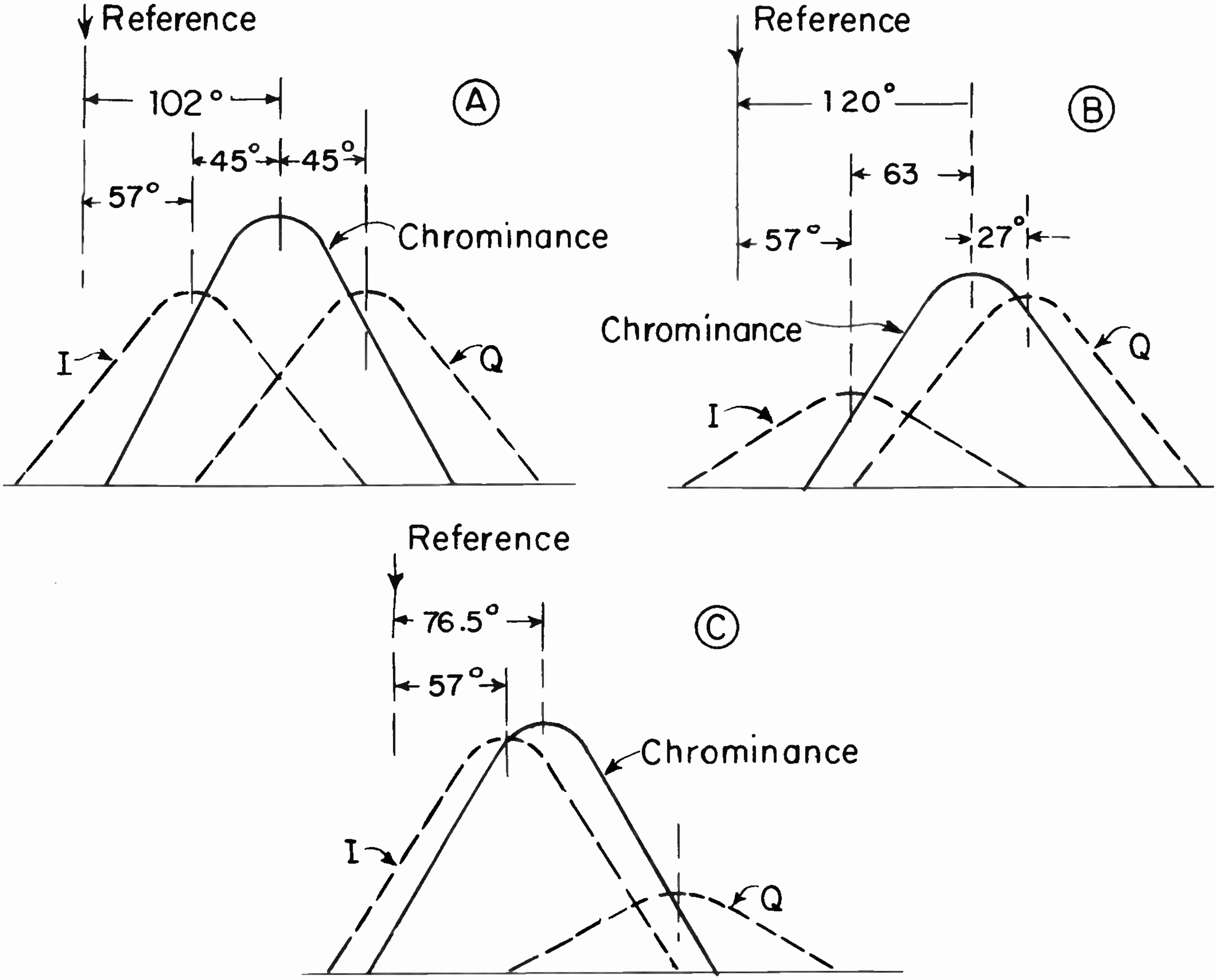

Fig. 17. Sine-wave representation of the manner in which the chrominance signal voltage results from combination of I- and Q-signal voltages.

shown. Negative alternations would be similar, but below the zero line.

In diagram A the I-signal and Q-signal are of equal amplitudes. As always, these two signals are separated by 90°. The resultant voltage, which is the chrominance signal, is half way between; it lags the I-signal by 45° and leads the Q-signal by 45°. Because phase of the I-signal now is 57° behind the reference voltage and the chrominance signal is 45° later than the I-signal, phase of the chrominance signal must be 102° behind the reference voltage. Note that amplitude of the chrominance signal is greater than that of either the I- or Q-signal, but is not equal to the sum of those amplitudes.

In diagram B, amplitude of the I-signal is only half that of the Q-signal. The resultant chrominance signal is 63° behind the I-signal, so must be 27° ahead of the Q-signal, since the I- and Q-signals always are 90° apart in phase. Because phase of the I-signal is 57° behind the reference voltage, and the chrominance signal now is another 63° behind the I-signal, phase of the chrominance signal is 120° behind the reference voltage. Note that amplitude of the chrominance signal is but little greater than that of the Q-signal.

Now look at diagram C of Fig. 17. The camera is scanning saturated red. Camera output voltages are such that relative values are 60 units for the I-signal and 21 units for the Q-signal. The resultant chrominance

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signal has amplitude of about 63.2 units, which corresponds to the degree of saturation. Phase of the chrominance signal is about 76.5° behind the reference voltage. This is chrominance phase angle when the camera scans a red area. It is the phase angle of the transmitted chrominance signal which will cause the receiver picture tube to show red on its screen.

The chrominance phase angle in diagram A would correspond to a slightly purplish red. The phase angle of diagram B results from and causes reproduction of the color called magenta. Phase of the chrominance signal, with respect to the reference voltage, results from whatever hue is being scanned by the camera, and causes that hue to appear on the picture tube. Amplitude of the chrominance signal results from saturation, and causes the same degree of saturation to appear at the picture tube.

All this goes back to relative and absolute voltages for primary red, green, and blue from the color camera. These voltages are combined in certain proportions for the I-signal, and in other proportions for the Q-signal. Then the I- and Q-signals combine to form the chrominance signal. The chrominance signal varies continually both in phase and in amplitude as the camera scans various hues and saturations. The I- and Q-signals do not change their phase with respect to the reference voltage or to each other.

Phase of the I-signal, 57° behind the reference voltage, corresponds to a hue that is orange red. This is the hue of the I-signal all by itself. Phase of the Q-signal by itself, 147° behind the reference voltage, corresponds to an approximately equal mixture of red and blue, which would be a variety of purple.

The two hues just mentioned, as related to phase of I- and Q-signals, quite apparently won't produce pictures in full color. It won't be enough to have oranges, reds, and purples ranging toward blue. This limited range of hues results from having only positive voltages for the I- and Q-signals. In addition we need greens and yellows and blue-green hues.

When the camera scans greens and yellows and blues, either or both the I-signal and the Q-signal will become a negative voltage. When the I-signal is negative, its phase corresponds to a nearly equal mixture of green and blue. When the Q-signal is negative its phase corresponds to yellowish-green.

Fig. 18 shows phases of the chrominance signal, with respect to the reference voltage, for all the principal hues or colors. On this chart are shown also phase relations of positive and negative I- and Q-signals with respect to the reference voltage.

Consider, as an example, the phase corresponding to red. This phase lags about 76.5° behind the reference voltage, on the positive side of the chart. Directly opposite red, on the negative side of the chart, is the color or hue called cyan, which is greenish-blue. In between red and cyan, the center of the chart is marked white. If red and cyan are suitably mixed the result is the visual sensation of white, although only two rather narrow bands of wavelengths would be present.

Red and cyan are complementary colors. Any two colors or wavelength bands which cause the senation of white or gray when mixed in proper proportions are called complementary colors. The chart shows that blue and yellow are complementary, and when mixed will cause the sensation of white or gray, with no apparent color or hue. You can see also that magenta, a bluish-red, is the complementary of green.

Earlier we learned that a complete I-signal, including both positive and negative primary color voltages, is the equivalent of white, or really disappears so far as hue and saturation are concerned. This is true also of the positive and negative Q-signals, as indicated on the chart.

It will be interesting to learn how sine-wave diagrams such as those of Fig. 17 may be changed to the relatively simple representations of color phases illustrated by Fig. 18. It goes without saying that the sine-wave method of showing phase relations and amplitudes of the complete chrominance signal is

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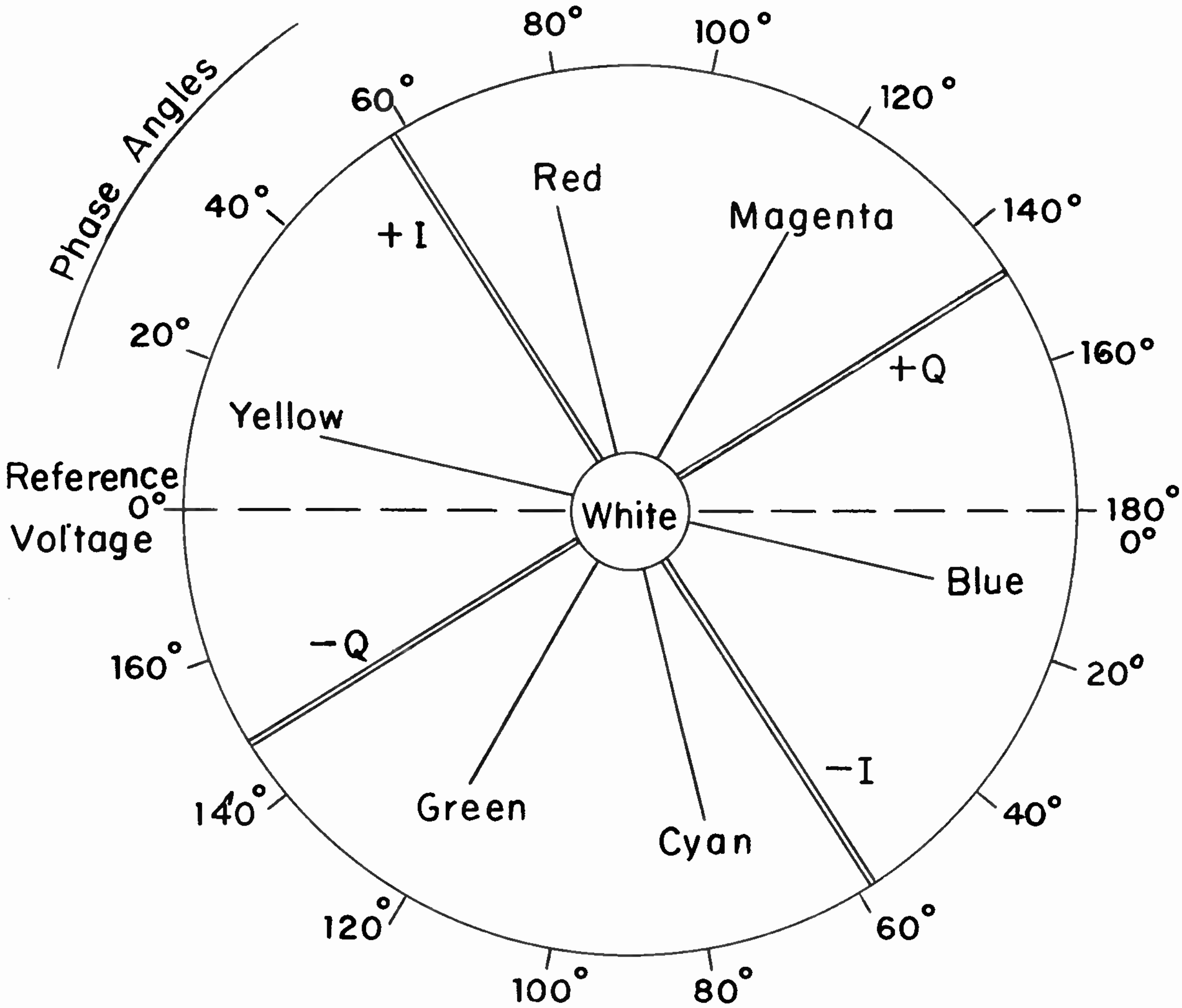

Fig. 18. The color phase chart for I- and Q-signals and for the principal hues.

difficult to draw and hard to interpret with any great accuracy. We cannot just guess at resultant phases and amplitudes, with the sine-wave method they have to be computed.

The easy way is shown by Fig. 19, where the whole operation is performed by drawing some straight lines with the help of a protractor for measuring angles, then making every required measurement with a ruler. Take, for example, the method of arriving at the phase angle and amplitude for red, as illustrated by diagram 1.

First we lay off a horizontal line which stands for phase of the reference voltage, and mark on it any convenient point, C, to be used as a center. Next, at an angle of 57° from the reference voltage, we draw from the center point a straight line representing the positive I-single. Extending this line the other side of center would show the negative I-signal. At an angle of 90° from the I-signal we draw another line for the positive Q-signal. This line might be extended past the center point to represent the negative Q-signal.

Assume that voltage of the I-signal in a particular case is 60 positive units. This is the percentage of red camera voltage in the I-signal. On your ruler select a distance proportional to 60 units of length. You might take one-quarter inch as equal to 10 units, then measure off six quarter-inches for 60 units of voltage. At this distance from the center point, C, place a mark on the positive I-signal line.

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Assume that voltage of the Q-signal is 21 positive units, which is the percentage of red camera voltage in the Q-signal. On the line for the positive Q-signal make a mark 21 units out from the center point.

At the 60-unit mark on the positive I-signal draw a line parallel to the Q-signal line, and from the 21-unit mark on the positive Q-signal draw another line parallel to the I-signal line.

From the intersection of the two lines last drawn run a straight line to center point C. This diagonal line represents both phase and amplitude of the chrominance signal for red. The angular position of this "red" line shows its phase relation to the reference voltage, while its length shows amplitude of the red chrominance signal in the same units used for marking the I- and Q-signals.

Compare what we have done in diagram 1 of Fig. 19 with the sine-wave diagram at C of Fig. 17. All values are the same. Then compare the angular position of the red signal line with that of the red signal line in Fig. 18. Everything checks.

Diagram 2 of Fig. 19 shows layout of a phase and amplitude line for the blue signal. Here we mark 31 units on the positive Q-signal and 32 units on the negative I-signal, because these are percentages of blue camera voltage in the Q- and I-signals.

Diagram 3 shows layout for the green signal. We use 28 units on the negative I-signal line and 52 units on the negative Q-signal line, because these are the percentages of green camera voltage in the I- and Q-signals. You will find that the blue and green lines on the layout diagrams are in the same angular positions with respect to reference voltage as on the complete phase diagram of Fig. 18.

The color phase diagram of Fig. 18 will prove useful when determining causes for faulty color reproduction. By noting which hues are too strong, too weak, or absent, it will be possible to locate faults as being in certain of the circuits which carry positive and negative I- and Q-signals.

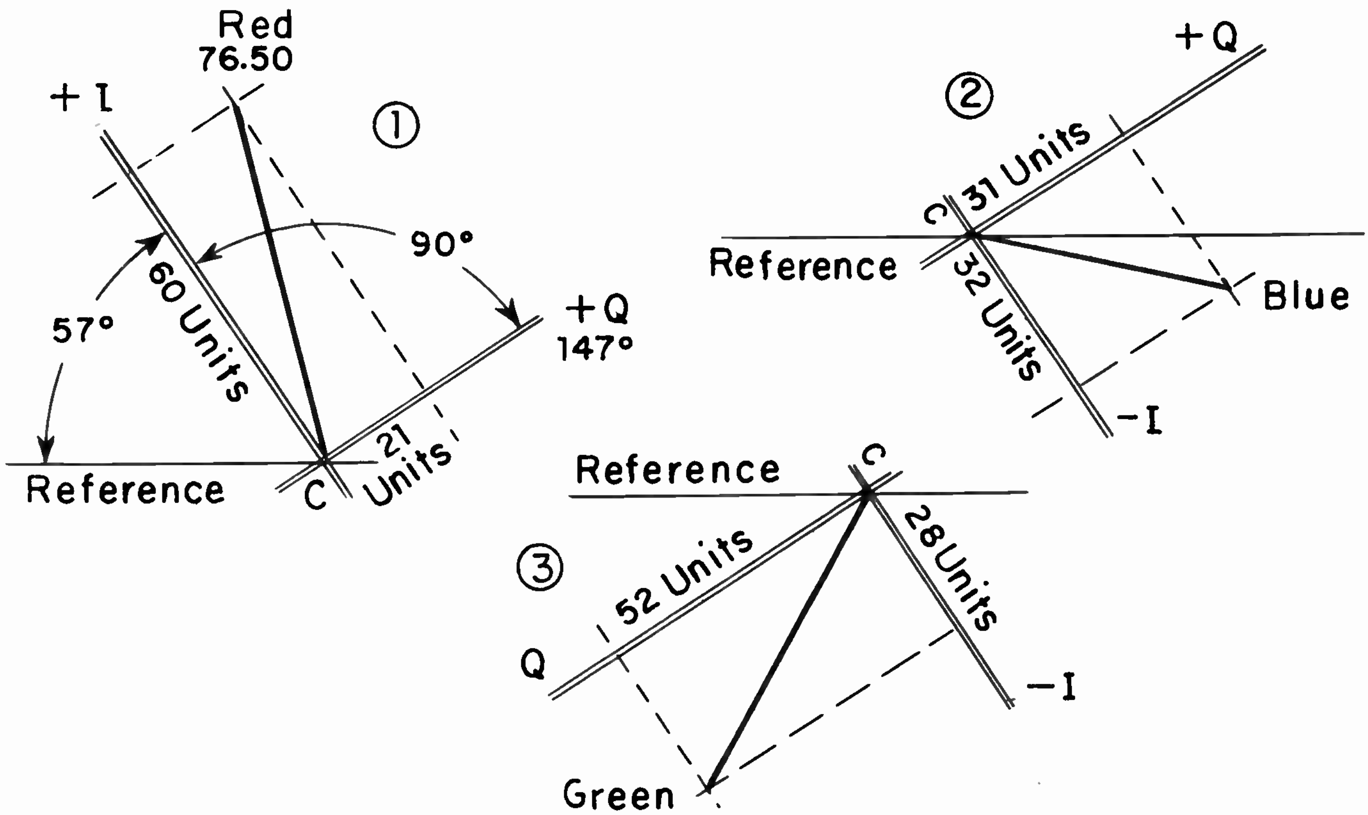

Fig. 19. How phase for hue, and amplitude for saturation in the chrominance signal are shown by drawing straight lines based on angles from a center point. These lines may be called vectors.

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TELEVISION

• RADIO

• ELECTRONICS

LESSON 98 — COLOR TELEVISION — PART THREE

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Lesson 98

COLOR TELEVISION—PART THREE

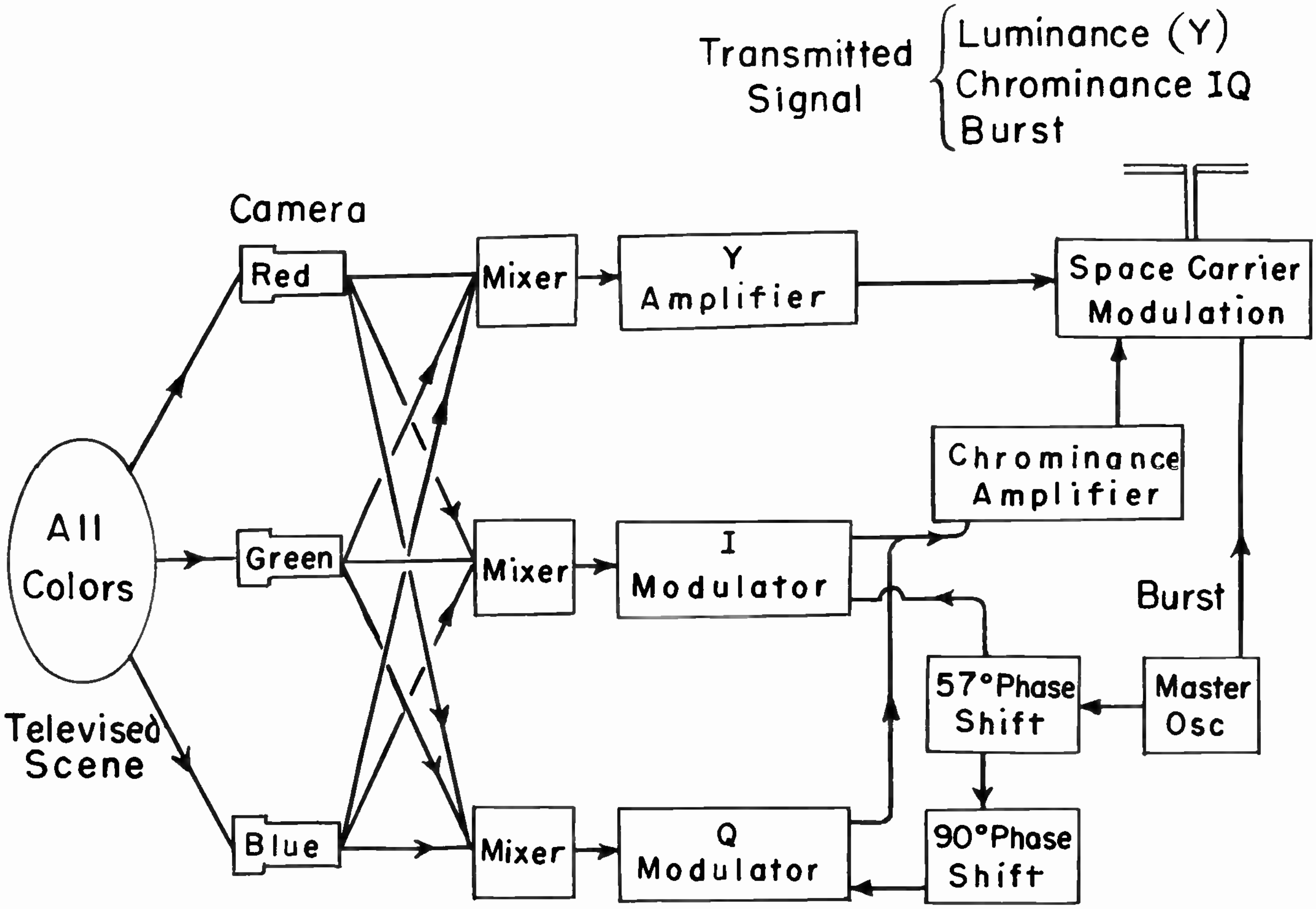

Fig. 1. The transmitter produces signal voltages representing all colors of televised scenes.

All the colors of a televised scene are represented in the luminance and chrominance signals produced at the transmitter. Principal steps in the process are shown by Fig. 1. Each step is reversed in the receiver sections and circuits shown by Fig. 2, and from luminance and chrominance signals are eventually reproduced on the picture tube all the colors of the televised scene.

In the accompanying table the actions which are opposite in transmitter and receiver are written opposite each other. Commencing with the televised scene, at the top of the left-hand column, you may read downward until reaching the transmitted signal. Then, commencing with the received signal at the bottom of the right-hand column, you may read upward until reaching the color image on the picture tube.

Note especially that the only reason for existence of the chrominance signal is to provide I- and Q-signals combined in such form that they may be transmitted in the same video-frequency range as the Y-signal or luminance signal. The chrominance signal appears in the transmitter only at the modulator outputs. It disappears in the receiver at the demodulator inputs.

The only reason for the burst signal is to synchronize frequency and phase of the color oscillator in the receiver with frequency and phase of the master oscillator in the transmitter, without having to transmit a continuous 3.58-mc signal.

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TRANSMISSION (Read Downward)	RECEPTION (Read Upward)
All colors of the televised scene are separated at the camera into three primary bands - red, green, and blue.	All colors of the televised scene are reproduced when the picture tube blends the red, green, and blue primaries.
In camera output amplifiers are signal voltages corresponding to the three primary color bands.	Primary signal voltages from the matrixes are strengthened in the three color amplifiers.
Certain proportions of the primary signal voltages are combined in the mixers.	Signal voltages from the Y-amplifier and the two demodulators combine in the matrixes, at whose outputs appear primary color signal voltages.
In one mixer is formed the Y-signal or luminance signal, which is amplified and becomes modulation of the space carrier.	Y-signal voltage from the video amplifier goes through the Y-amplifier or luminance amplifier to all three matrixes.
In the second mixer is formed the I-signal and in the third is formed the Q-signal. These two color signals go to the I- and Q-demodulators.	From the I- and Q-demodulators the two color-signal voltages go to the matrixes, which are counterparts of mixers in the transmitter.
The master oscillator generates continuous 3.58-mc voltage. Part of this voltage is shifted 57° in phase, and applied to the I-modulator. Then part of the 57° voltage is shifted another 90°, and applied to the Q-demodulator.	The color oscillator generates continuous 3.58-mc voltage, which is shifted 57° in phase (when demodulation is of I- and Q-signals rather than of B-Y and R-Y). The voltage 57° out of phase goes to the I-demodulator. A 3.58-mc voltage having additional shift of 90° is applied to the Q-demodulator.
In the I-modulator is formed the I-signal voltage, which is used to modulate the 57° voltage from the master oscillator. In the Q-modulator is formed the Q-signal voltage, which modulates the 3.58-mc voltage that is an additional 90° out of phase.	Output of the I-demodulator will contain only the I-signal. The Q-signal from the chrominance amplifier to the I-demodulator will be removed by 3.58-mc voltage of suitable phase. Similarly, the Q-demodulator delivers only the Q-signal, with its I-signal removed by another 3.58-mc voltage of required phase.
The two out-of-phase modulated voltages combine to form the chrominance signal, which becomes space carrier modulation and is transmitted.	The chrominance signal from the video amplifier goes through the chrominance amplifier section to the I- and Q-demodulators.
Continuous 3.58-mc voltages are used in the modulators, then suppressed or removed from the chrominance signal. However, continuous 3.58-mc voltages in the original phase must reappear in the receiver as a reference voltage, so master oscillator frequency and phase are transmitted in the form of bursts.	Burst voltage from the video amplifier goes to the color oscillator section, which is the counterpart of the master oscillator in the transmitter. The color oscillator generates a continuous 3.58-mc voltage, which is synchronized in frequency and phase by burst voltage.
Now we have luminance, chrominance, and burst signals in the form of modulation on the space carrier, which is transmitted. These are modulations on the composite television signal for color.	The space carrier on which are luminance, chrominance, and burst signals is amplified and demodulated in the tuner, i-f amplifier, video detector, and video amplifier of the receiver.

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LESSON 98 — COLOR TELEVISION — PART THREE

We shall examine some typical circuits used in color television receivers for carrying out the processes of Fig. 2. Because color television practices are subject to frequent change, it would be of little avail to examine circuits for any particular receiver. But basic processes and principles do not change, and by studying typical individual circuits and sections it will become possible to understand almost any of their probable combinations.

LUMINANCE AMPLIFIERS. Connections in one kind of luminance amplifier or Y-amplifier section are shown by Fig. 3. A contrast control potentiometer, across the video detector output, feeds the grid of the video amplifier. Output of the video amplifier goes to the Y-amplifier, also to the chrominance section.

On the input to the video amplifier is a series resonant circuit tuned to act as a 4.5-mc trap. The purpose is the same as that of a 4.5-mc trap in any television receiver, to prevent interference due to beating of video

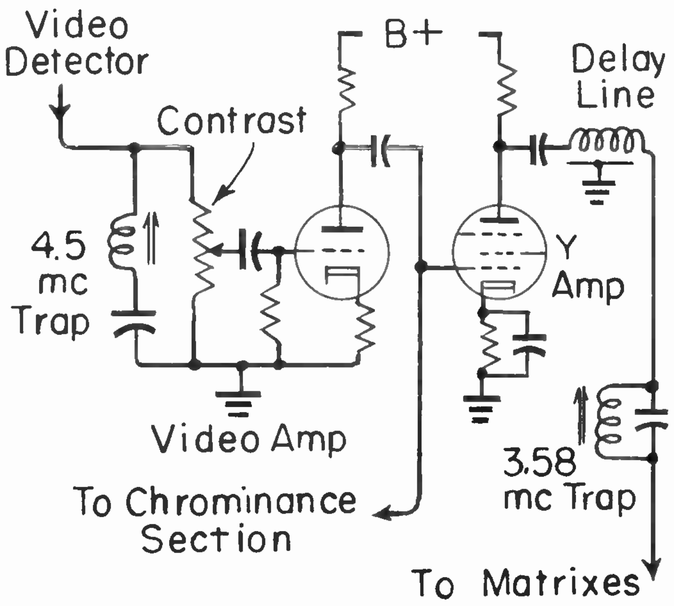

Fig. 3. Circuit relations between video amplifier and Y-amplifier.

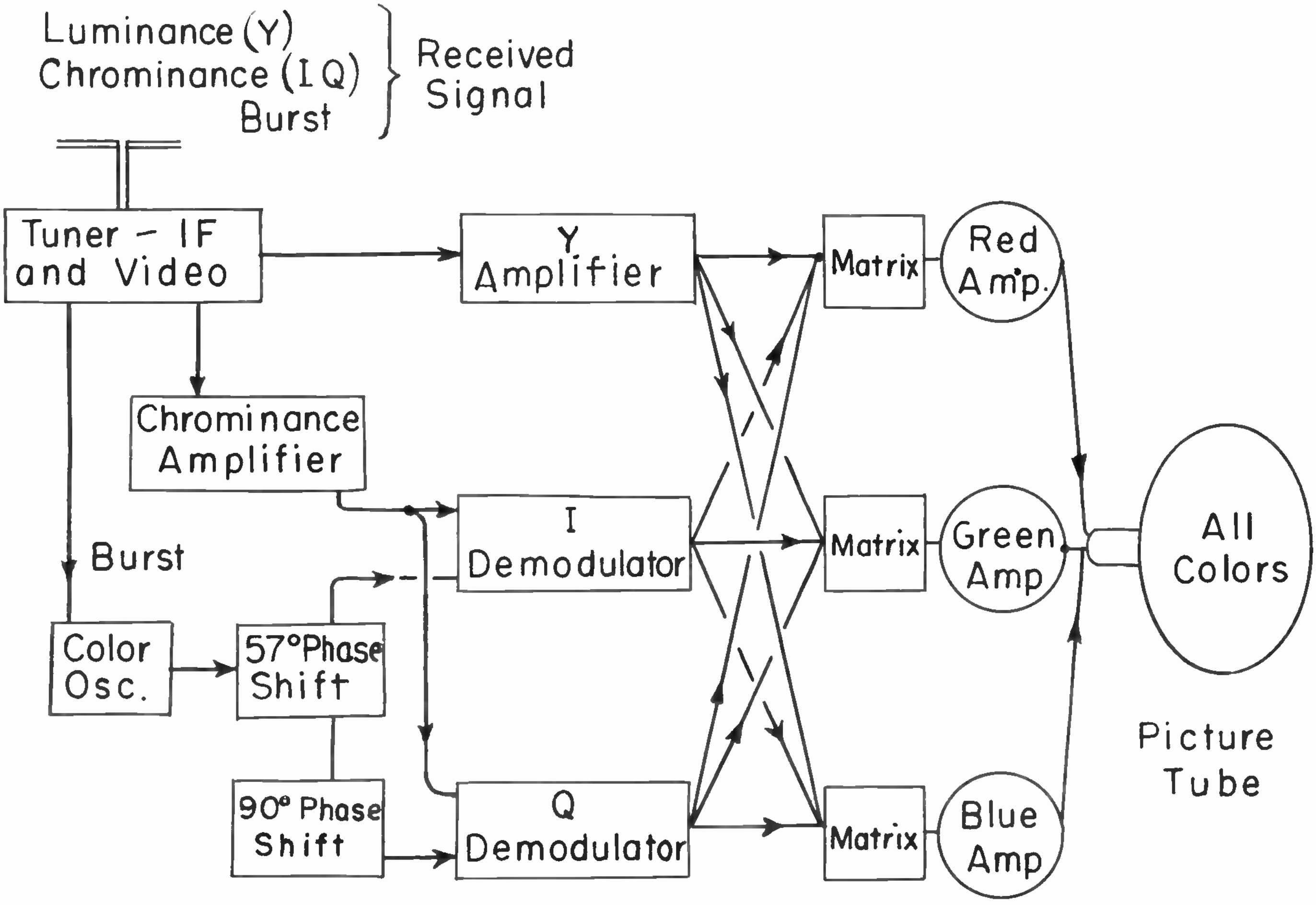

Fig. 2. The receiver reproduces all colors by utilizing the signal voltages.

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and sound intermediates from reaching the picture tube.

In the lead which goes from the Y-amplifier output to the matrixes is a 3.58 mc trap in the form of a parallel resonant circuit. The purpose of this trap is to prevent 3.58-mc burst voltage from going on into following circuits and reaching the picture tube. The intermittent burst voltage could place an interference pattern on all color pictures.

Traps for either 4.5 mc or for 3.58 mc, or traps for both these frequencies, may be found at various places in video amplifier and luminance amplifier circuits.

Somewhat different circuit connections for a video amplifier and a Y-amplifier are illustrated by Fig. 4. The video detector output feeds the video amplifier grid. Amplified signal voltage from the video amplifier plate contains bursts, which go to the color oscillator section, also the 4.5-mc frequency modulation sound signals. Voltage from the plate is used also for automatic gain control.

The video amplifier acts also as a cathode follower, whose cathode resistor is a contrast control potentiometer. From this contrast control the demodulated video signal goes to the Y-amplifier and also to the chrominance section.

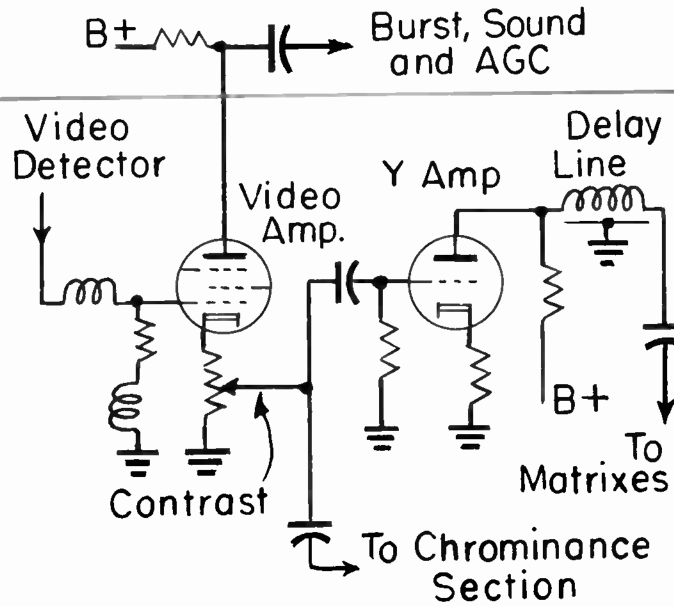

Fig. 4. Video amplifier output feeds all following sections of the receiver, including the Y-amplifier.

Fig. 5 shows connections for still another kind of luminance amplifier section. Video signals for the Y-amplifiers, also for the chrominance and burst amplifiers, are taken from the cathode of the video amplifier. There are two contrast control potentiometers, ganged on a common shaft and operated together, with one feeding the luminance signal and the other feeding the chrominance signal to their respective sections.

There are two Y-amplifiers in cascade.

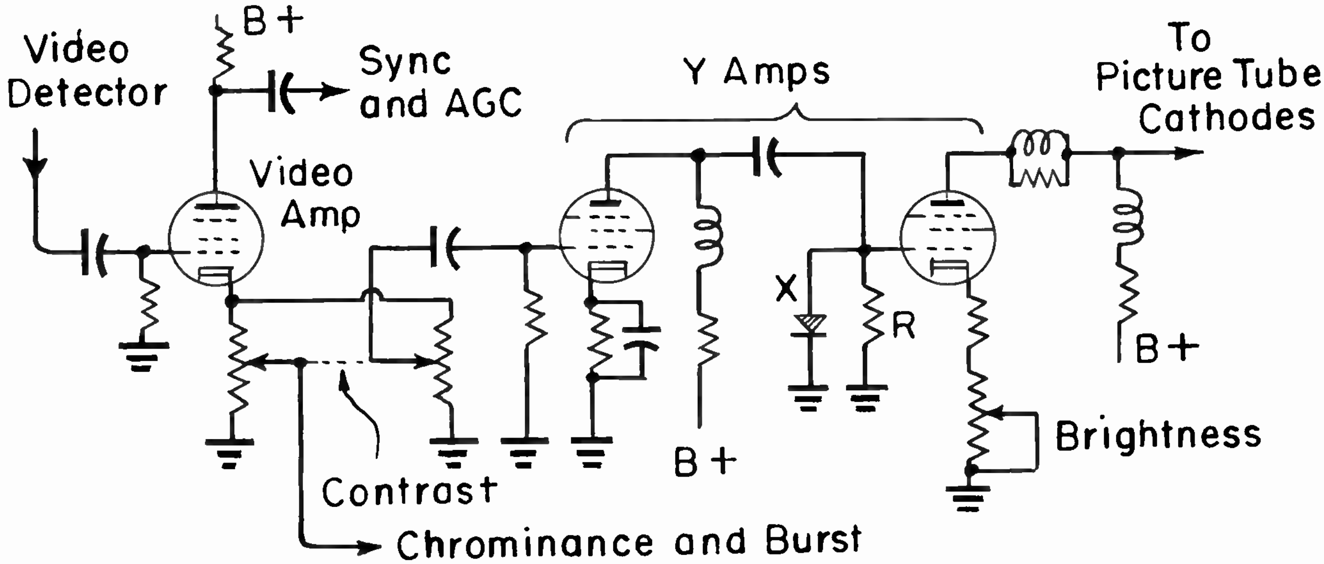

Fig. 5. Features of a Y-amplifier section which feeds picture tube cathodes.

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On the grid of the second Y-amplifier is a crystal diode acting as a bias rectifier in connection with grid resistor R. Plate output of the second Y-amplifier goes to the cathodes of the picture tube rather than to color matrixes. This means that part of the color-signal mixing takes place between grids and cathodes of the picture tube. When a Y-amplifier output goes to picture tube cathodes the brightness control used by the operator usually is in the same amplifier output circuit, or on the amplifier cathode as in Fig. 5.

DELAY LINES. In the output leads from Y-amplifiers in Figs. 3 and 4 you will see symbols marked "Delay Line". The need for such units is explained as follows. When a signal voltage enters any kind of circuit or circuit element, even a simple conductor, the signal does not reach the far end of the circuit instantly. There is some slowing or some delay.

We encountered this effect when studying resonant lines, and described the delay in terms of velocity constant or velocity of propagation. Something similar happens in connectors between bays of stacked antennas. It is the presence of capacitance and inductance in a line or a circuit that slows the signals.

As shown at the top of Fig. 6, the luminance signal from the output of a Y-amplifier passes through only a few circuit elements before reaching the color amplifiers or picture tube, and suffers little delay.

But, as in the middle diagram, the I-signal, the Q-signal, or both of them, must go through additional amplifiers, inverters, splitters, and filters before getting to the color amplifiers or picture tube. Consequently, the I- and Q-signals are subjected to much more delay than the Y-signal. Were nothing done about it, color portions of pic-

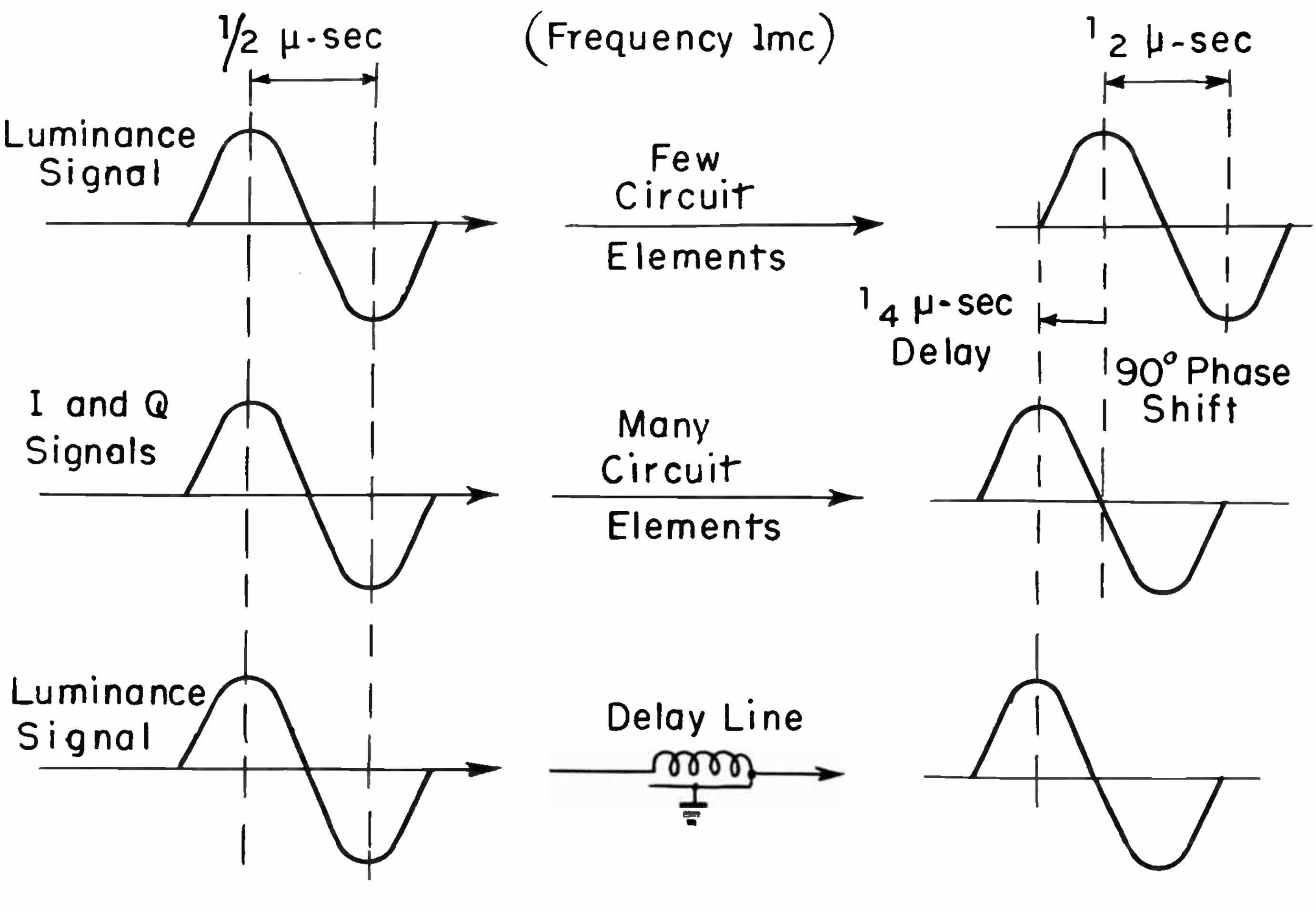

Fig. 6. An artificial time delay line holds back the luminance signal as much as other signals are delayed in passing through many circuit elements.

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tures might be displaced with respect to monochrome portions.

In order that all the signals may reach the picture tube at the same instant we may delay the Y-signal as much as the other signals are delayed. As shown at the bottom of Fig. 6, this is done by inserting a delay line somewhere in the path of the luminance or Y-signal. How much delay must be added depends on design and construction of circuits, and varies in different receivers.

Luminance delays often are on the order of one microsecond. It is usual practice to employ a specially constructed delay line which appears much like coaxial cable but contains a coiled or helical conductor within a flexible shield and an insulating outer cover. A style of line often used provides 0.6 microsecond delay per foot of its length. In addition to providing time delay, this line acts somewhat like peaking coils in shaping the frequency response. Delay line impedance is high, and, as with coaxial cable or transmission line, does not vary with frequency.

CONTRAST CONTROLS. As you may see in Figs. 3, 4, and 5, contrast controls are in such positions, electrically, that they simultaneously vary input signal strength to both the luminance and chrominance sections. This keeps signal strengths in the two sections of correct relative proportions no matter how the contrast control is adjusted. The unit may be a single potentiometer, as in Figs. 3 and 4, or two potentiometers may be on a single shaft as in Fig. 5.

COLOR OSCILLATOR SECTION. It is the purpose of the color oscillator section of the receiver to furnish the two demodulators with continuous voltages at 3.58 mc; the voltage to one demodulator being 90° out of phase with voltage to the other. Like all oscillators, this one operates at a frequency determined by connected tuned circuits. This might be called the free-running frequency.

Frequency and phase of the color oscillator must be maintained in synchronism with those of the master oscillator at the transmitter. This is done by feeding to the

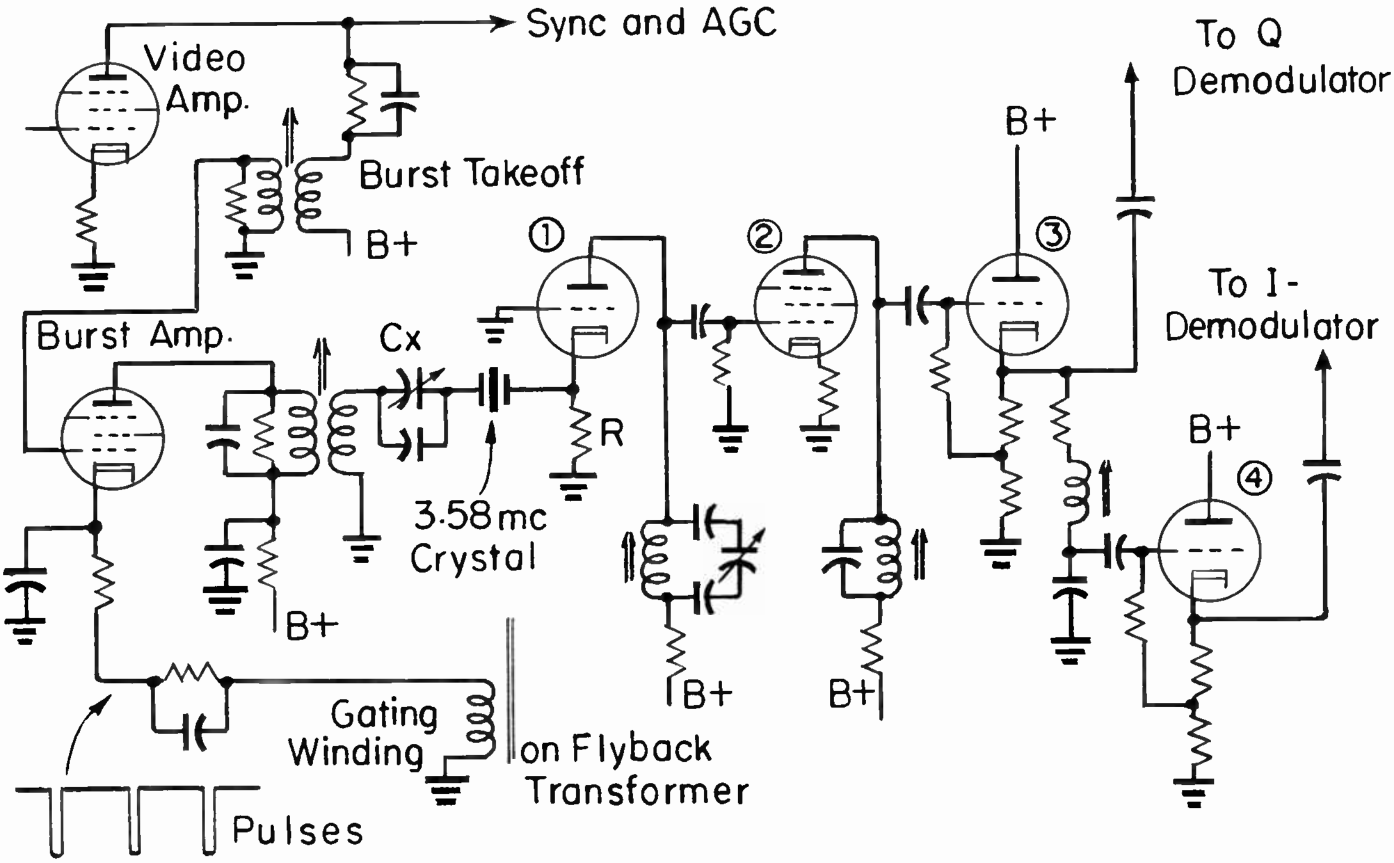

Fig. 7. Circuits in a color oscillator section.

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oscillator circuit the burst voltages which are part of the composite video signal.

Fig. 7 shows circuits which may be used in a color oscillator section. Connected to the plate of the video amplifier is the primary of a burst takeoff transformer tuned to 3.58 mc. The secondary of this transformer goes to the grid of a burst amplifier tube.

In the plate circuit of the burst amplifier is another transformer tuned to 3.58 mc. The secondary of this transformer contains an oscillating crystal and a cathode resistor R on a grounded grid amplifier tube, 1. Adjustable capacitor Cx allows compensating for slight differences between capacitances of crystals and their holders.

The grounded grid amplifier is followed by a pentode amplifier, 2. In the plate circuits of tubes 1 and 2 are parallel-resonant impedance couplers, both of which are adjustably tuned to 3.58 mc. The plate of amplifier 2 feeds to the grid of cathode follower 3, whose cathode output goes to the Q-demodulator.

In the cathode circuit of tube 3 and the grid circuit of tube 4 are a resistor, an adjustable inductor, and a capacitor for shifting the phase of the 3.58 mc voltage by the required 90° at the grid of tube 4. This tube is another cathode follower, whose cathode output goes to the I-demodulator.

GATING OR KEYING THE BURST. The only portion of the composite video signal that should be applied to the color oscillator is the burst, consisting of eight or nine cycles of 3.58-mc voltage occuring on the back porch of horizontal sync pedestals. To pass the burst while excluding other parts of the video signal, the burst amplifier is gated or keyed to make it conductive only during the burst period.

Gating is accomplished in Fig. 7 by connecting the cathode of the burst amplifier to a small winding on the horizontal output transformer or flyback transformer. Resistors in this cathode circuit normally maintain the amplifier cathode positive, as would any cathode resistors. This provides enough negative grid bias to keep the burst amplifier cut off for video signals. But during each horizontal retrace period, in which occurs the burst, the gating winding delivers a strong pulse of negative voltage to the amplifier cathode. This is equivalent to positive voltage on the grid. Then the tube conducts during the burst.

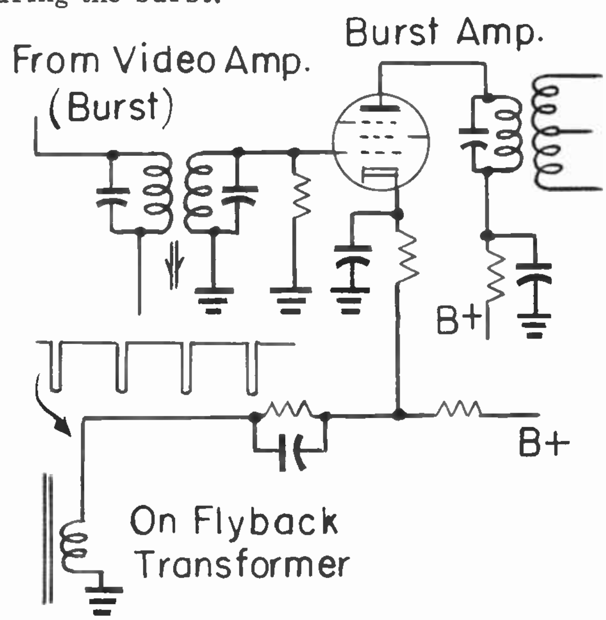

Fig. 8. Another way of gating the burst amplifier by negative pulses on its cathode.

Fig. 8 shows a somewhat similar gating system, except that here the cathode of the burst amplifier normally is held positive by a connection to B-plus.

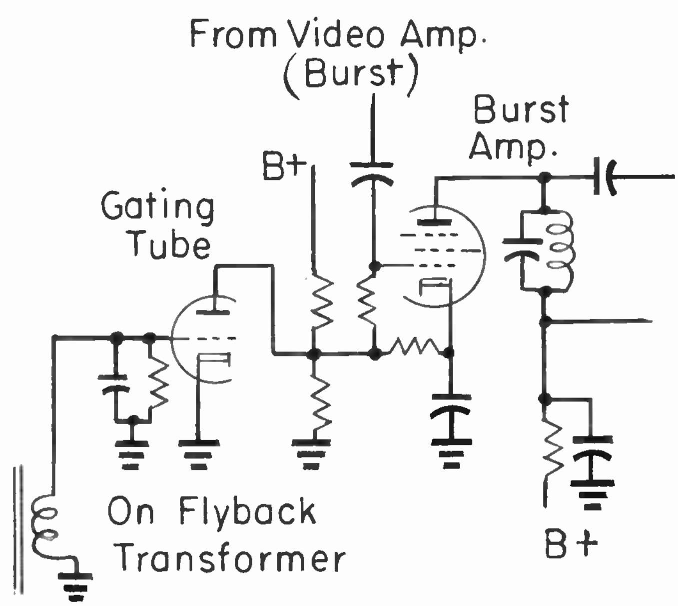

Fig. 9. A separate gating tube is used ahead of the burst amplifier.

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Fig. 9 illustrates a method of using a separate gating tube to control voltage on the cathode of the burst amplifier. The winding on the flyback transformer is so connected as to deliver positive pulses to the grid of the gating tube, resulting in negative pulses at its plate. The plate of the gating tube and cathode of the burst amplifier normally are held positive by connection to a resistance voltage divider between B-plus and ground. Negative pulses from the plate of the gating tube make the cathode of the burst amplifier relatively negative during bursts, and thus allow the amplifier to conduct.

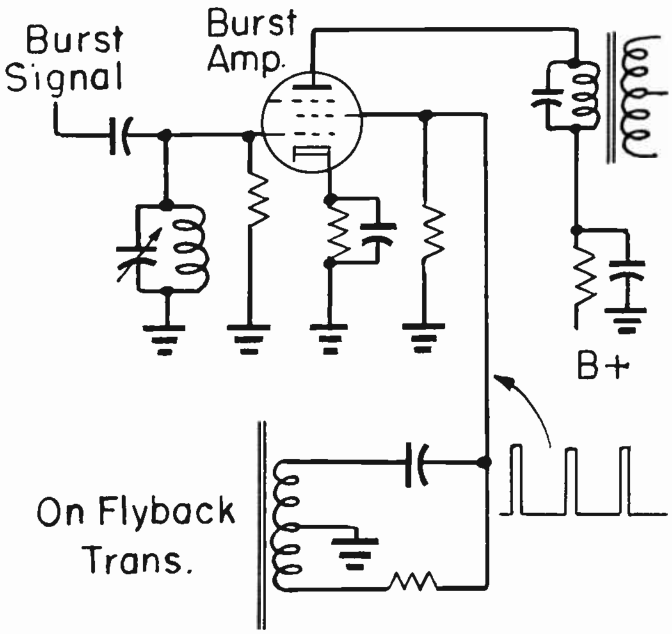

Fig. 10. Gating by means of positive pulses on the screen of the amplifier.

In Fig. 10 the gating winding on the flyback transformer is connected to the screen of the burst amplifier. Positive pulses from this winding act on the screen to make the amplifier conductive during horizontal retrace periods. At other times the screen voltage is zero or negative, and prevents conduction.

Resistors and capacitors in leads from gating windings to burst amplifiers or gating tube in Figs. 7 to 10 cause a slight time delay of voltage pulses which make the amplifiers conductive during the burst which follows each horizontal sync pulse.

It should be noted that gating or keying helps also to prevent noise pulses from affecting color synchronization. This action is similar to that in keyed agc systems which prevent noise from affecting automatic gain voltages on i-f and r-f amplifiers in any type of receiver.

AUTOMATIC PHASE CONTROL. In many color oscillator sections is an automatic control quite similar to the automatic frequency control (afc) used in connection with horizontal sweep oscillators in practically all black-and-white sets. These automatic controls for the color oscillator employ principles with which we become acquainted when studying horizontal sweep oscillators.

In many cases the color oscillator control circuits are practically identical with horizontal afc systems. To distinguish between the color oscillator control and the sweep oscillator control, both found in color receivers, it is convenient to speak of the color oscillator system as an automatic phase control (apc) although it is also an automatic frequency control.

Fig. 11 shows features found in many apc systems. Output of the burst amplifier goes to one side of a twin-diode phase detector. To the other side of this detector comes a voltage from some point beyond the output of the color oscillator. Any frequency difference or phase difference between voltages on the two sides of the phase detector produces a d-c correction voltage. The value of this voltage is proportional to the amount of difference. Its polarity depends on whether oscillator voltage has become advanced or retarded with respect to burst voltage.

The d-c correction voltage goes through a filter network to the grid of a reactance tube. Plate and cathode of this reactance tube are connected across the oscillator inductor L. The reactance tube acts like a variable capacitance across this inductor, with the value of effective capacitance changing in accordance with d-c correction voltage on the grid. Thus the correction voltage varies the resonant frequency of the oscillator tank circuit, which includes the inductor. This much of the action is essentially the same as in the type of horizontal sweep afc system employing a reactance tube.

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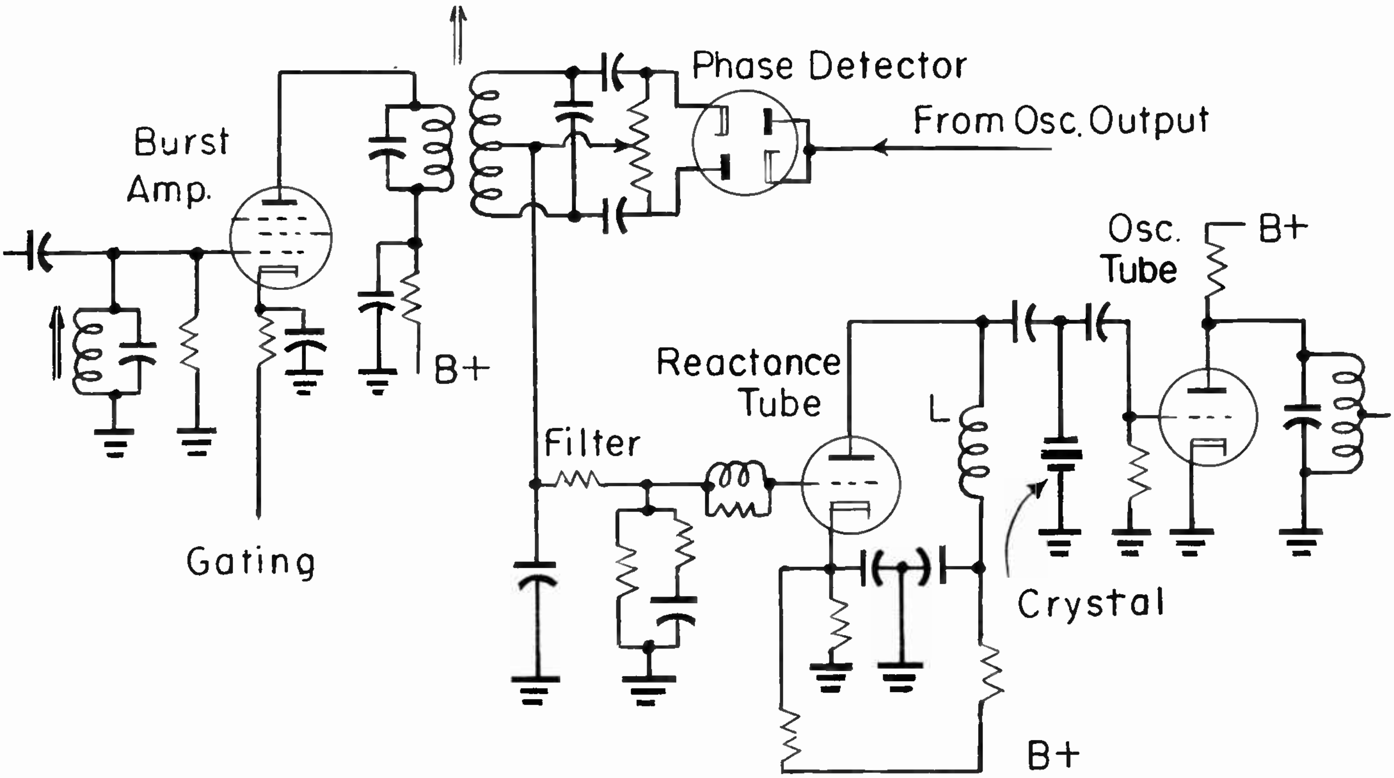

Fig. 11. An automatic phase (and frequency) control using a phase detector.

Across the tank inductor is also an oscillating crystal, whose natural frequency is 3.58 mc. Finally, there is the grid-cathode circuit of the oscillator tube. The rather elaborate method for maintaining correct frequency and phase of the color oscillator is justified by the fact that the least shift of phase will alter all the colors in reproduced pictures. It is interesting to know that frequency tolerance of the master oscillator at the transmitter is only plus or minus 11 cycles in 3.58 megacycles. This is an accuracy of about three parts in a million.

In color oscillator apc systems it is common to find the feedback voltage for the phase detector taken from some point at which oscillator output has been greatly amplified. That is, between oscillator output and feedback connection there may be several tubes. In some receivers there is a special tube, in the feedback line, used solely for amplifying the voltage going to the phase detector. Strengthening of the oscillator voltages applied to the phase detector allows maintaining the oscillator phase and frequency within very close limits.

OSCILLATING CRYSTALS. At the output of the color oscillator section we must have voltages which continue uninterruptedly at a frequency of 3.58 mc. Yet at the input we have only intermittent bursts. Each burst lasts for about $2\frac{1}{2}$ microseconds, followed by an interval of about 60 microseconds before the next burst. During these intervals the color oscillator must continue to operate at constant frequency and with least possible reduction of amplitude.

The amplitude requirement calls for an oscillatory circuit of high Q-factor, a circuit with small energy losses in proportion to its reactance. An oscillating crystal provides this kind of performance. The Q-factor may approach 30,000 in a crystal circuit having such sharp tuning and narrow frequency response as to pass the bursts. The crystal is intermittently excited by the bursts, and continues to oscillate at its natural frequency with very little drop of amplitude between bursts.

Not all color receivers have frequency control crystals in their color oscillator circuits. Similar performance may be had from

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capacitance-inductance resonant circuits designed and constructed for very high Q-factor.

HUE CONTROLS. In spite of all the automatic phase and frequency controls in the color oscillator section there will be sufficient change of values in various circuit elements to cause undesired phase shifts, and consequent wrong colors or hues in reproduced pictures. The undesired phase shifts may occur almost anywhere between the burst takeoff at the video amplifier and the 3.58-mc inputs to the demodulators. Since phase error may occur anywhere, it follows that phase correction may be made almost anywhere in the color oscillator system, not necessarily at the same point as the error.

Phase correction is made by some form of manual adjustment accessible to the set operator. Most of these hue adjustments are small variable capacitors, although potentiometers sometimes are used.

Fig. 12 shows electrical positions of some hue controls. In diagram 1 the control capacitor is between the video amplifier and the burst amplifier, connected from the amplifier grid to ground. In diagram 2 the hue control is on a tuned impedance coupler between the burst amplifier and the phase detector of the apc system. In diagram 3 the control is on a coupler between the color oscillator tube and a 3.58-mc amplifier which follows the oscillator.

Associated with the hue controls used by the set operator are adjustable inductors. These inductors form a sort of coarse control for phase and hue, which is set during service operations. The operator's control then acts as a fine adjustment for hue. Looking back at our color phase diagram will make it plain that a very small shift of phase could change reds to oranges or magentas, and blues to purples or cyans. The hue control is adjusted to produce colors which appear natural to the viewer.

PHASING OF OSCILLATOR OUTPUT. At the output of the color oscillator section it is necessary to have two 3.58-mc voltages, one with phase lagging or leading the other by 90°. These two 3.58-mc voltages will be

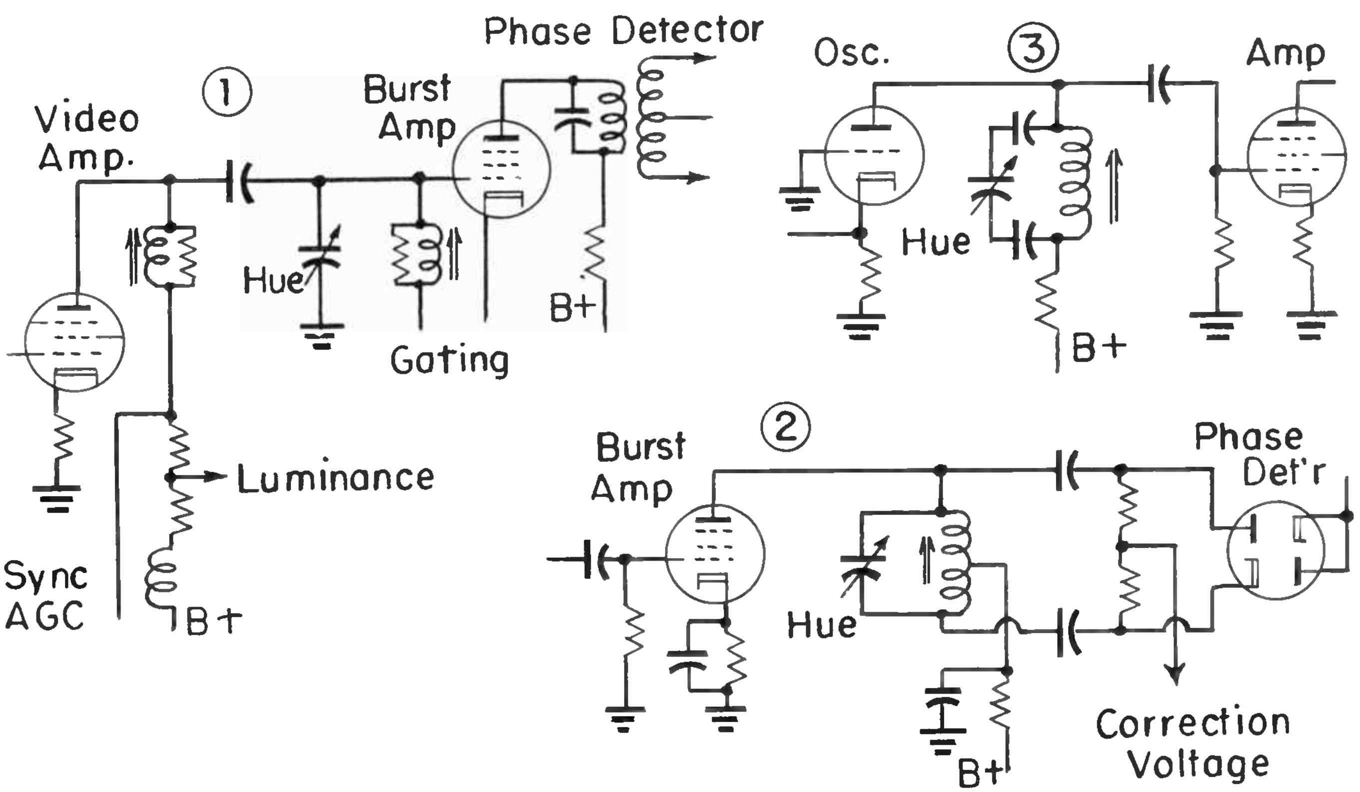

Fig. 12. Adjustable controls for hues reproduced by color receivers.

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used in the demodulators. We may take the 3.58-mc voltage for one demodulator directly from the color oscillator or an amplifier following the oscillator. Part of this voltage may be put through some kind of 90° phase shifting circuit before going to the other demodulator.

Any of several methods may be employed for phase shifting. One way is to use a transformer having both primary and secondary tuned to resonance at 3.58-mc, as shown in principle at A of Fig. 13. At resonance the secondary voltage of a doubly tuned transformer is 90° out of phase with primary voltage.

Whether secondary voltage lags or leads primary voltage by 90° depends on which end of the secondary is used as high side and which end goes directly or indirectly to ground, with primary connections unchanged. If voltage at one end of the secondary leads the primary, using the opposite end of the secondary as the high side will provide a lagging voltage.

A practical application of this method of phase shifting is illustrated at B in Fig. 13. From the plate of a 3.58-mc amplifier following the color oscillator a voltage goes to one demodulator. This voltage goes also to the primary of a phase-shift or quadrature transformer, whose secondary supplies for the other demodulator a 3.58-mc voltage 90° out of phase.

Another method of securing 90° phase shift employs an inductor and capacitor connected in series across the 3.58-mc voltage source. If inductor and capacitor are series resonant at 3.58-mc, and have negligible ohmic resistance, voltage across the inductor leads source voltage by 90°, while voltage across the capacitor lags source voltage by 90°. The principle is illustrated by Fig. 14.

Applications employing this second general method of phase shifting are shown by Fig. 15. In these practical circuits are resistors, inductors, and capacitors in addition to the inductor and capacitor which provide phase shift. The added elements are for

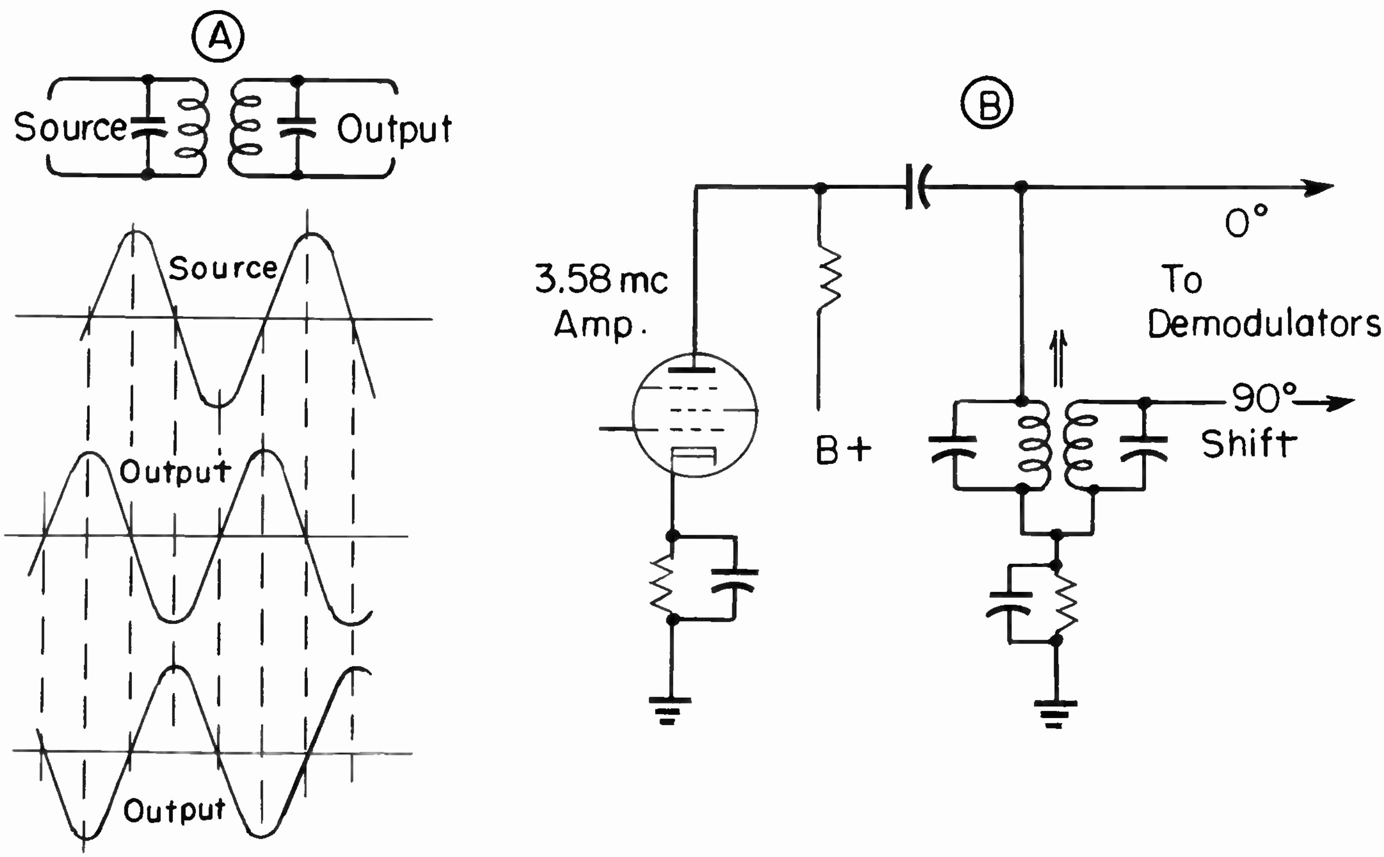

Fig. 13. Securing 90° phase shift by means of a resonant transformer.

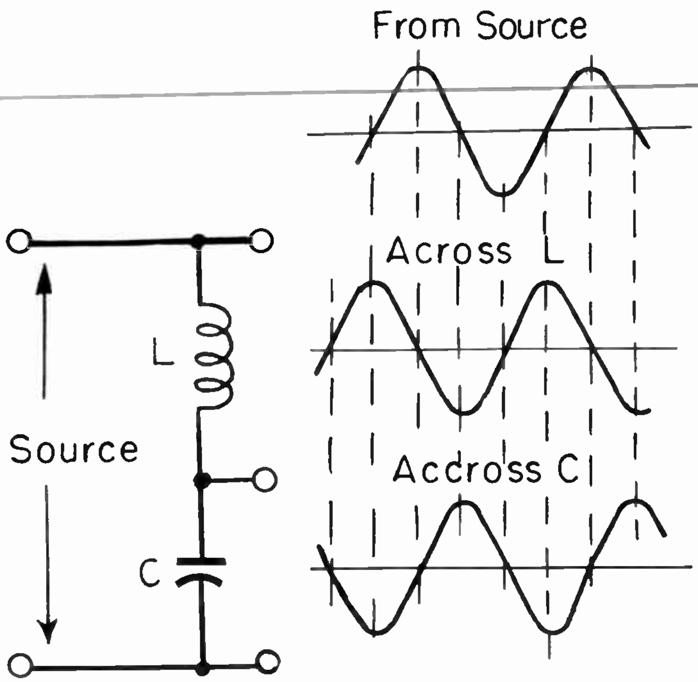

Fig. 14. The principle of phase shift by means of series resonant inductor and capacitor.

tuning the circuits to resonance and for maintaining satisfactory waveforms of voltages going to the two demodulators.

BANDPASS AMPLIFIERS. At the demodulators we require not only two 3.58-mc voltages differing in phase by 90°, but also the chrominance signal which is to be demodulated. The chrominance signal is extracted from the complete video signal by a bandpass amplifier section, and goes from this section to the demodulators.

Fig. 16 illustrates one of many kinds of bandpass amplifiers. The video signal from the cathode of a video amplifier goes first through a 4.5-mc trap for suppressing the intercarrier beat and keeping it from picture tube circuits, just as in black-and-white receivers. Several such traps may be used in color receivers. The video signal then goes through a contrast control to the grid of the bandpass amplifier, also to the Y-amplifier or luminance amplifier.

We have learned that all color signals which make up the chrominance signal are included within the range of video frequencies from 2.1 or 2.3 mc up to 4.0 or 4.1 mc. Frequency response of the bandpass amplifier section is limited to this chrominance range by a bandpass filter in the plate circuit. This filter cuts off all frequencies lower than 2.1 to 2.3 mc. The lower video frequencies do not pass through the bandpass amplifier, but they do go through the Y-amplifier section, and are added to the picture tube signal after the demodulators.

Output of the bandpass amplifier in Fig. 16 goes to a saturation control, and from there to the demodulators. The saturation control may be called a chrom control, an intensity control, or by some other appropriate name.

As a rule the saturation control is on the front panel, accessible to the operator. This control determines strength of color signals

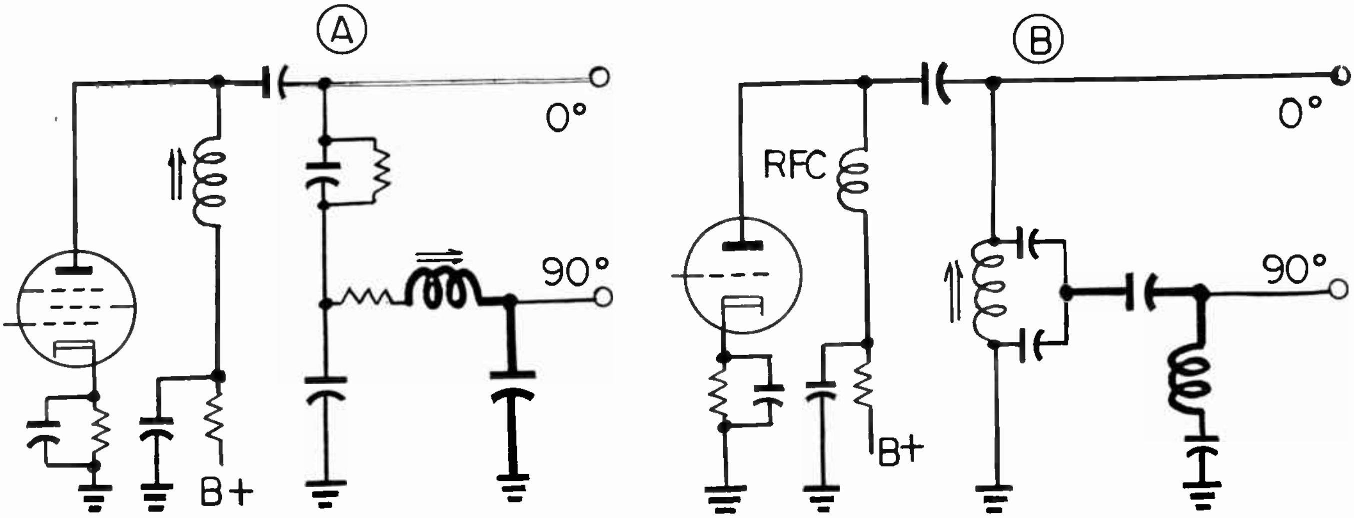

Fig. 15. Circuits for obtaining 90° phase shift with an inductor and capacitor.

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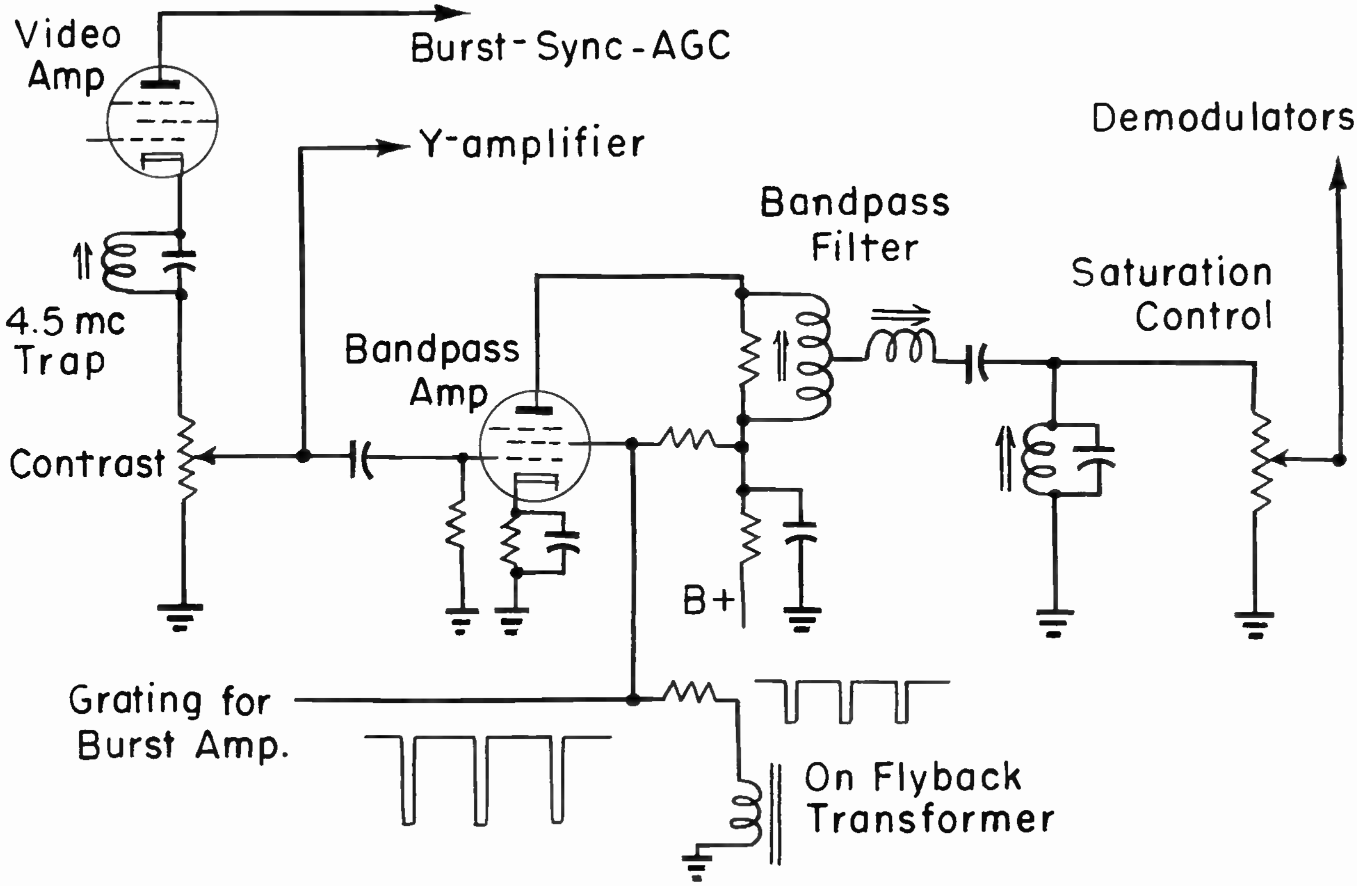

Fig. 16. A bandpass amplifier section from which the chrominance signal is delivered to demodulators.

applied to the demodulators and later mixed with the luminance signal. The result is variation of proportions of color and of white or gray in reproduced pictures - which is saturation.

With a saturation control turned to minimum there will be no color or only faint color. Advancing this control changes any and all hues from palest tints to strongest or most vivid colors which can be produced. The hues do not alter, only their saturation should vary.

The saturation control is not necessarily at the output of the bandpass amplifier. It may be any control which will vary gain of the bandpass amplifier section. For example, gain and saturation may be varied by adjustable cathode bias on any bandpass amplifier tube, or by adjustable grid input to such an amplifier.

Since the bandpass amplifier receives on its grid the entire video signal, it receives the 3.58-mc burst voltage, which is within the pass band of the amplifier. The burst is not allowed to go through the bandpass amplifier section to the demodulators, for it could cause various picture faults. In receivers using d-c restorers on color amplifiers, background brightness might be affected by bursts rather than by sync pulses or pedestal levels.

In the lower part of Fig. 16 is shown one method of "gating" out the bursts. On the horizontal flyback transformer is a small winding that supplies negative voltage pulses which are applied to the screen of the bandpass amplifier. These pulses occur during horizontal retrace or blanking intervals, within which occur the bursts. Driving the amplifier screen negative cuts off the amplifier during bursts, and they do not pass on to the demodulators.

The same negative pulses used for stopping amplification in the bandpass amplifier during bursts are used also for gating the

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burst amplifier. There the pulses are applied in such manner as to allow the burst amplifier to operate only during bursts.

Fig. 17 illustrates other connections which may be used for bandpass amplifiers. Here the 4.5-mc intercarrier beat trap and the contrast control are on the plate circuit of the video amplifier. The saturation control is an adjustable cathode-bias resistor on the bandpass amplifier. The plate circuit of this amplifier is coupled to a cathode follower, at the extreme right, from which the chrominance signal goes to the demodulators.

A notable feature in Fig. 17 is the method of gating the bandpass amplifier to prevent passage of bursts. Between amplifier grid and gating pulse connection is a crystal diode. This diode rectifies more or less completely the signal coming to the grid, leaving strong positive alternations and attenuating negative alternations.

During instants in which negative gating pulses are applied, these pulses overcome the positive signal alternations, and prevent amplification. Thus the amplifier is gated out for bursts, but operates normally at all other times. The rectified signals may again become alternating in following elements.

For receivers in which gating pulses for the burst amplifier must be positive, these same positive pulses may be applied to the cathode of a bandpass amplifier. Making the cathode of an amplifier highly positive makes its grid highly negative with respect to the cathode, and amplification is prevented during bursts. It may be mentioned that gating pulses sometimes are taken from a horizontal yoke or damper circuit instead of from the flyback transformer.

<u>COLOR DEMODULATORS.</u> The chrominance signal at the output of the bandpass amplifier is a 3.58-mc voltage modulated to carry, on a single waveform, all the primary colors and all their changes of hue and saturation. The transmitter process that produces this modulation must be reversed at the receiver to recover the color signals. Let's consider first what happens at the transmitter, shown in a very elementary way at the left in Fig. 18. There is a more complete diagram in Fig. 1.

<u>1.</u> Red, green, and blue voltages from the camera are put into three mixers. From the mixers come three new voltages, each containing certain proportions of red, green, and blue information. One of these voltages is the luminance or Y-signal, with which we are not now concerned. One of the other mixers delivers a combination of red, green, and blue which is the I-signal. The remaining mixer delivers a combination which is the Q-signal.

<u>2.</u> The I-signal goes to one modulator, wherein it becomes modulation on a 3.58-mc

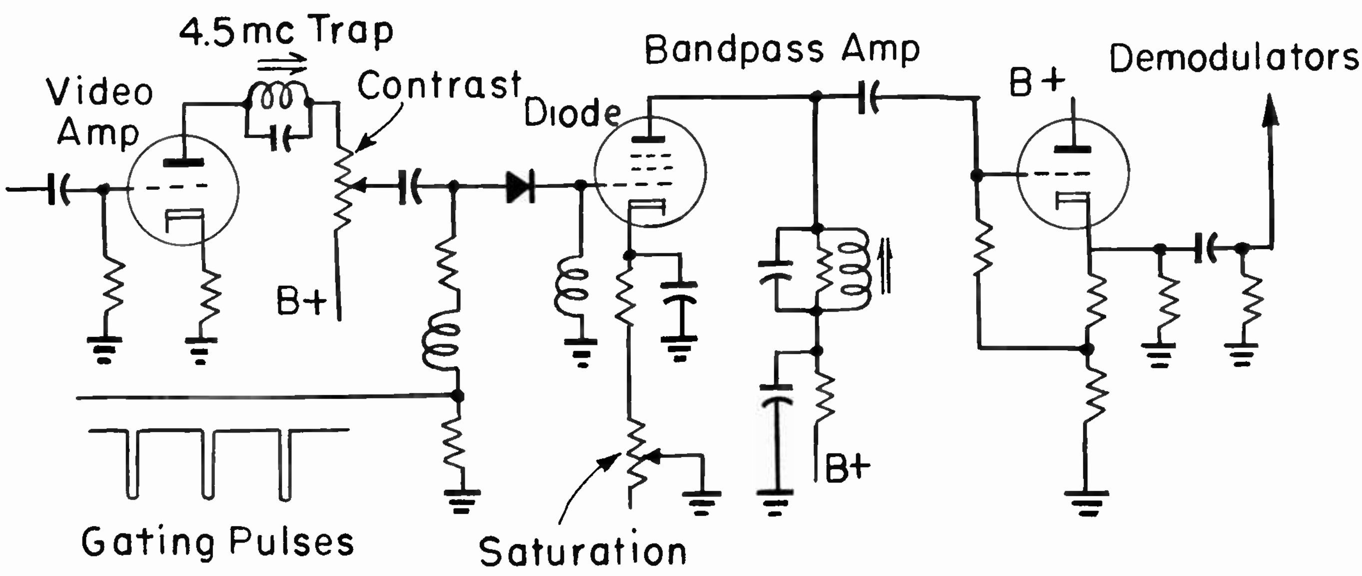

Fig. 17. Other circuits such as may be used in bandpass amplifiers.

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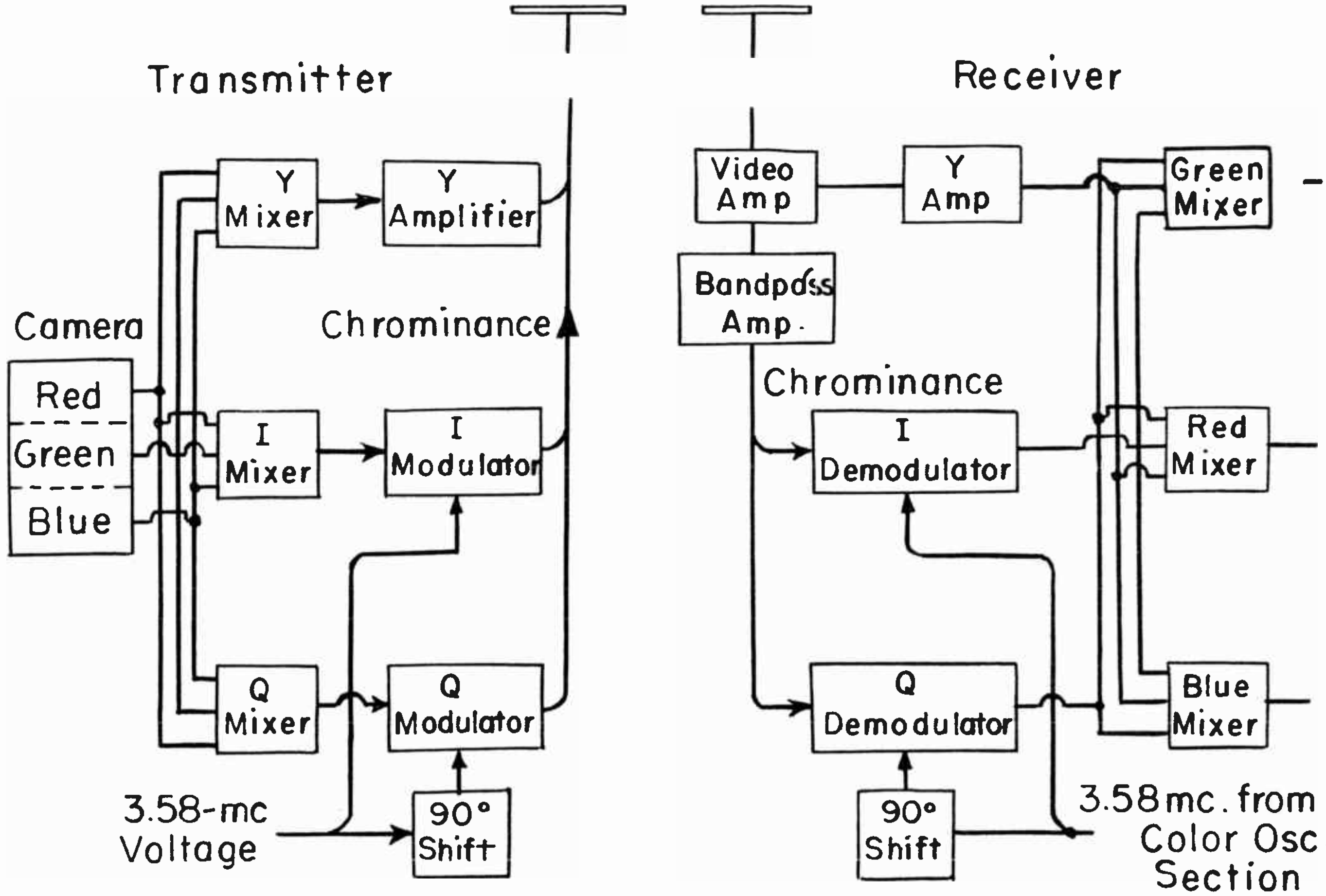

Fig. 18. Modulation at the transmitter is reversed by demodulation at the receiver.

voltage furnished by the master oscillator. The Q-signal goes to a second modulator, and becomes modulation on a second 3.58-mc voltage which differs in phase by 90° from the first one.

3. Outputs of the two demodulators are combined into the chrominance signal, which is transmitted.

The reverse process, which occurs in the receiver, is shown much simplified at the right in Fig. 18. In Fig. 2 is a more complete diagram of the receiver.

1. We obtain the complete chrominance signal from the bandpass amplifier.

2. This complete chrominance signal is applied to two demodulators. To one demodulator is applied also a 3.58-mc voltage originating in the color oscillator. The chrominance signal and this 3.58-mc voltage act together in this demodulator to cancel the Q-portion of the chrominance signal, and leave at the output only the I-signal.

The second demodulator gets a 3.58-mc oscillator voltage 90° out of phase with the first one. Here the chrominance signal and the 3.58-mc quadrature voltage act together to cancel the I-portion of the chrominance signal and leave at the output only the Q-signal.

3. The I- and Q-signals from the two demodulators go to mixers or matrixes, and combine in such manner that the matrix system delivers red, green, and blue color signals.

I AND Q SIGNALS VERSUS R-Y AND B-Y SIGNALS. Circuit diagrams of color receivers show two demodulators. In some receivers these are the I-demodulator and the Q-demodulator. In other receivers the names are R-Y and B-Y demodulators. The same circuits may be used for I-, Q-, R-Y,

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and B-Y demodulators, and their electrical principles are the same. The difference is in phase relations of chrominance signal components to the reference phase fixed by the master oscillator at the transmitter, and transmitted by means of bursts to the receiver.

To commence an examination of these phase relations we shall go back to the transmitter. As at A of Fig. 19, the burst voltage, which is at reference phase, is the only voltage transmitted directly from the master oscillator. The remainder of master oscillator voltage goes through a circuit that shifts its phase by 57°.

The 3.58-mc voltage which has been shifted 57° is applied to the I-modulator. To this modulator is applied also the I-signal, which comes through a mixer from the color camera. This I-signal modulates the 3.58-mc voltage which has been shifted 57°, and modulated output becomes part of the chrominance signal.

The 3.58-mc voltage that already has been shifted 57° next is shifted another 90° in a second phase-shift circuit. The doubly shifted 3.58-mc voltage is applied to the Q-modulator. To this modulator comes also the Q-signal, from a mixer and the color camera. The Q-signal modulates the doubly shifted 3.58-mc voltage, and the modulated output becomes the remaining part of the chrominance signal.

The result of all this phase shifting is shown at B of Fig. 19, which is a portion of our color phase chart. The reference phase, corresponding to the transmitted burst, is represented by a horizontal line to the left of center. The positive I-signal is shifted 57° from the reference phase. The positive Q-signal is shifted 90° from the positive I-signal, placing the Q-signal 147° from the reference phase.

The I- and Q-signals are shown as positive on the diagram. I- and Q-signals which are negative (in opposite phase) may be obtained by applying the positive signals to grids of triode or pentode inverters, and taking negative-phase signals from the plates. Negative I- and Q-signals are shown in correct phase positions by broken lines on the color-phase chart. Receiver demodula-

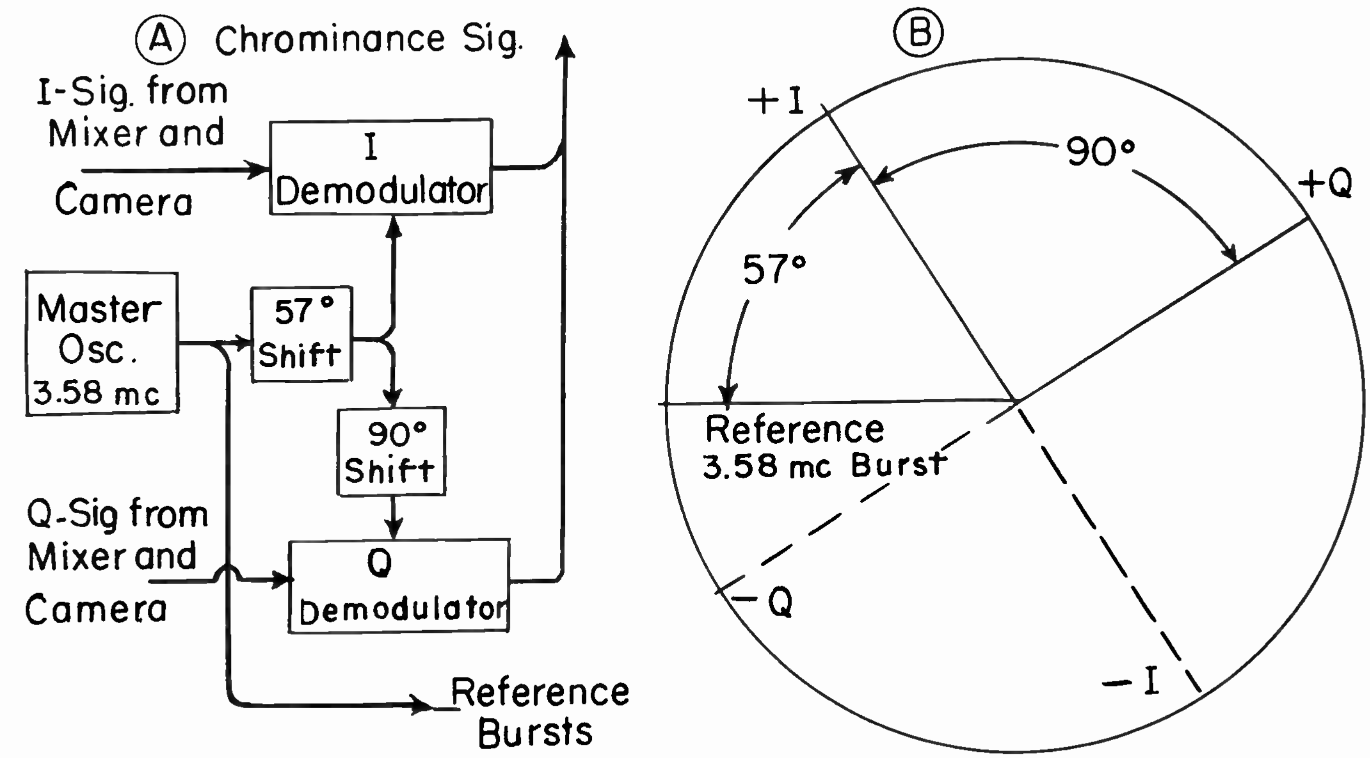

Fig. 19. Phase relations between the reference burst and I- and Q-signals which are demodulated.

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tors operating on signal phases of Fig. 19 are called I- and Q-demodulators.

We should note the following with respect to the I and Q system of demodulation. Burst voltage that syncs the color oscillator in the receiver is at the reference phase. It is not shifted either by 57° or by 147°. The 3.58-mc voltage at this reference phase, corresponding to burst voltage, is not applied directly to either demodulator. First it must be effectively shifted by 57°, then applied to the I-demodulator, after which it is shifted another 90° and applied to the Q-demodulator.

The initial 57° phase shift at the receiver may be obtained in various ways. There might be the necessary shift in some tuned circuit at the output of the color oscillator system, ahead of the 90° shift circuit. Another method would be to introduce an appropriate shift in some circuit between the video amplifier and the burst section or color oscillator section. If a resonant transformer is used, it may shift the phase by 90°. Then another shift of 33° used in such a way as to subtract from the 90° shift will leave a 57° phase shift.

Now we shall make a radical change in the method of receiver demodulation, by shifting the phase of the color oscillator 33° with respect to phase of the reference burst voltage. This is shown at A of Fig. 20. Phase of the I-signal is, of course, shifted 33° in the same direction, which places the I-signal 90° from the original reference phase, because the sum of 33° and 57° shifts is 90°. Phase of the Q-signal is similarly shifted, for it must remain 90° from the I-signal.

With the color signals shifted in this manner they no longer are called I- and Q-signals. As shown at B, the former positive I-signal now is the positive R-Y signal, and the former positive Q-signal is the positive B-Y signal. Negative R-Y is in opposite phase to positive R-Y. Negative B-Y is in opposite phase to positive B-Y, bringing negative B-Y in phase with the reference burst voltage. Demodulation of R-Y and B-Y signals may be called color-difference demodulation, since we work with differences between R or B signals and the Y-signal.

All hues and saturations may be recovered by demodulation of either I- and Q-signals or R-Y and B-Y signals. Amplitudes will differ in the two methods, but by mixing suitable proportions of these amplitudes the final results are equivalent.

<u>DEMODULATOR ACTION.</u> Any I-demodulator or any R-Y demodulator should

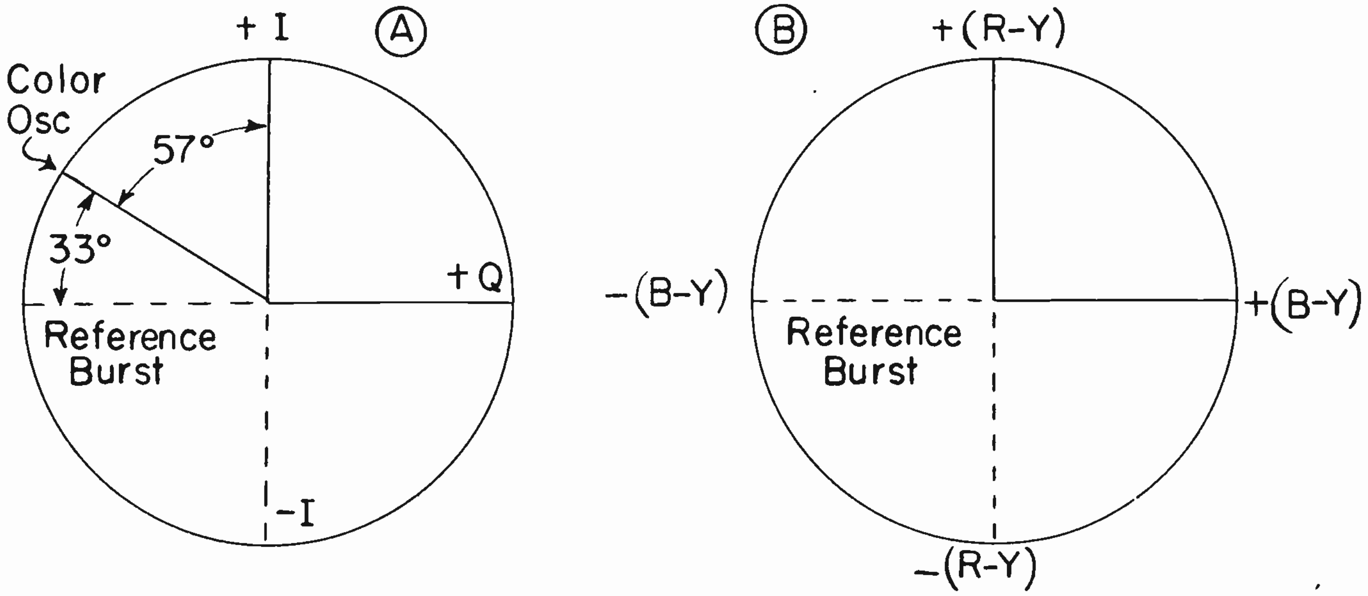

Fig. 20. Phase relations between the reference burst and R-Y and B-Y signals which are applied to demodulators.

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deliver in its output a voltage whose changes of amplitude and polarity correspond to changes at the I modulator in the transmitter during the same periods of time. Any Q-demodulator or any B-Y demodulator should deliver an output corresponding to color information at the Q-modulator of the transmitter during the same time instants.

It should be kept in mind that both modulators at the transmitter always receive a combination of red, green, and blue camera voltages, but these voltages are of different amplitudes and polarities at the two modulators.

I- and Q-signals cancel only while the camera scans white or gray, with no color. If color is scanned, there will be corresponding changes of the combination voltages going to both modulators. These changes of voltage at both modulators must be reproduced at both demodulators in the receiver.

Changes of camera voltage amplitude, which correspond to various saturations, are transmitted as changes of amplitude in the chrominance signal. Changes of camera voltage polarity, resulting from hues, are transmitted as changes of phase in the chrominance signal. Therefore, any demodulator must convert changes of chrominance amplitude into changes of amplitude at the demodulator output, and must convert changes of chrominance phase into changes of polarity at the demodulator output.

An I-demodulator or R-Y demodulator makes the conversions with respect to the received I-signal component of the chrominance signal, while the Q-demodulator or B-Y demodulator makes them with respect to the Q-component.

Application of a 3.58-mc voltage to one demodulator causes it to recover color information originally in the transmitted I-signal. Application to the other demodulator of a 3.58-mc voltage 90° out of phase with the first one causes this second demodulator to recover color information originally on the transmitted Q-signal.

A type of color demodulator shown by Fig. 21 uses a pentode tube. The diagram

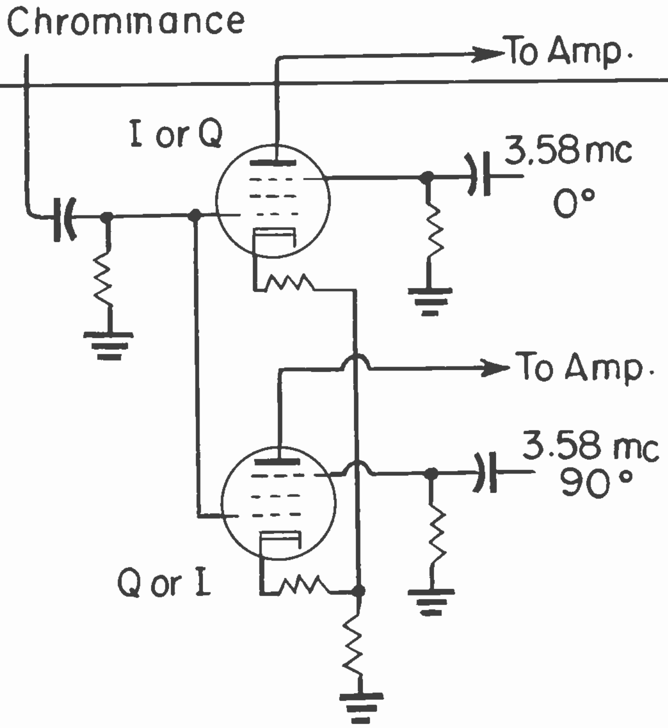

Fig. 21. Circuits for pentode tubes used as demodulators.

shows the two demodulators required in a receiver. If one is an I or R-Y demodulator, the other is a Q or B-Y demodulator.

The chrominance signal from the band-pass amplifier is applied to the first grids of both demodulators. To the third grid of one demodulator is applied one of the 3.58-mc voltages from the color oscillator section. To the third grid of the other demodulator is applied the 3.58-mc voltage that is 90° out of phase with the first one.

The third grid in a pentode usually is called the suppressor. Here we are not using these grids for suppression of secondary emission, rather we are using them as additional control grids.

Action in a pentode demodulator is similar in some respects to that in a multi-grid converter tube such as used for combined mixer and oscillator in radio broadcast receivers. In the pentode demodulator there is no oscillator action, as in a converter, but two control voltages act on a single electron stream passing from demodulator cathode to plate, as in the converter. The single electron stream is varied first by chrominance

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signal voltage on the first grid, then by 3.58-mc voltage on the third grid.

In the plate output of the pentode demodulator appears a voltage whose amplitude, with respect to average value, varies with amplitude of the chrominance signal, thus reproducing the effects of saturation. Polarity of demodulator plate voltage, with respect to its average value, changes according to phase variations of the chrominance signal, thus reproducing the effects of hue.

If the third grid of a pentode demodulator receives 3.58-mc voltage in phase with color oscillator output there is demodulation of the I-signal or R-Y signal component of the chrominance signal. If the third grid receives a 3.58-mc voltage 90° out of phase there is demodulation of the Q-signal or B-Y signal component of the chrominance signal.

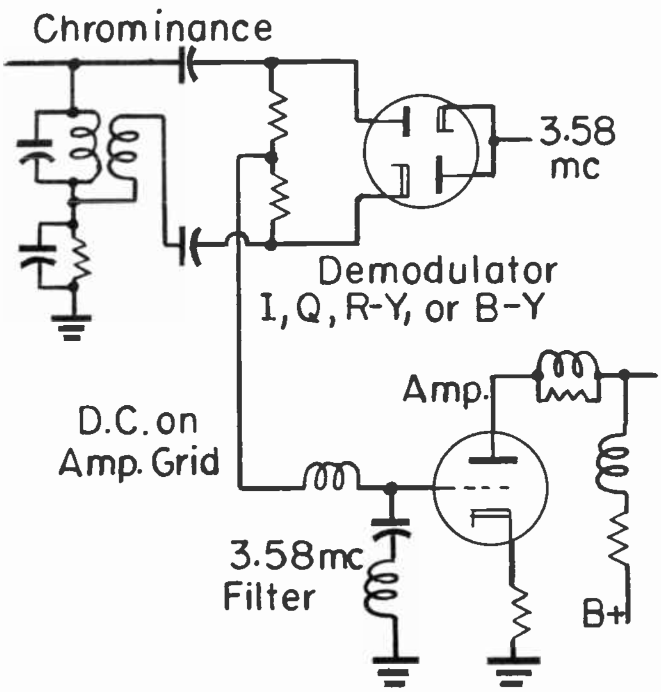

Fig. 22. A twin-diode used as a color demodulator.

A type of color demodulator illustrated by Fig. 22 makes use of a twin-diode in a circuit practically the same as that of phase detectors used in some afc systems for horizontal sweep oscillators. You will recall that the afc system brings two voltages in opposite phase from a sync inverter to one plate and one cathode of the phase detector. To the other plate and cathode, tied together, is applied a voltage fed back from the output side of the sweep oscillator.

In the afc phase detector output is a voltage whose polarity and amplitude vary according to differences between frequencies of sync voltage and oscillator output voltage. A similar output voltage would result from differences of phase instead of frequency on the two sides of the phase detector, because change of either phase or frequency causes relative time shift of the two applied voltages.

For a twin-triode color demodulator the chrominance signal is divided into two parts having opposite phase, and these parts are applied to one plate and one cathode of the demodulator. Opposite-phase chrominance voltage may be secured from a transformer secondary, or from an inverter tube. To the other plate and cathode of the demodulator, tied together, is applied a 3.58-mc voltage from the color oscillator section.

At the demodulator output is a voltage varying in amplitude according to chrominance amplitude, and varying in polarity according to chrominance phase. This varying output voltage is the I-signal or R-Y signal, or else the Q-signal or B-Y signal, depending on whether the 3.58-mc voltage is at 0° phase or at 90° phase with respect to color oscillator voltage.

Demodulator output in Fig. 22 is applied to the grid of a following amplifier. The amplifier is not part of the demodulator circuit, but is shown to indicate what may be done with demodulated signal voltage. A receiver would require two of the twin-diode demodulators, one to handle color information originally on the I-signal, the other to handle information originally on the Q-signal.

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Lesson 99

COLOR TELEVISION – PART FOUR

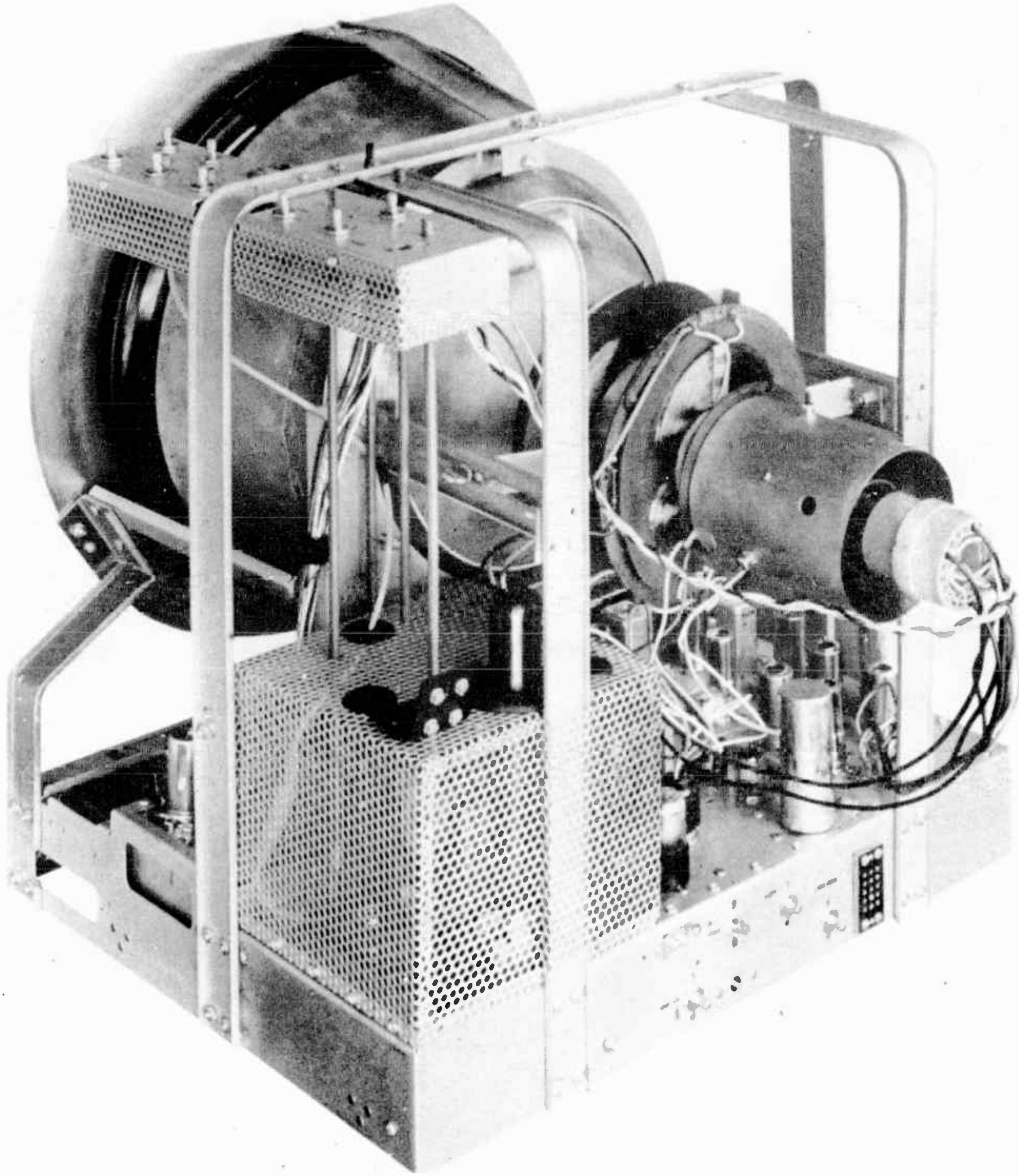

Fig. 1. This is one of the first Admiral color TV receivers. Most of the service adjustments for color are in the elevated housing at the left of the picture tube.

Every picture which appears on the screen of a color tube must be formed by some combination of red, green, and blue - for these are the only kinds of phosphors. Not only all colors, but also whites and grays must be formed in this manner. During reception of monochrome signals it is necessary to maintain such proportions of red, green, and blue voltages as will reproduce only white, gray, and black.

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In the luminance signal or Y-signal we have correct proportions for producing only monochrome pictures during black-and-white reception. Color is added by chrominance signals during reception of color broadcasts, but during black-and-white broadcasts the chrominance signals should balance out, or else the chrominance section and demodulators should be made inoperative. Otherwise there will be random color effects in monochrome pictures.

COLOR KILLERS. The simplest method of cutting off the chrominance section for black-and-white reception is by means of a manually operated switch that disables the demodulators. An example is shown at A of Fig. 2. Opening the color switch removes B-voltage from both plate and screen of the I-demodulator, and from the screen of the Q-demodulator.

Other systems operate automatically, utilizing a color killer tube whose action depends on the fact that bursts are present in color transmissions, but not in monochrome transmissions. One type of color killer circuit is shown at B in Fig. 2. The grid of the color killer tube is connected to one side of the phase detector in the apc system for the color oscillator. At this point there is negative d-c voltage to ground only during color transmissions, and the killer grid is biased to cutoff during color programs. During black-and-white reception the negative d-c voltage is absent, and the color killer tube remains conductive.

To the plate of the color killer tube are applied positive voltage pulses from a winding on the flyback transformer. While the killer tube is conductive during monochrome reception these pulses cause charging of capacitor C in the marked polarity. Potential from the negative side of C is applied to the grid return circuit of the bandpass amplifier, holding that amplifier cut off during monochrome reception.

During color reception, with the killer grid biased to cutoff, the positive pulses on its plate can cause no conductionfor charging capacitor C, which discharges through the paralleled resistor. With C discharged, no negative potential is applied to the grid of the bandpass amplifier. The amplifier remains active, to pass the chrominance signal to the demodulators. Other color killer systems bias the demodulators to cutoff during black-and-white reception.

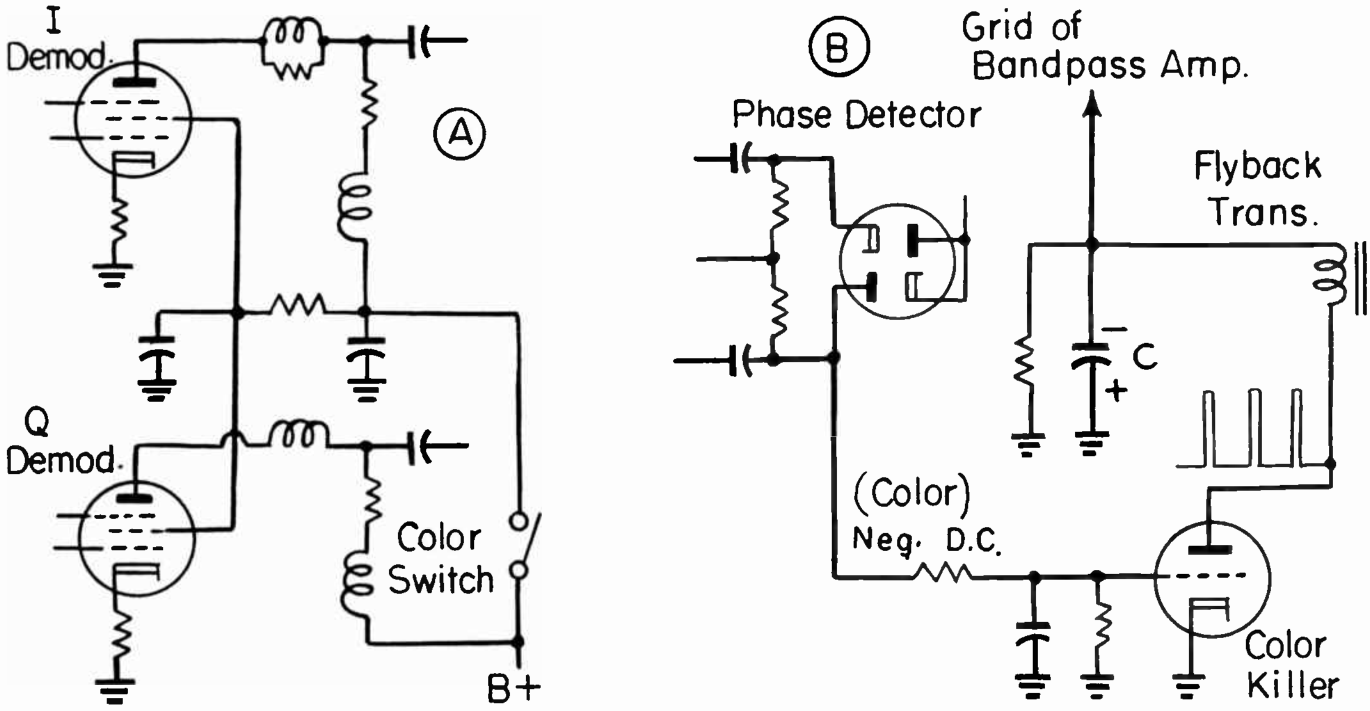

Fig. 2. Methods for cutting off color during black-and-white reception

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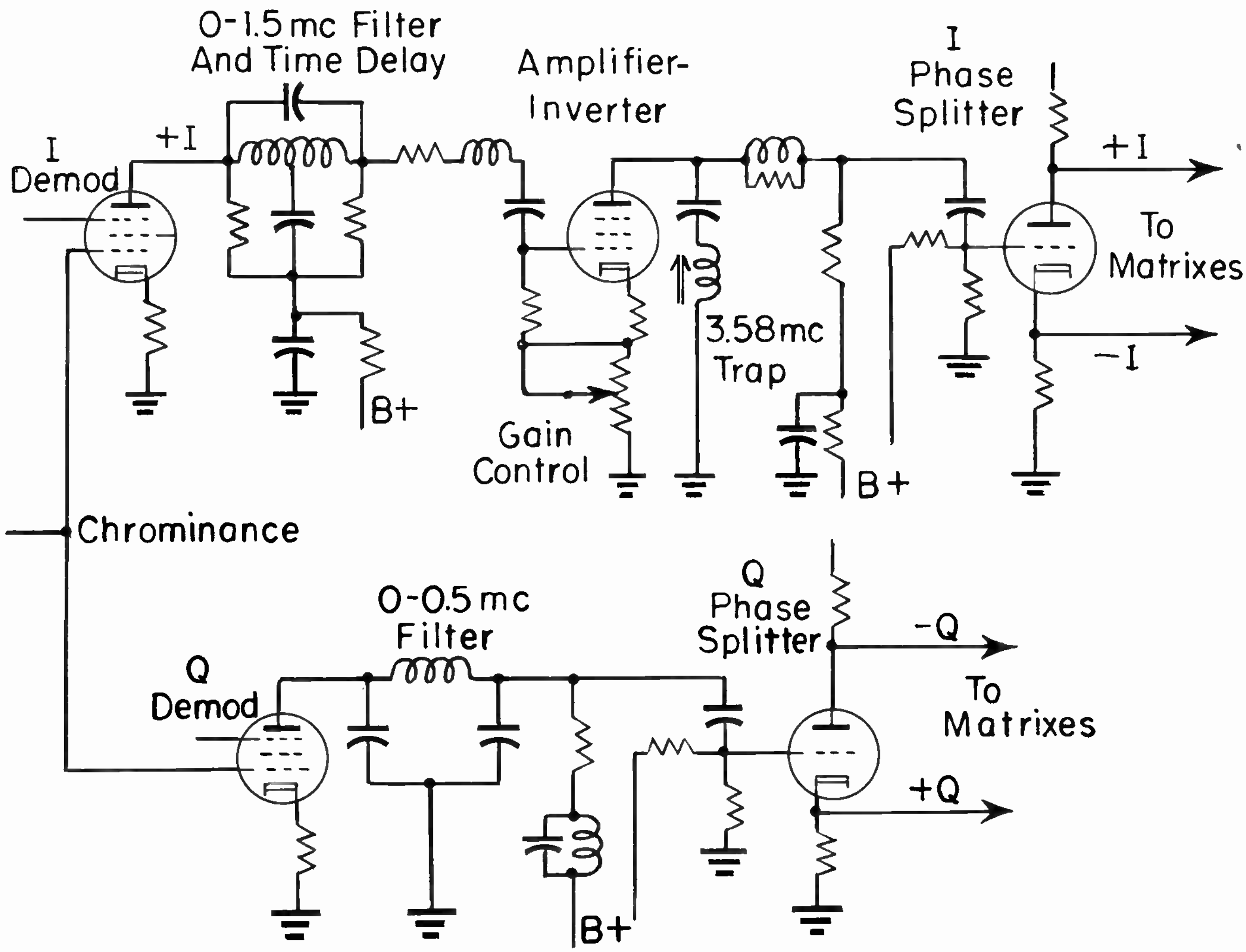

Fig. 3. Filtering and time delay in demodulator output circuits.

DEMODULATOR FILTERING AND TIME DELAY. Earlier we learned that frequencies in I-signal sidebands extend to about 1.5 mc from the color carrier, while frequencies in Q-signal sidebands extend only to about 0.5 mc. As shown by Fig. 3, in the output circuit of an I-demodulator will be filtering to limit the response to about 1.5 mc, and in the output of the Q-demodulator will be filtering for cutoff at about 0.5 mc. We are referring now to frequency ranges of I- and Q-signals after demodulation. Do not confuse them with frequency range of the entire chrominance signal, which is from about 2.1 to 4.1 mc before demodulation.

Because demodulator output filters are to pass low frequencies, and cut off at some high frequency, they have the form of a low-pass filter. This means one or more series inductors with one or more capacitors shunted to ground, just as in low-pass filters of B-power supplies. The demodulator filters cut off, or bypass to ground, any 3.58-mc voltages that come through the demodulators, also any high-frequency remnants of luminance or video signals that might have come through the bandpass amplifier.

When demodulation is of R-Y and B-Y signals, output filtering on both demodulators may limit the response to about 0.5 mc. Since the R-Y signal is developed from demodulation of an original I-signal (extending to 1.5 mc) an 0.5-mc filter will remove the higher frequencies of this signal in the same manner that it removes higher frequencies from the B-Y signal.

With demodulation of I- and Q-signals the narrower pass band for the Q-signal (0 to 0.5 mc) causes more time delay than the

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wider pass band for the I-signal. To equalize the times required for signals to go through both systems, an additional time delay is incorporated in the I-demodulator output circuit.

Time delay in the I-signal circuit may be secured with a delay line of the same general style used in luminance circuits, but more often it is secured by suitable design of the output filter on the I-demodulator. When output filters limit responses of both demodulators to the same range, as 0 to 0.5 mc, signals pass through both systems in the same time, and no additional delay is needed for either one.

Because the I-signal from a demodulator has wider frequency response it normally is weaker or shows less gain than the Q-signal, with its narrower response. To equalize the signal strengths an amplifier usually is in the I-signal system, but not in the Q-signal system. This amplifier also inverts polarity of the I-signal between amplifier grid and plate.

At the output ends of both demodulator sections in Fig. 3 are phase splitters that provide, from plates and cathodes, positive and negative I-signals, and positive and negative Q-signals. Positive and negative R-Y and B-Y signals would be secured similarly, from phase splitters. Signals in both polarities go from the phase splitters to the mixers or matrixes.

In Fig. 3 the outputs of both demodulators are shown as positive. Then, at the plate of the amplifier-inverter in the I-system is a negative I-signal, at the cathode of the phase splitter there is negative-I, and at the splitter plate there is positive-I. Since there is no inverter in the Q-system, the Q-phase splitter furnishes positive-Q at its cathode and negative-Q at its plate. In some receivers the demodulator outputs are negative. This would reverse all the polarities at cathodes and plates of both phase splitters.

Frequency-limiting filter inductors may or may not have movable slugs for frequency adjustment. The time delay element in the I-system, either separate or combined with a filter, may be connected between demodulator and amplifier as in Fig. 3, or may be between amplifier and splitter. Traps tuned to 3.58 mc may be used at various points in circuits following either or both demodulators.

MIXERS OR MATRIXES. At the outputs of phase splitters following I- and Q-demodulators are I- and Q-signals of both polarities. Mixing certain proportions of these phase splitter outputs will produce the red, green, and blue signal voltages required for grid-cathode circuits of picture tubes. This is accomplished in mixers or matrixes consisting of resistors of suitable values and accuracy. Resistance values depend on strengths and polarities of I- and Q-signals. During reception of black-and-white transmissions the mixers should produce such proportions of red, green, and blue signal voltages as combine into whites and grays.

I-, Q-, and Y-signals may be combined with mixer connections of Fig. 4. For each primary color we take certain proportions of the input signals, as written on the mixer blocks of the diagram. Red, green, and blue signal voltages go from the mixers to color amplifiers, and to three grids of a three-gun picture tube. The picture tube cathodes are tied together and connected to the brightness control. Compositions of Y-, I- and Q-signals fed to the mixers of Fig. 4 are as follows.

+Y	=	+ .30 R	+ .59 G	+ .11 B
+I	=	+ .60 R	- .28 G	- .32 B
-I	=	- .60 R	+ .28 G	+ .32 B
+Q	=	+ .21 R	- .52 G	+ .31 B
-Q	=	- .21R	+ .52 G	- .31 B

Consider, for an example, how the red signal voltage is formed. Fig. 4 shows that the red signal is made up by taking 1.00 times the +Y signal, 0.96 times the +I signal, and 0.63 times the +Q signal. If you take these proportions of each input signal as given in the preceding list, and add together all the values of red, of green, and of blue, the result will be 1.00 red, but positive and negative values of green and blue will cancel, to leave zero for these two.

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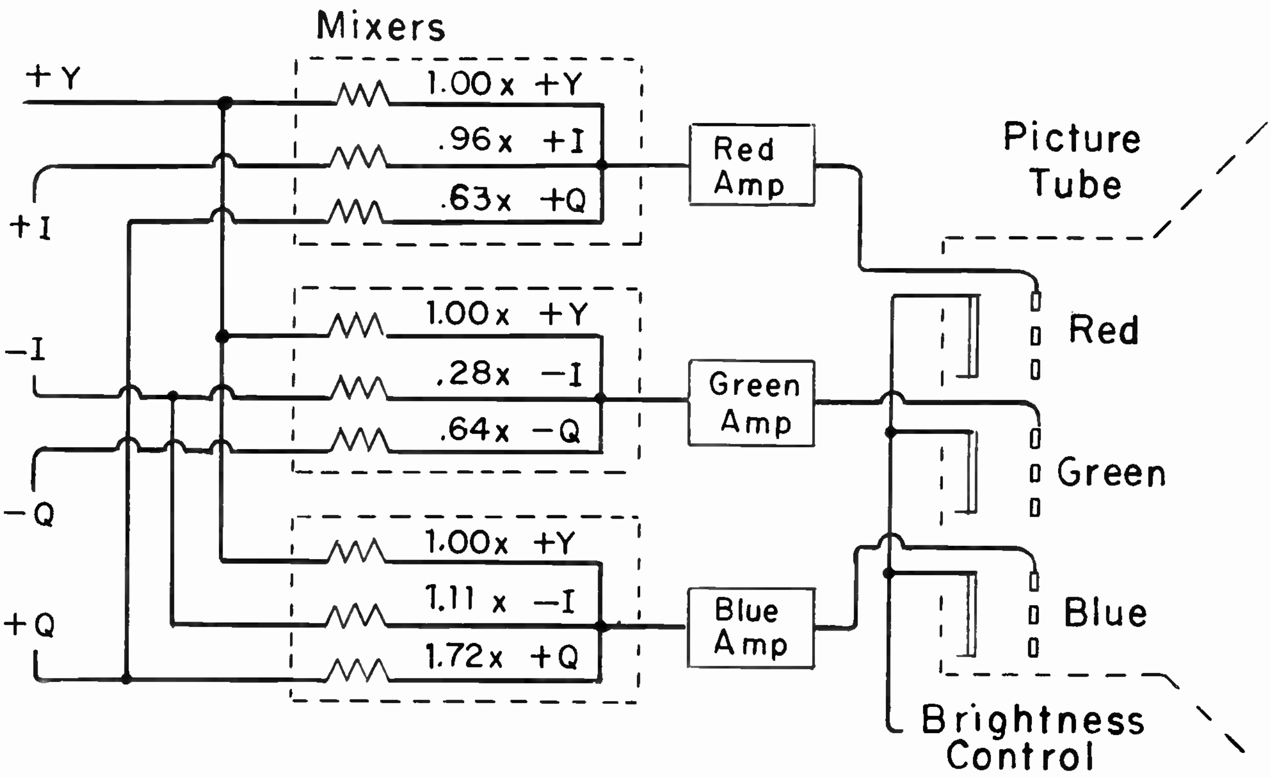

Fig. 4. Mixer system producing primary color voltages from I- and Q-signals.

Since values are given to only two decimal places, round off any third place products. Similar computation for the green signal will give 1.00 of green, with other primaries balanced out. The blue signal will turn out 1.00 of blue, and other primaries zero.

When tubes in demodulator sections are replaced, and when resistors and other elements change their values with age, original proportions of signals may change. Such changes are compensated by adjustable service controls at various points. In Fig. 3 there is a cathode-bias gain control on the amplifier-inverter tube.

Fig. 5 shows circuits which include many controls between phase splitters and outputs of resistance mixers. Control 1 is used to obtain correct red signal voltage, 2 and 3 are for green voltage, and 4, 5, and 6 for blue signal voltage.

If demodulation is of R-Y and B-Y signals, instead of I and Q, the mixing is carried out in somewhat different manner. Proportions of R-Y and B-Y signals which produce a given hue are not the same as proportions of I- and Q-signals for the same hue, because there are difference of phase with respect to the reference signal.

Fig. 6 shows circuits often used following R-Y and B-Y demodulators. Note that cathodes of the three-gun picture tube are tied together, and to them is applied a negative Y-signal from the Y-amplifier. Composition of this signal in terms of red, green, and blue is written on the diagram. This negative Y-signal on the cathodes has the same effect as a positive Y-signal at each grid. Therefore, in considering grid action, we may assume a positive Y-signal whose composition is shown just below that of the negative Y-signal.

From the R-Y amplifier an R-Y signal goes directly to the grid of the red gun in the picture tube. From the B-Y amplifier a B-Y signal goes directly to the blue grid. Compositions of the color-difference signals are on the diagram.

To obtain a G-Y signal we use resistance mixing to multiply the R-Y signal by minus 0.51, and to multiply the B-Y signal by minus 0.19. The result is a G-Y signal applied to

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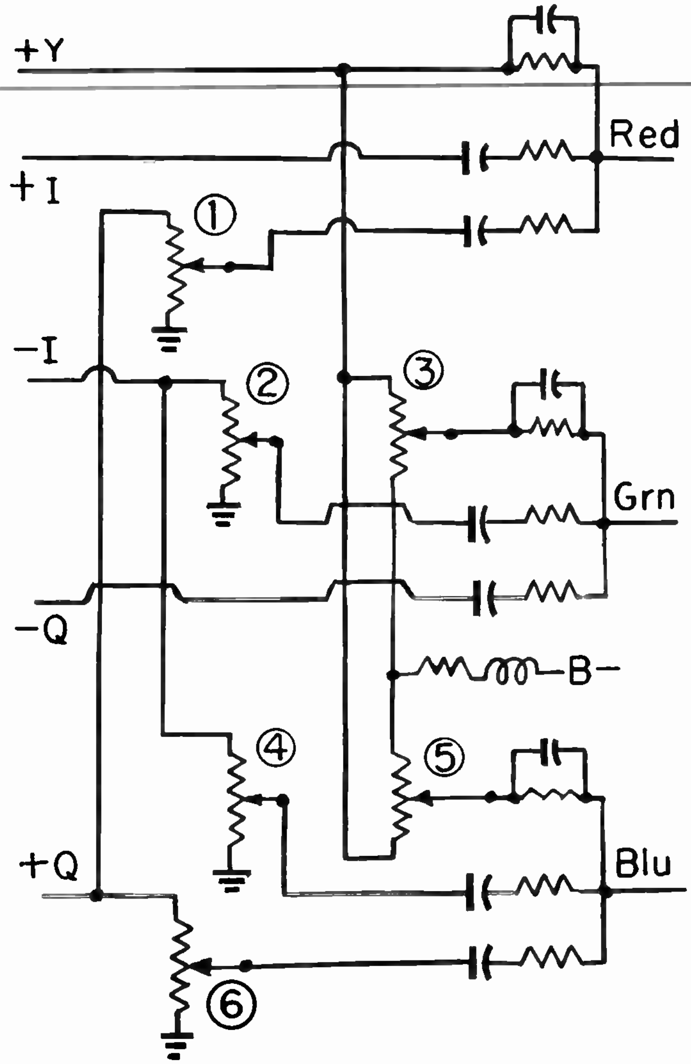

Fig. 5. Service controls associated with a matrixing system for I- and Q-signals.

the G-Y amplifier. The G-Y signal is obtained from the R-Y and B-Y outputs of the demodulators. Don't forget that multiplying plus and minus gives minus, and that multiplying two negatives gives plus. If you have forgotten some of your arithmetic, assume that the written values are correct, which they are.

Let's see what happens in the picture tube when the color-difference signals are applied to the three grids, and the equivalent of +Y is on the grids, by way of the -Y signal on the cathodes. Add together +Y and R-Y on the red grid, thus,

+Y	=	+ .30 R	+ .59 G	+ .11 B
R-Y	=	+ .70 R	- .59 G	- .11 B
Sum	=	+1.00 R	zero G	zero B

We find at the red grid 100% of the red signal voltage, but zero for both green and blue. We have obtained red signal voltage from Y and R-Y signals. Adding +Y and G-Y will give 100% green and zero of both other primaries. Adding +Y and B-Y yields 100% blue and zero of the other two primaries. With this method we say that part of the matrixing is done in the picture tube.

There are various other ways of obtaining red, green, and blue signal voltages by mixing the Y-signal with R-Y and B-Y color difference signals. In some receivers the grids of the picture tube are tied together, and to them is applied a negative Y-signal. Then R-Y, G-Y, and B-Y voltages are applied to the three cathodes. Mixing yields the three primary color signals.

Fig. 7 shows a method of using R-Y and B-Y demodulation with the Y-signal applied to resistance mixers rather than to either the grids or cathodes of the picture tube. Inverters are employed to furnish positive and negative color difference signals.

Commencing at the upper mixer, where the +Y signal is combined with the R-Y signal, +Y and -Y cancel to leave only +R, which is the red signal. In the middle mixer a G-Y signal is obtained from R-Y and B-Y signals, as in Fig. 6. When the G-Y and +Y signals are combined, -Y and +Y cancel to leave +G, which is the green signal. In the lower mixer are combined +Y and B-Y, with cancellation of +Y and -Y to leave +B, which is the blue signal voltage.

COLOR AMPLIFIERS. Between outputs of resistance mixers or matrixes and grid-cathode circuits of picture tubes in some receivers are three color amplifiers, one for each primary color, and all alike. Each amplifier may consist of a single stage using a pentode, or of two stages with a twin-triode or two pentodes. Circuits are similar to those of video amplifiers in black-and-white receivers, with response extended to about 3.5 mc. The color amplifiers may feed either grids or cathodes of picture tubes, depending on polarity of color signal voltages at amplifier outputs. We find the same polarity relations as in monochrome receivers.

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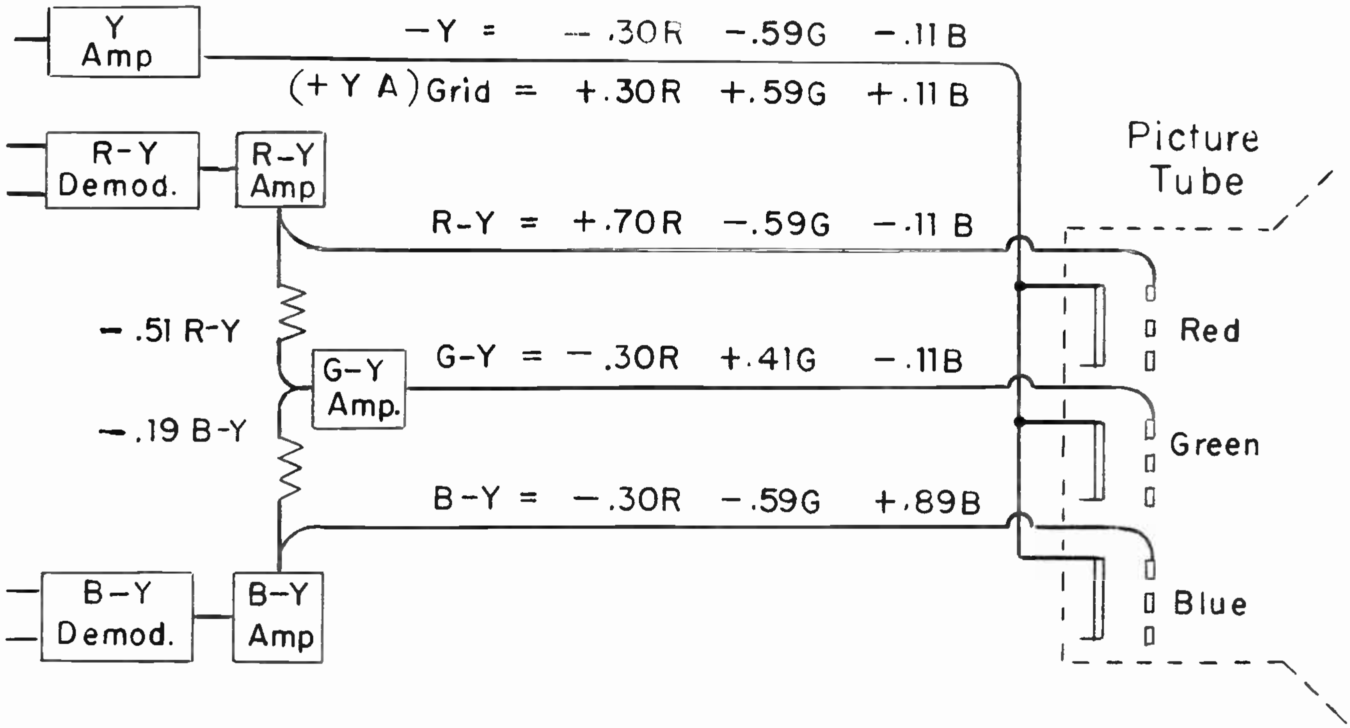

Fig. 6. Production of the G-Y signal from R-Y and B-Y signals.

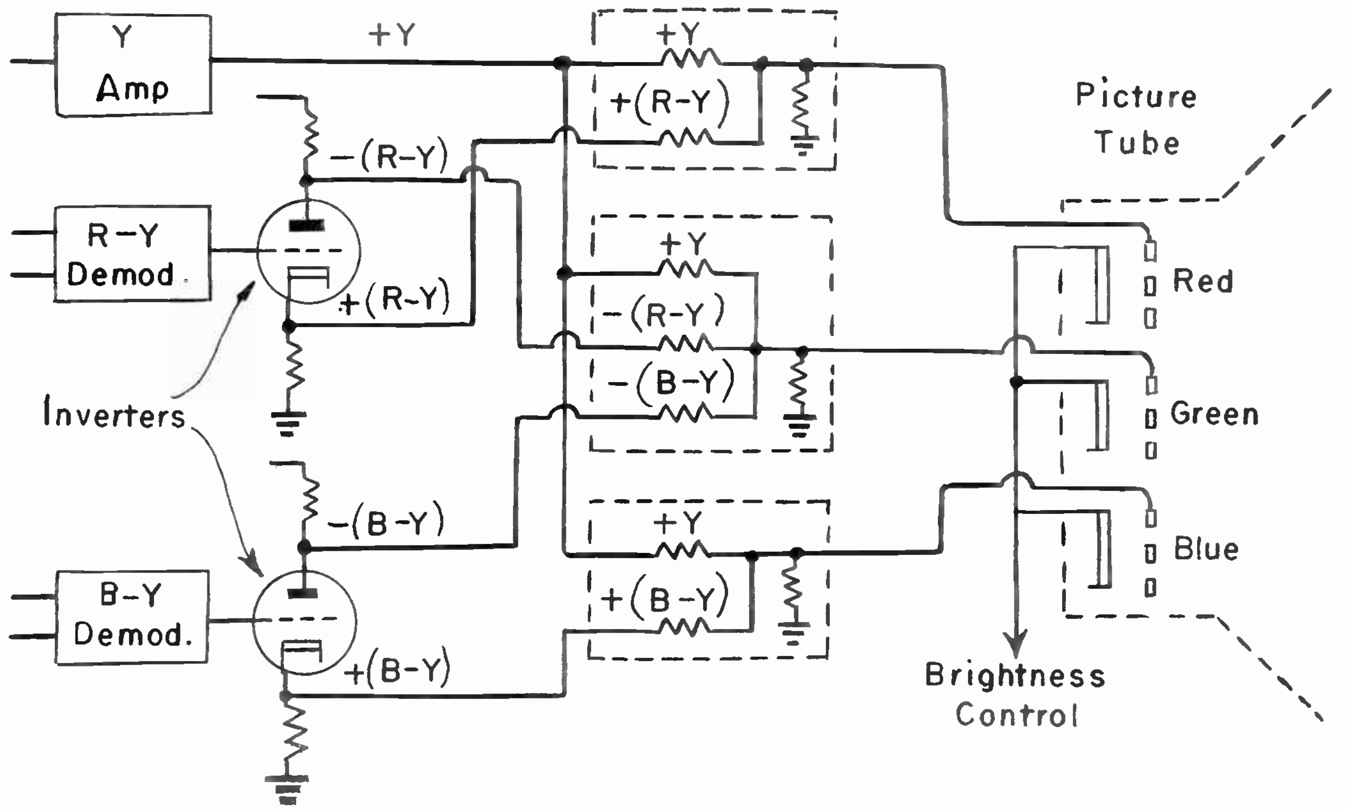

Fig. 7. Matrixing for color-difference signals with all signals to picture tube grids.

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Color amplifiers, especially those for green and blue, commonly are provided with gain controls, such as adjustable cathode-bias resistors or a potentiometer on the output connected much like a volume control in radio sound receivers. Adjustable output is necessary because green and blue phosphors in the picture tube do not require voltages so strong as that on the red phosphor to cause equal light outputs. Controls are adjusted to bring green and blue illuminations down to the level of the red.

In many color receivers there are d-c restorers between the output of each color amplifier and the picture tube grid-cathode circuits. The function of the restorers is the same as in monochrome receivers, to maintain correct background or average brightness. Circuits are no different than used in monochrome receivers. The three restorer circuits usually are handled by a single tube containing three diodes; a type of tube made especially for color television.

THREE-GUN PICTURE TUBES

In a three-gun picture tube three electron beams pass in such directions through openings in an aperture mask or shadow mask that each beam can fall on phosphor dots for only one primary color. This principle is illustrated by Fig. 8. Phosphors for the three primary colors are deposited in the form of dots or very small circles on a glass plate which becomes the viewing screen. In the CBS tube this screen is on the inside of the spherical face plate that forms the front of the tube, just as in black-and-white picture tubes.

The phosphor dots are in groups of three. Each group consists of one dot for red, another for green, and a third for blue, arranged in the form of a triangle. Relative positions are such that, no matter which three adjacent dots are considered, they always include red, green, and blue. Each group may be called a triad or a trio. There are approximately 1450 complete groups on each square inch of screen surface.

The three electron beams come from three guns, one for each primary color. The red signal voltage acts on the grid-cathode in one gun, the green signal in another, and the blue signal in the third. The three guns operate simultaneously, all the time.

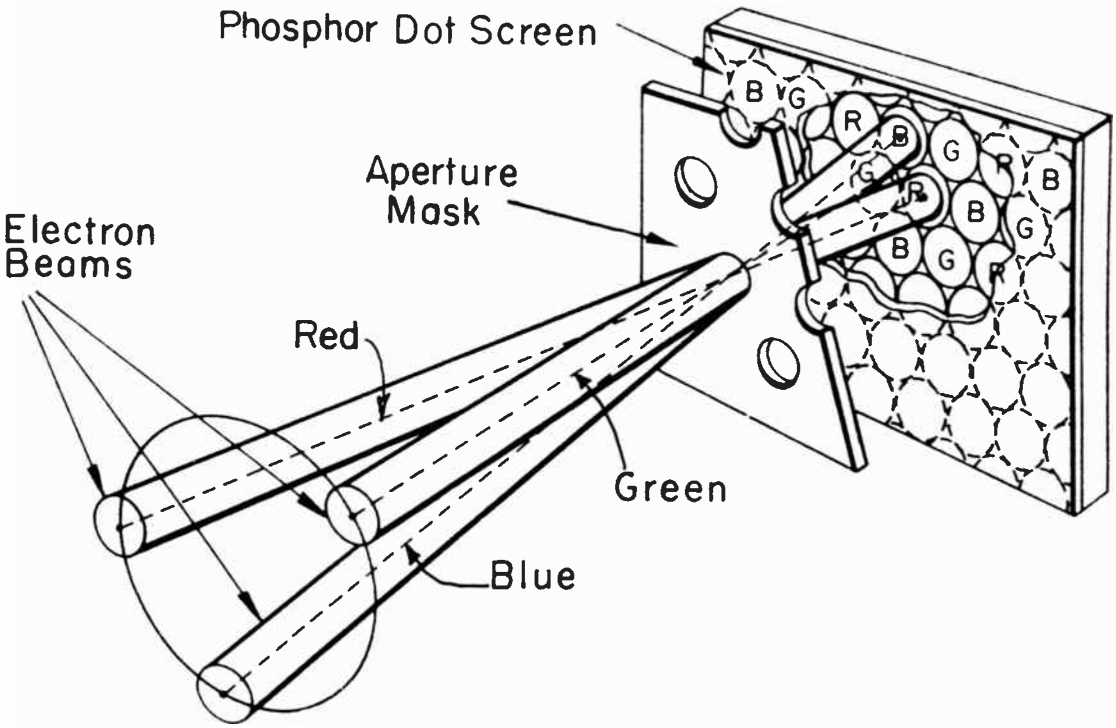

Fig. 8. The basic principle of the three-gun color tube with aperture mask, as shown for the CBS-Colortron.

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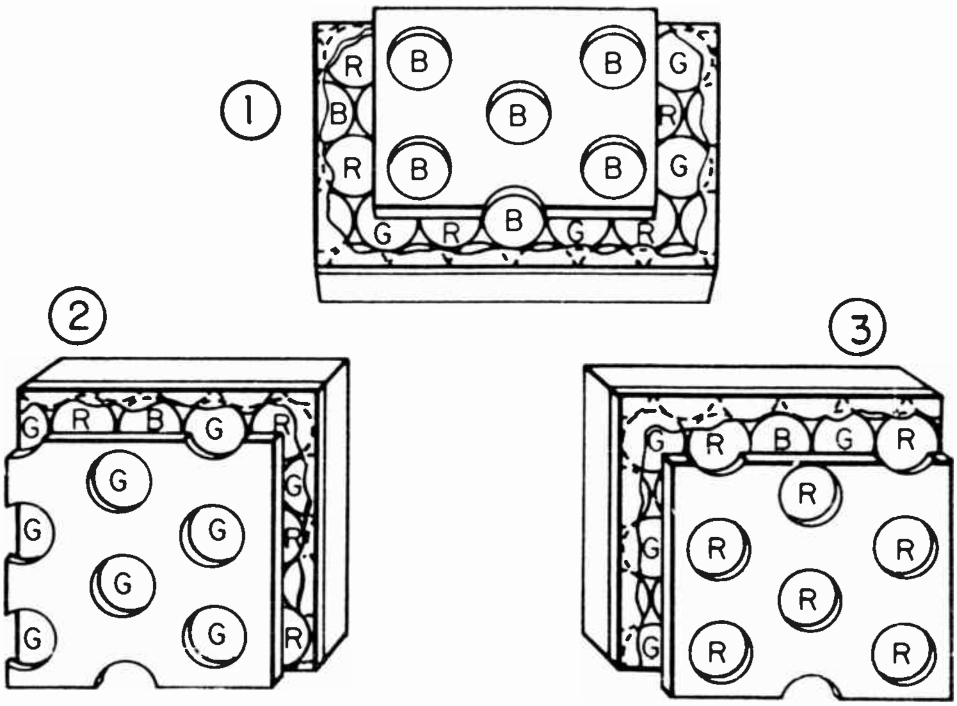

Fig. 9. Beams from each of the three electron guns can strike only phosphor dots for one color.

In the aperture mask is one circular opening for each group of dots. Each opening is very slightly smaller than the diameter of one dot. The beam from each gun passes through the mask openings at such an angle as to strike only dots for the color corresponding to that gun. Dots for the other two primary colors in any given group are shadowed by the solid areas of the mask.

As you can see at 1 in Fig. 9, the beam from the blue gun can "see" only blue phosphor dots in any group. Similarly, at 2, the green gun sees only green dots, and as at 3 the red gun sees only red dots. Red, blue, and green images are formed at the same time, and blend into full-color pictures during reception of color broadcasts.

Screens of color picture tubes are aluminized or metallized. This improves brilliance and contrast, while preventing formation of ion spots without need for an ion trap or trap magnet.

Principal structural elements of a CBS-Colortron are illustrated by Fig. 10. The three electron guns are built as a unit, located in the tube neck near the base. The guns are equally spaced, at 120-degree intervals, with each gun inclined slightly toward the central axis of the tube.

About 0.4 inch behind the phosphor dot screen on the face plate is the curved aperture mask which is held in position by spring clips. Three V-shaped surfaces or V-blocks on the mask rest on three hemispheres, which are raised points of glass molded around the edge of the face plate, outside the picture area.

A graphite coating on the interior of the glass funnel or flare extends down into the neck of the tube and over the forward element of the gun assembly. The rear edge of glass face plate member and the edge at the front of the funnel are welded during manufacture, with between them a metal flange which is the external terminal or connection for the high-voltage anode.

FOCUSING. Electrostatic focusing is employed in three-gun color picture tubes. Grid number 3 in each electron gun is the focusing electrode. It is necessary to provide a focusing lens in each individual gun because the three guns are off center with respect to the tube axis; none of them lie exactly on the axis as would be the case with

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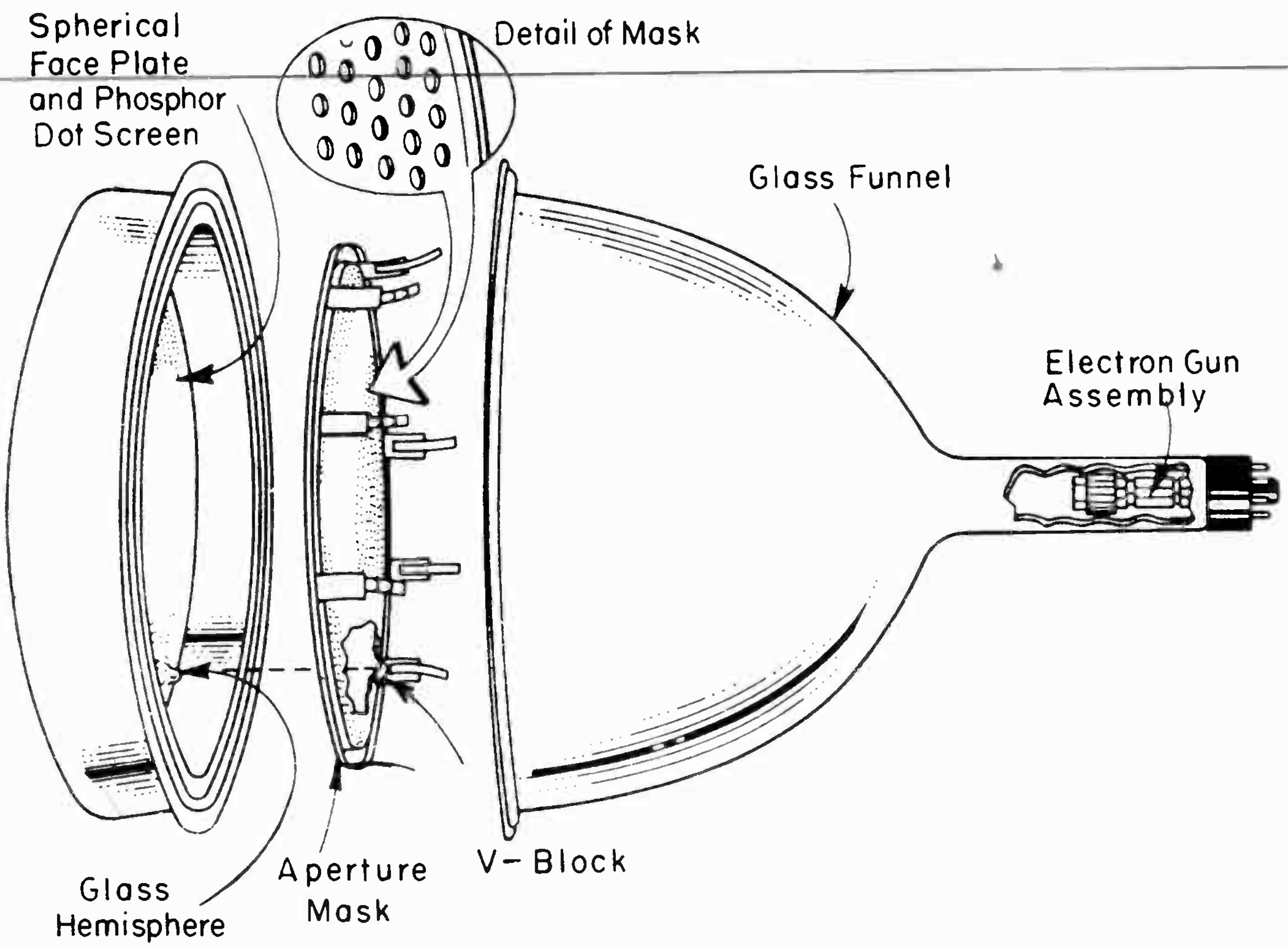

Fig. 10. The phosphor dot screen is on the face plate, with the aperture mask supported just back of the face plate in this CBS-Colortron tube.

only one gun. The three focusing grids are, however, tied together and to them is applied a single focusing voltage. The value of focusing voltage depends on the type of model of tube, ranging from about 2.5 kv to as much as 8 kv.

In a black-and-white picture tube moderately poor focusing at some places on the screen causes some fuzziness at those places, but the effect usually is not too objectionable. In a color picture tube the focused beam must hit within each single phosphor dot, whose diameter may be no more than 0.015 inch, and must do this everywhere on the screen. Poor focusing anywhere will allow the beam to spread and become larger than a phosphor dot. Then, where only a single primary color should appear, there will be other colors from adjacent dots.

Supposing the beam at A in Fig. 11 is properly focused at the center of the screen, then is deflected to B. If distance from the electron gun to point of sharpest focus remains unchanged, this point will lie behind the screen when the beam is deflected at B, and at the phosphor dot screen will be an enlarged electron spot.

Focusing of the beam at the center of the mask, or with the beam not deflected, may be called static (stationary) focusing. To maintain good focus at points away from the center, with the beam deflected, it is necessary to vary the focusing voltage proportionately to the amount of deflection. This variation of focusing voltage is called dynamic (moving) focus.

A constant or unvarying d-c voltage adjusted to suitable value is sufficient for static

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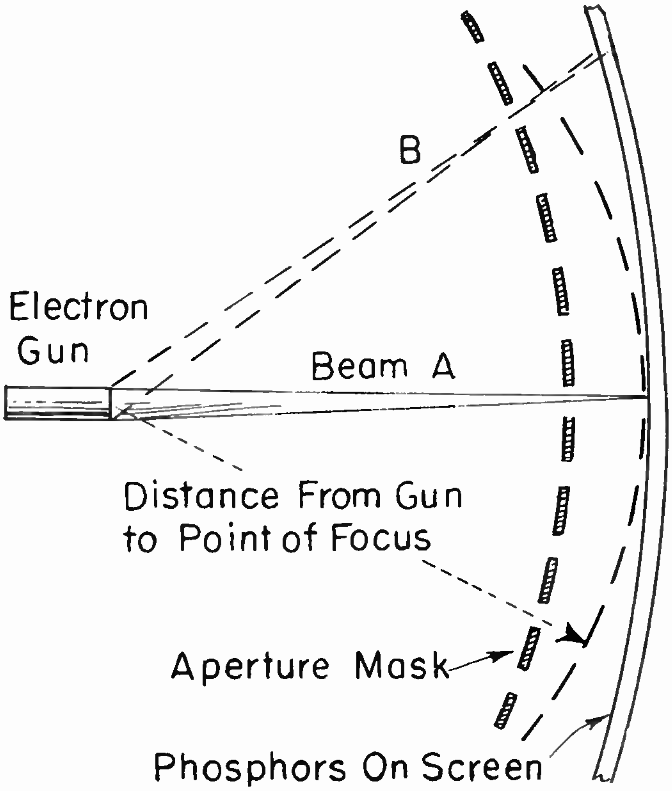

Fig. 11. Correct focusing at the center of the screen would not be maintained elsewhere without dynamic correction.

focusing. But this voltage must be varied proportionately to beam deflection, both horizontally and vertically, for dynamic focusing.

One of many possible methods for providing horizontal and vertical dynamic focusing voltage is illustrated by Fig. 12. To begin with, voltage for static focus is obtained from a focus rectifier operated from the flyback transformer in much the same way that a high-voltage rectifier for anode voltage would be operated. To the positive output of the focus rectifier is connected a voltage divider which may be adjusted to give satisfactory static focus at the center of the picture tube screen.

To the static focus voltage, which is pure d-c, are added through capacitor Cf two varying voltages for dynamic focusing. Horizontal dynamic focusing voltage originates at the cathode circuit of the horizontal output tube or horizontal sweep amplifier, and is taken through a horizontal dynamic adjustment to the grid of a horizontal amplifier. The plate of this amplifier feeds into the primary of a "dynamic" transformer, in whose secondary circuit is capacitor Cf.

Vertical dynamic focusing voltage originates at the vertical output amplifier or vertical sweep amplifier. The primary of the vertical output transformer is in series with the primary of another transformer whose secondary feeds to the grid of a vertical amplifier. Output of this vertical amplifier goes to the dynamic transformer winding that is connected to capacitor Cf. Combined static and dynamic focusing voltage is thus applied to the third grids of the picture tube.

CONVERGENCE. Focusing is not the only problem is obtaining necessary registration of electron beams and phosphor dots in tubes using aperture masks or shadow masks. Fully as important, and even more difficult, is the matter of obtaining correct convergence. Convergence refers to meeting of the three beams from the three electron guns at any single opening in the aperture mask. From Fig. 8 it is plainly evident that, unless the beams meet and cross one another at mask openings, the beams won't "diverge" beyond the mask to strike the proper phosphor dots.

There is a difficulty in convergence quite similar to that encountered in focusing of the beams when they are deflected. Referring to Fig. 13, if the three beams are directed at such angles that they converge properly at the center of the mask, A, and if distances from the guns to the point of convergence remains unchanged when the beams are deflected, as to B, convergence will not occur at the mask, but back of it. The arc followed by the point of convergence is not the same as that of a section through the mask. We need static convergence at the center of the mask, and dynamic convergence at places away from the center.

The three beams may be converged for both static and dynamic conditions by either of two methods. With one method, convergence voltages are applied to a convergence electrode within the picture tube. The other method utilizes magnetic fields produced by electromagnets around the outside of the tube neck. Some color picture tubes are designed

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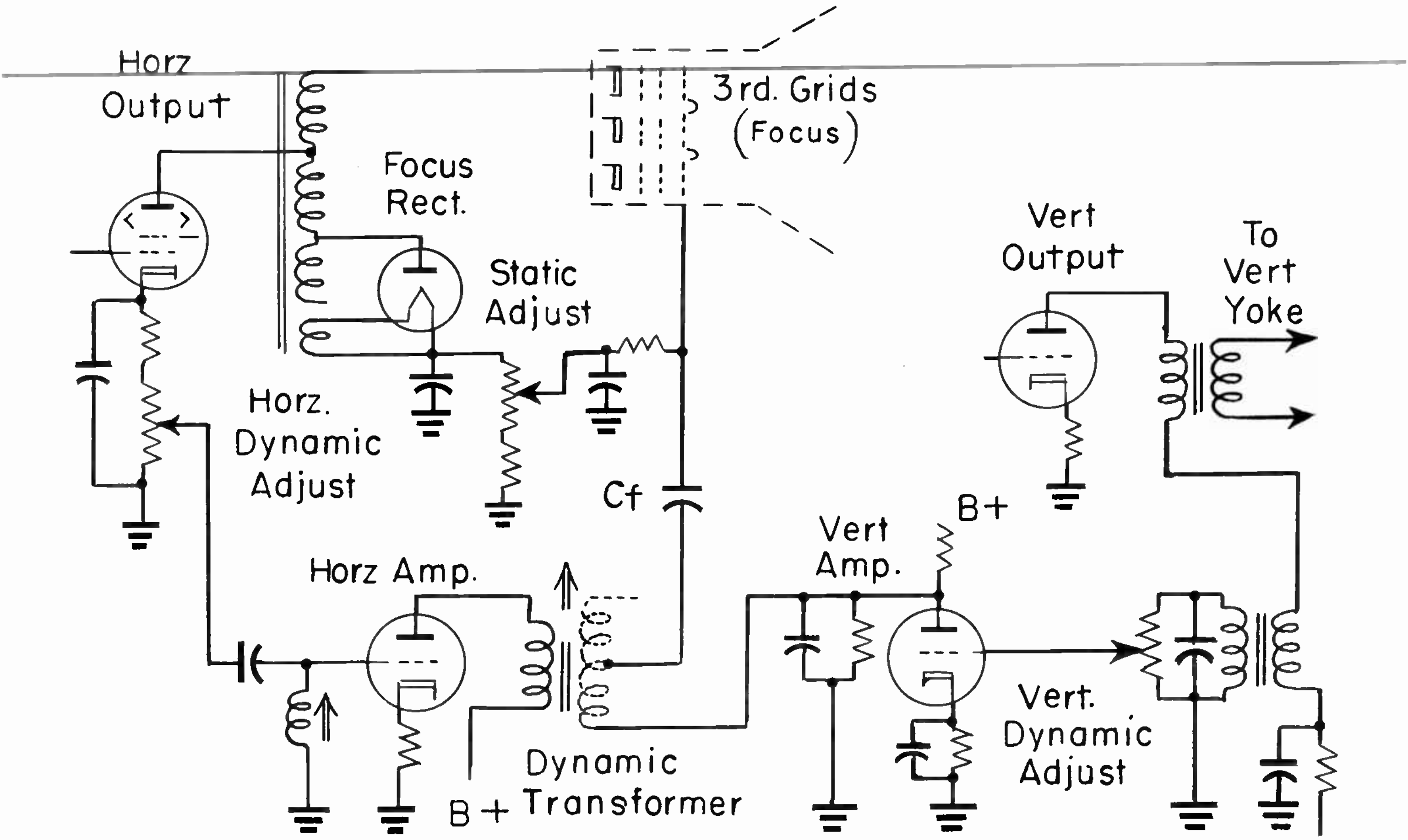

Fig. 12. Circuits for obtaining dynamic focusing and dynamic convergence voltages.

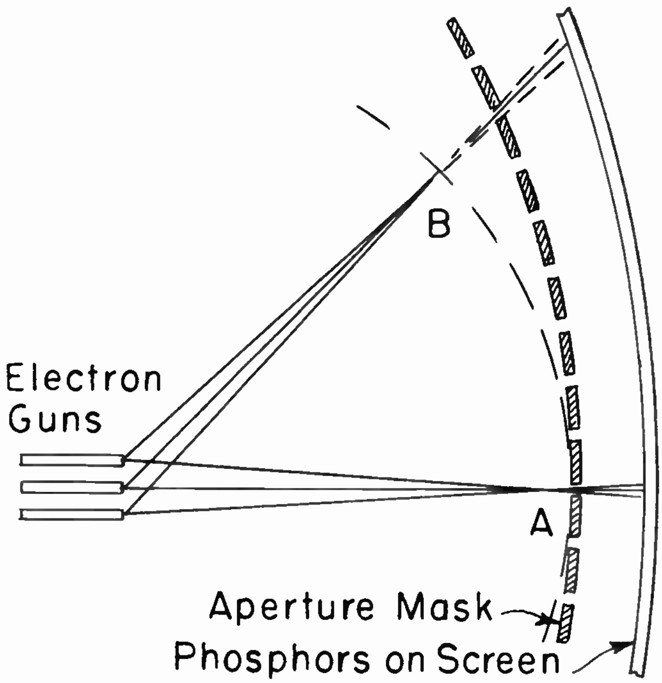

Fig. 13. Without dynamic correction, the beams which converge properly at the center of the mask would not do so when there is deflection.

for electric (voltage) convergence, others for magnetic or electomagnetic convergence.

To provide dynamic convergence with the electric or electrostatic method it is necessary to vary convergence voltage proportionately to deflection of the beams. For dynamic convergence with the magnetic system, currents in the convergence electromagnets must be varied proportionately to beam deflection.

ELECTROSTATIC CONVERGENCE. For electric or electrostatic convergence the picture tube contains a convergence electrode, grid 4, which is a large cylinder just ahead of the three electron guns. There is only one convergence electrode for the entire tube, not one for each gun.

Were electrostatic convergence to be used in connection with the electrostatic focusing of Fig. 12, it might be done by adding to that earlier circuit the parts shown in

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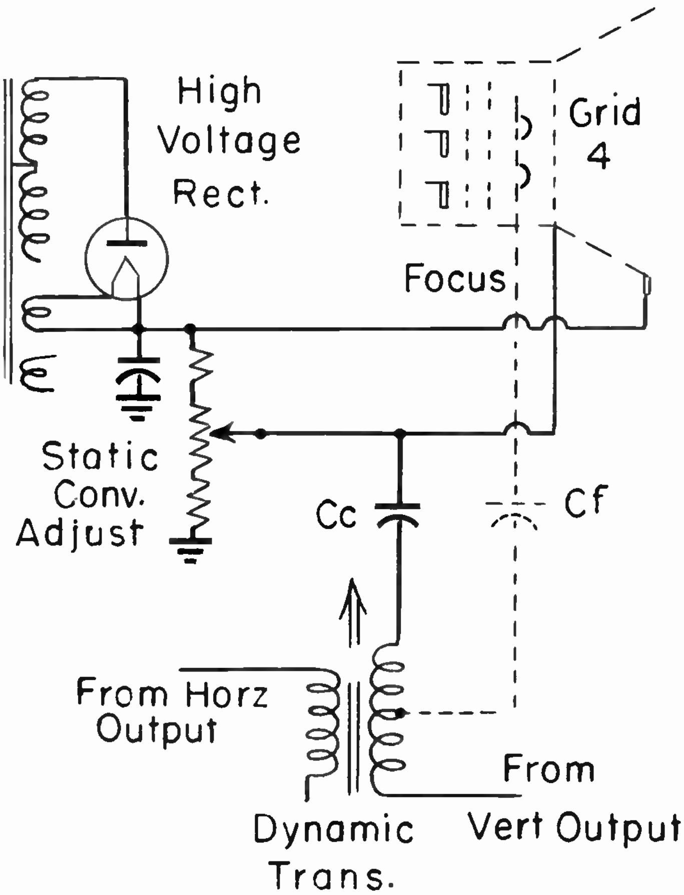

Fig. 14. Addition of these elements to the circuit of Fig. 12 provides static and dynamic electric convergence voltages.

Fig. 14. Static convergence voltage of about 8.5 to 10 kv is taken from a voltage divider or bleeder on the high voltage rectifier that furnishes second-anode or ultor voltage for the picture tube. There is adjustment on the bleeder system for static convergence voltage.

To the static convergence voltage are added varying voltages for horizontal and vertical dynamic convergence. These added voltages are brought through capacitor Cc from the same dynamic transformer that furnishes dynamic focusing voltages, but from the higher tap which was not connected in Fig. 12. The horizontal dynamic adjustment shown on the cathode of the horizontal output tube in Fig. 12 is for horizontal dynamic convergence. The vertical dynamic adjustment of Fig. 12 is for vertical dynamic convergence. These adjustments have principal effect on convergence, but make corrections for focusing at the same time.

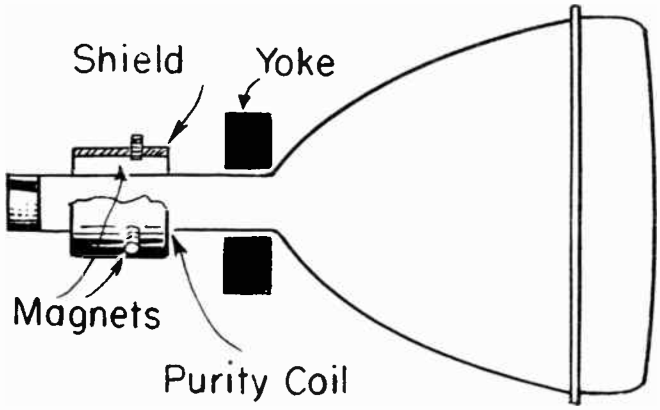

Fig. 15. Beam positioning magnets are on a shield which encloses a purity coil around the neck of this picture tube.

Around the neck of a picture tube built for electrostatic convergence, near the base, is a cylindrical magnetic shield of mu-metal or something similar. Into this shield thread three small permanent magnets as shown by Fig. 15. These are beam positioning magnets that allow making individual adjustment of each electron beam for proper convergence at the center of the aperture mask and phosphor screen.

The beam positioning magnets are equally spaced around the tube neck, so that each matches the position of one electron gun. Moving these magnets will shift the beams in directions at right angles to the shift caused by varying the convergence voltage. Reversing the magnets end for end in their threaded openings reverses the direction in which they shift the beams. Placing of the magnets is part of the process of static convergence adjustment.

Sometimes it is necessary to slightly modify the beam deflection as caused by the yoke, in order to have proper convergence at corners and edges of the raster. This may be done with small "tabs" of mu-metal inserted at the front of the yoke.

MAGNETIC CONVERGENCE. Around the neck of the picture tube in Fig. 16, just back of the yoke, are supported three electromagnetic coil assemblies used for magnetic convergence. In the electron gun assembly, within the neck, are three sets of pole pieces mounted above the anode. Fields from the

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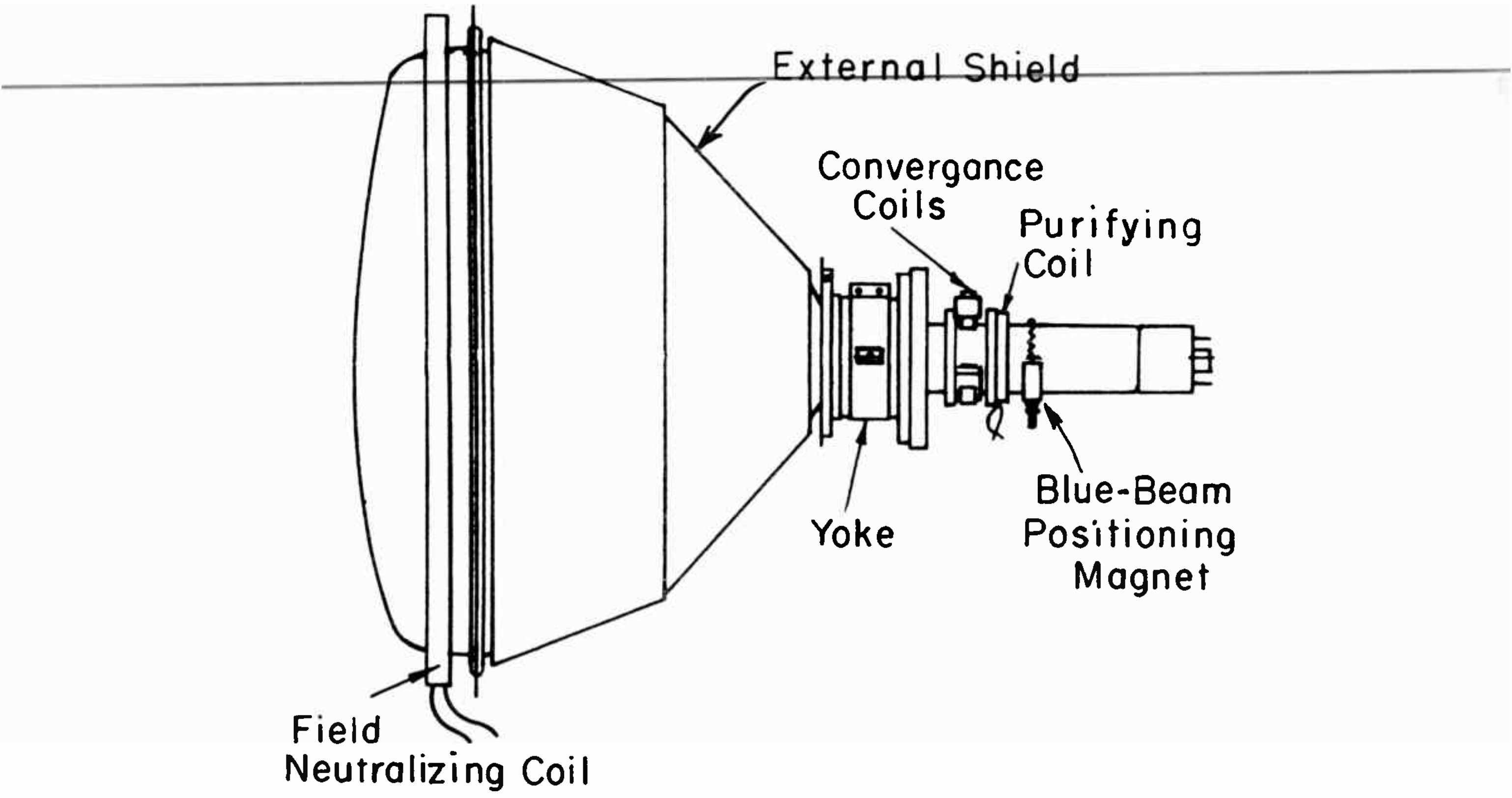

Fig. 16. Locations of various "accessories" on the neck and face plate member of a CBS-Colortron.

external electromagnets induce fields in the internal pole pieces.

The three convergence coils are equally spaced around the tube neck, as are the three electron guns on the inside. Each of the three magnetic fields acts on the electron beam from one gun to properly converge that beam. There is one electromagnetic assembly for the red gun, a second for the green gun, and a third for the blue gun.

In each electromagnet assembly are two windings, one for horizontal convergence and the other for vertical convergence. The horizontal convergence windings are marked A in Fig. 17, and vertical convergence windings are marked B. This is a diagram of circuits suggested by CBS-Hytron for obtaining horizontal and vertical dynamic convergence currents for the three electromagnets. Circuit connections leading into the convergence coil windings are similar across the top, center, and bottom of the diagram. One group of connections would be for convergence of the "red" beam, another for the "green" beam, and the third for the "blue" beam.

Horizontal dynamic convergence current is derived from voltage pulses which come from the horizontal output or flyback transformer through the lead at the left that goes to three horizontal convergence adjustments, one for each beam. Vertical dynamic convergence current is derived initially from the cathode circuit of the vertical output or vertical sweep amplifier. After one stage of amplification the vertical waveform goes to three vertical convergence adjustments, one for each beam. The vertical convergence waveform goes then through three separate amplifiers and coupling transformers to the vertical windings of the three convergence coils.

The field of each electromagnet will move the corresponding electron beam radially, outward or inward, with respect to the common axis of the three beams. Extent of this movement depends on settings of horizontal and vertical convergence adjustments, such as those in Fig. 17.

For any required correction of static convergence, small additional d-c magnetic

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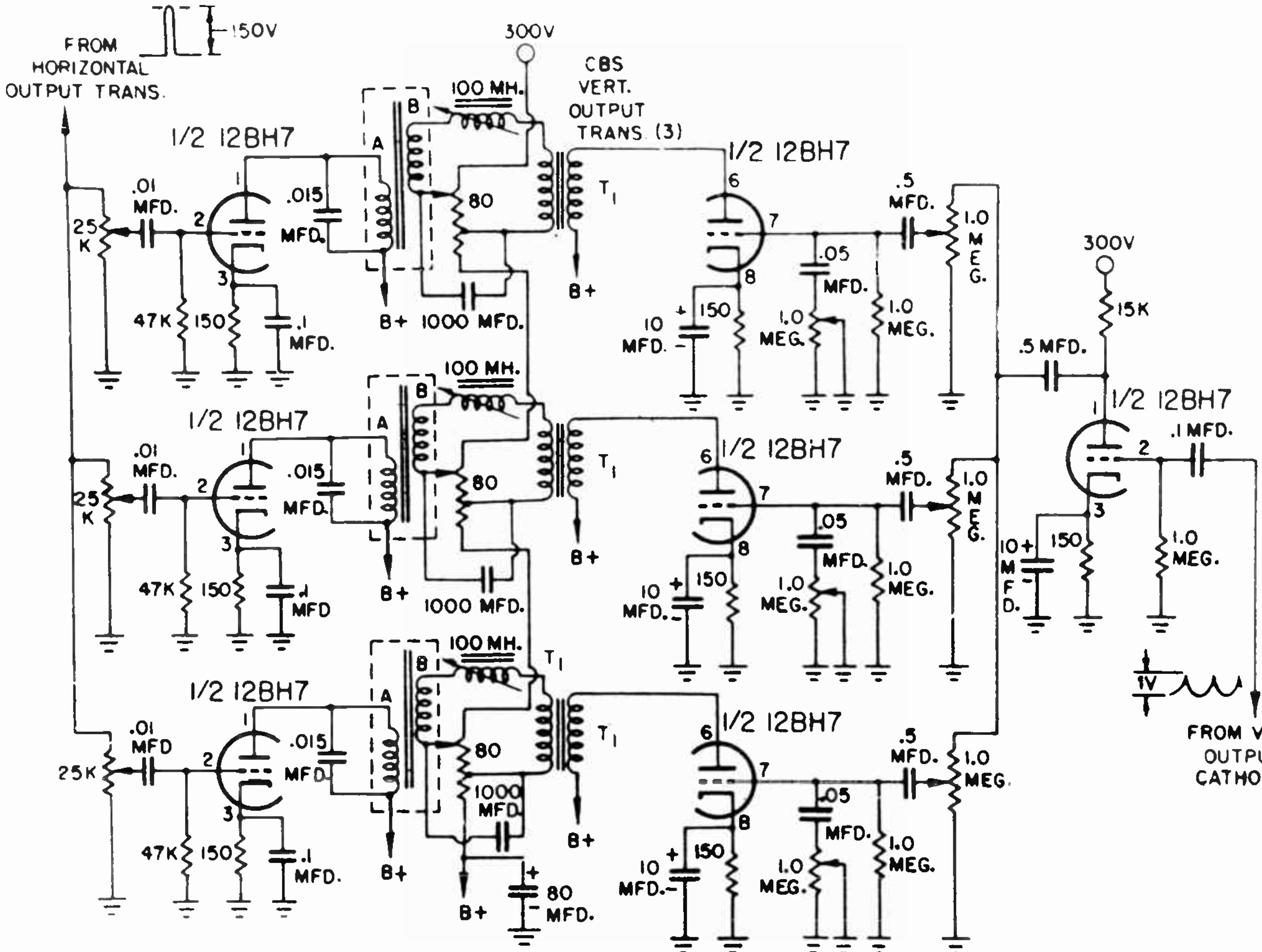

Fig. 17. Circuits for obtaining horizontal and vertical dynamic convergence currents.

fields may be induced in the electromagnets and pole pieces. The principle is the same as used for centering by means of small d-c currents and fields in the yoke, which are in addition to the alternating deflection fields.

If d-c magnetic fields added in the three convergence electromagnets do not allow enough radial adjustment for static convergence at the center of the screen, additional adjustment is provided by the blue-beam positioning magnet shown on Fig. 16. This is a permanent magnet that may be moved to shift the beam from the blue gun with respect to the central axis. The position of this magnet, and its polarity, determine the amount of correction applied.

PURITY CONTROLS. Closely related to adjustments for convergence, and actually part of the entire system for properly converging the electron beams, is a purifying coil or purity coil whose location on a tube having magnetic convergence is shown by Fig. 16. On the tube of Fig. 15, which has electrostatic convergence, a purity coil is located within the cylindrical mu-metal shield, and around the outside of the neck. A purifying or purity coil carries direct current, and produces a magnetic field at right angles to or perpendicular to the axis of the picture tube.

The magnetic field of the purifying coil acts on all three electron beams at the same time. Rotating the coil around the neck of the tube, or moving the coil toward or away from the base, and varying the coil current, shifts the electron beams so that each strikes the center of a phosphor dot and strikes only one dot at a time when the beams are focused and converged, then deflected.

Purity adjustment allows shifting the beams enough, when at the center of the

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screen, to make their common axis coincide with or come into exact alignment with the axis of the tube. Then the beams will reach openings in the aperture mask at angles which insure striking the phosphor dots correctly. The result is best possible color purity, which means production of each primary color without contamination by the other primaries.

Current for a purifying coil is obtained from one of the B-voltage lines in the receiver. This current is varied by an adjustable resistor in much the same way as are d-c currents for centering in yoke coils.

FIELD NEUTRALIZING COIL. Around the outside of the front face of the picture tube in Fig. 16 is shown a field neutralizing coil, sometimes called a rim coil. This coil carries direct current. It furnishes a steady magnetic field that neutralizes or balances the effects on electron beams of any stray fields around the tube, including the magnetic field of the earth as well as fields from other components on the chassis. Such external fields may affect both focus and convergence.

Current for the field neutralizing coil is taken from a B-voltage line, usually through a tapped potentiometer whose adjustment controls not only strength of the neutralizing field but also its direction or polarity as may be required. Such a potentiometer control acts similarly to those used for centering by means of direct current in a deflection yoke. The field neutralizing coil is not used in all color receivers.

PICTURE TUBE SHIELDING. Color picture tubes are protected against effects of external fields by means of shields made of mu-metal or something equivalent, almost completely enclosing the funnel or flare of the tube. Such shielding is shown by Fig. 16. In addition, the cylindrical shield around the outside of the purity coil in Fig. 15, the shield that carries the beam positioning magnets, protects the electron beams while they are moving at relatively low velocity through the neck of the picture tube.

On the outside of the glass funnel or flare of color picture tubes is a conductive

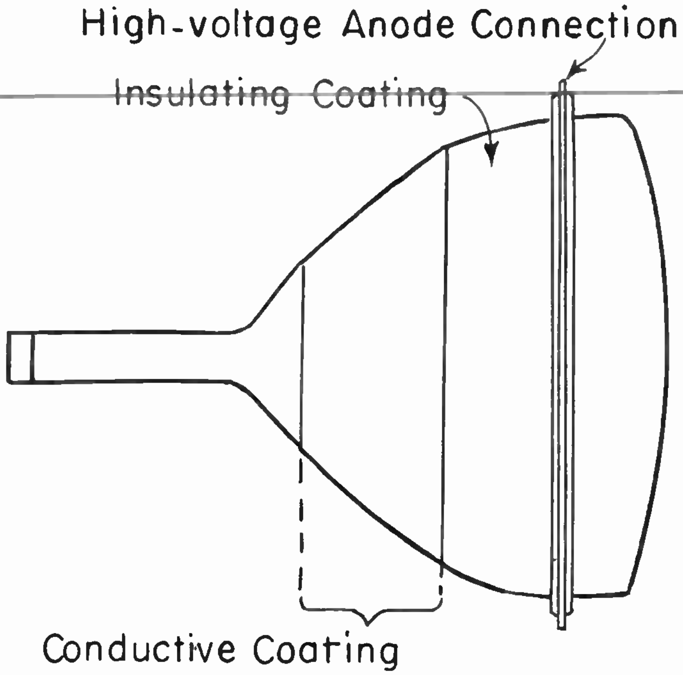

Fig. 18. Conductive and insulating coatings on a color picture tube.

coating in the approximate position shown in Fig. 18. Ahead of this, toward the face plate, is an insulating coating. The high-voltage connection for the second anode or ultor is made to a metal rim or flange at the seal or weld between face plate and funnel.

TUBE BASING CONNECTIONS. At A of Fig. 19 are shown basing connections of the 19VP22 color picture tube, which is the RETMA type number of the CBS-Colortron "205" tube. This is a size usually called 19-inch. At B are basing connections for the 15GP22 (RCA) and the 15H22 (CBS) 15-inch color picture tubes.

On the 19-inch tube is a base with positions for 14 pins, but there are no pins at positions 8 and 10. On the base of the 15-inch tube are positions for 20 pins, but no pins are at positions 10, 11, 12, or at 14, 15, and 16. On the 19-inch tube pin 9 connects to grids 3, which are the focusing grids. This tube is designed for magnetic convergence. On the 15-inch tube pin 6 is connected to grids 3, the focusing grids, and a connection goes from pin 13 to grid 4, which is the electrostatic convergence electrode.

On both tube types are three pins for cathode, control grid, and screen grid in the

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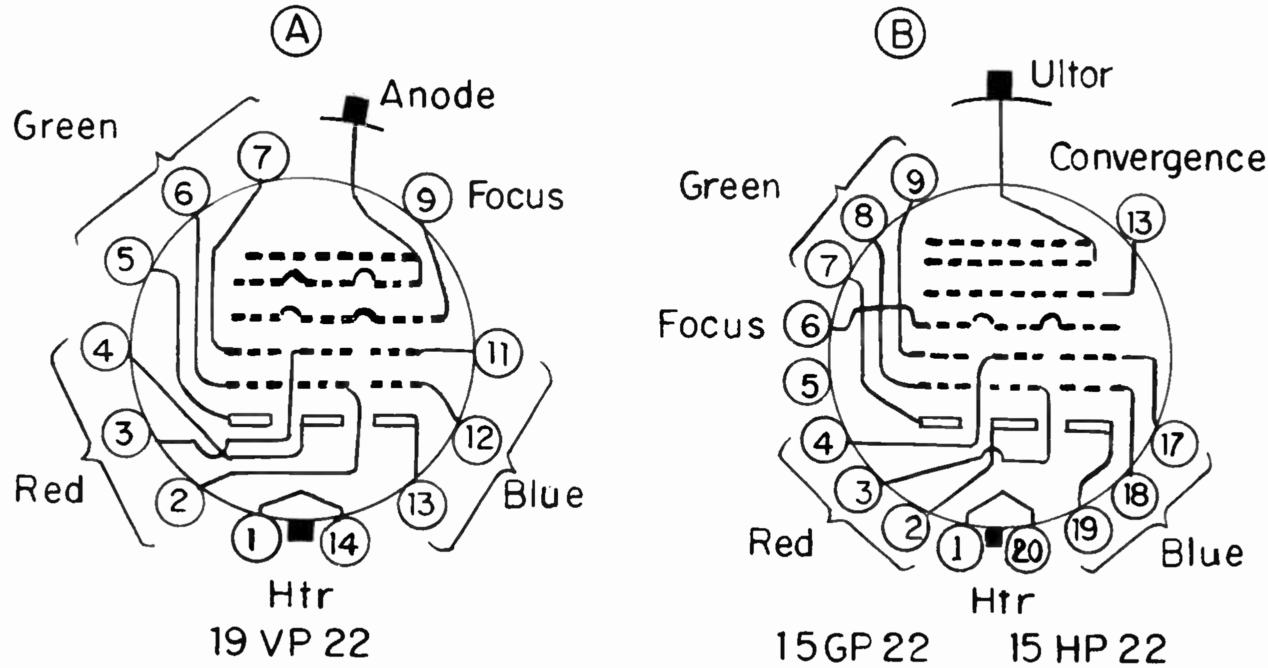

Fig. 19. Basing connections of color picture tubes.

red gun, three other pins for these elements in the green gun, and another group of three pins for cathode, grid, and screen in the blue gun. The high-voltage anode or ultor in both tubes goes to the metal flange back of the face plate.

Fig. 20 shows at A the relative positions of the three electron guns, the base pins, the central locating key, and vertical and horizontal center lines of the phosphor screen for the 19VP22 color picture tube. This view would be when looking toward the base of the tube, from the rear. Relative positions of all these parts are shown at B for the 15GP22 and 15HP22 color picture tube, again in relation to vertical and horizontal center lines of the phosphor dot screens.

COLOR BALANCE. We have examined numerous service adjustments at demodulators, phase splitters, matrixes, and color amplifiers. These adjustments relate chiefly to production of correct red, green, and blue signal voltages. There is, however, still another adjustment or set of adjustments used for balancing the intensities of color illumination from the three kinds of phos-

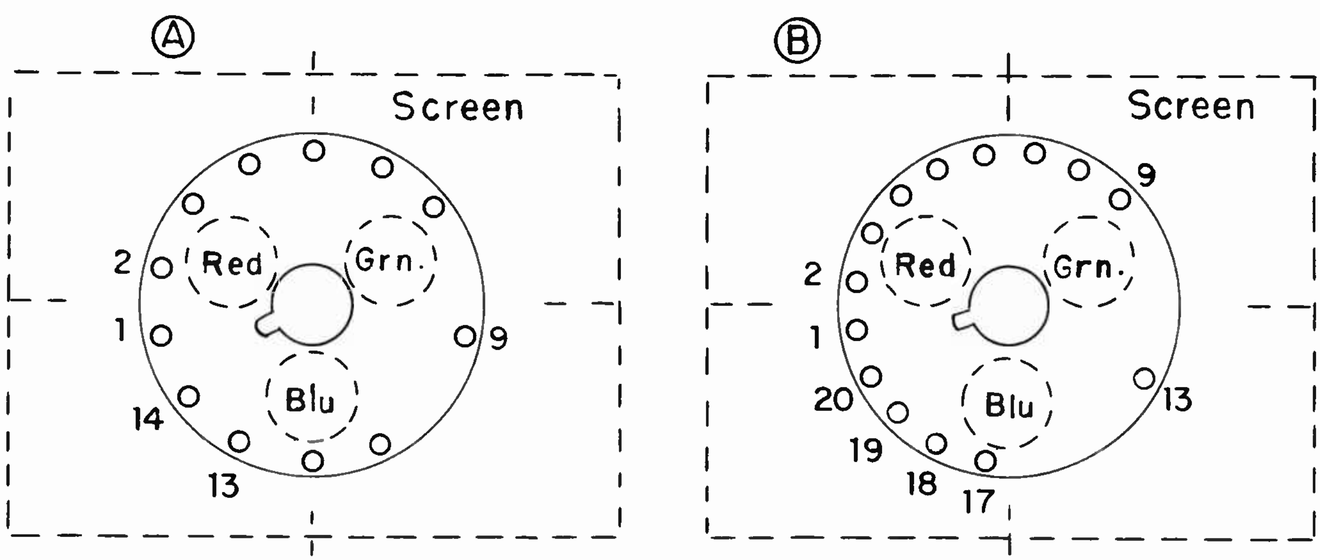

Fig. 20. Positions of electron guns and base pins in relation to viewing screens.

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phors in the color picture tube. This is done by adjusting the voltages applied to second grids or screen grids in the three electron guns.

Balancing is needed because differences in light outputs of the three kinds of phosphor materials, even with equal grid biases, could cause the appearance of colors during monochrome reception, when pictures or rasters should show only white and tones of gray.

There are individual controls for voltages on the three screen grids. These grids are not internally connected together, but go to separate base pins. Screen grid potential with references to cathodes usually is in the neighborhood of 200 volts, as an average, but is adjustable from less than 100 volts to slightly more than 300 volts.

BRIGHTNESS CONTROL. When all three grids of all three cathodes of a three-gun picture tube are connected together, as in

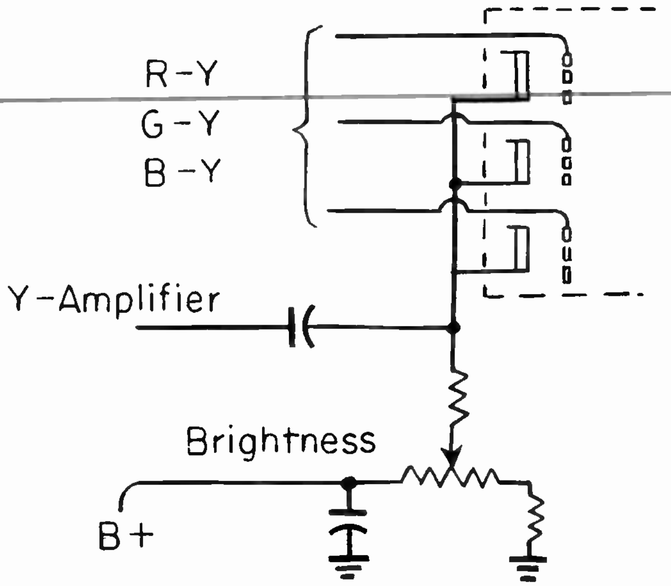

Fig. 21. Brightness control on the cathodes of a three-gun picture tube.

many receivers employing R-Y and B-Y demodulation, the brightness control may connect to the joined elements in the same general manner as for monochrome receiv-

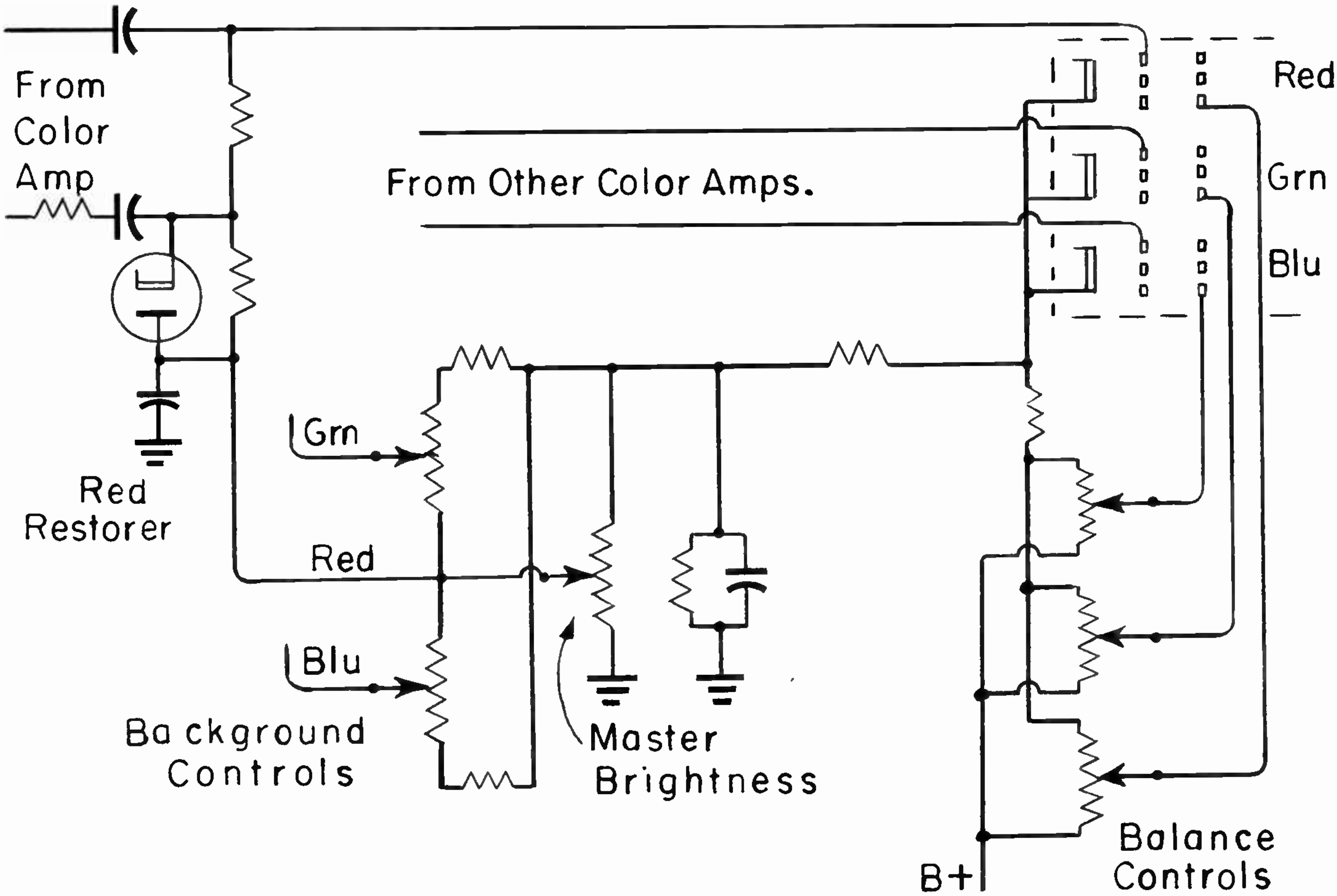

Fig. 22. Brightness and background controls, also color balance controls.

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ers. One such arrangement is illustrated by Fig. 21.

Fig. 22 shows connections for brightness controls and color balance controls as used in several receivers having d-c restorers on the outputs of each color amplifier. The three color balance controls are adjustable, for applying suitable positive B-voltages to the three cathodes, thus making the grids relatively negative to the cathodes in various degrees.

Connected between cathodes and control grids of the picture tube is one master brightness control, which usually is a front panel control for the operator. There are also green background and blue background controls. Three d-c restorer diodes are used, although only one is shown. Connections to the other two are similar. The master control regulates overall brightness. The green and blue background controls are adjusted to prevent appearance of colors during reception of black-and-white transmissions.

HIGH VOLTAGE POWER SUPPLIES. High voltage for anodes or ultors of color picture tubes is obtained from flyback systems operating on the same principles as in monochrome receivers. Horizontal output transformers are larger than in monochrome sets because of higher voltages, a greater number of voltages and windings, and greater currents in three-gun color picture tubes.

Any failure of vertical or horizontal deflection, leaving a line trace or a concentrated spot, could permanently damage both the phosphor screen and the aperture mask in the tube. This is guarded against in various ways. One method is to take voltages for second grids or screen grids in the picture tube from a boosted B-voltage circuit which is active only while the horizontal deflection is operating to maintain the electron beam in motion.

Changes of high voltage, such as often accompany fluctuations of power line voltage to monochrome receivers, make pictures slightly larger or smaller. This does no particular harm. But in a three-gun color tube there are openings in the aperture mask to consider, and any considerable change of high voltage and picture size will throw the beams out of registry with mask openings.

Changes of average picture brightness during progress of a color program tend to alter high voltages. This is because anode current in color picture tubes is much greater than in monochrome picture tubes, and variation of this current with brightness varies the voltage drops in rectifiers, bleeders, and voltage dividers. For all these reasons it is common practice to provide automatic regulation in the high-voltage supply.

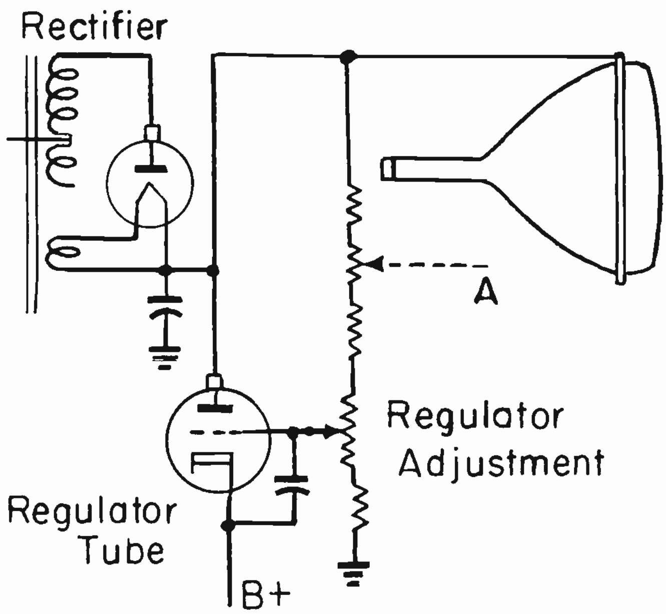

Fig. 23. Automatic regulation on a high-voltage power supply.

A method often used for high-voltage regulation is shown by Fig. 23. The regulator tube is a triode, with its plate cap connected to the high-voltage lead for the picture tube anode. The cathode of the regulator tube goes to a B-plus line furnishing 400 to 500 volts. The grid goes to the slider of an adjustable potentiometer which is part of a voltage divider string connected between the high-voltage line and ground or B-minus.

The regulator adjustment is at such an electrical position in the voltage divider string as to maintain the grid of the regulator tube more or less negative in relation to its cathode.

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When picture tube anode voltage tends to increase as less current is taken by the anode, more current flows in the divider string, and voltage on the regulator grid tends to become more positive, or actually less negative with respect to the cathode. This decreases plate-cathode resistance in the regulator tube, which then takes more current and increases the load on the high-voltage rectifier to pull high voltage down to normal.

Should anode voltage tend to decrease, with more anode current for brighter pictures, the regulator tube takes less current from the high voltage rectifier, and anode voltage is held close to its normal value. An additional regulated voltage may be taken from another control at A in Fig. 23, provided current at this other tap is negligible, as would be the case for an electrostatic convergence electrode.

In a 6BD4-A voltage regulator tube, with normal 25 kv on its plate, current through this tube would vary from about 1500 microamperes with the grid $7\frac{1}{2}$ volts negative to about 200 microamperes with the grid 15 volts negative. The regulator adjustment is set during servicing so that voltage at the picture tube anode or ultor shows no appreciable change when brightness is varied from maximum to minimum.

Anode or ultor voltages on color picture tubes may be between 20 kv and 25 kv, or even higher. Because high-voltage power supplies are designed for larger currents and better voltage regulation than in black-and-white receivers, these voltages may be really dangerous. Make measurements only with a high quality probe designed for 30 kv or more, with long leakage paths, good barriers, and preferably with a grounded cable shield and grounded arc baffle. Never make spark tests, or tests with a neon bulb, on color picture tubes.

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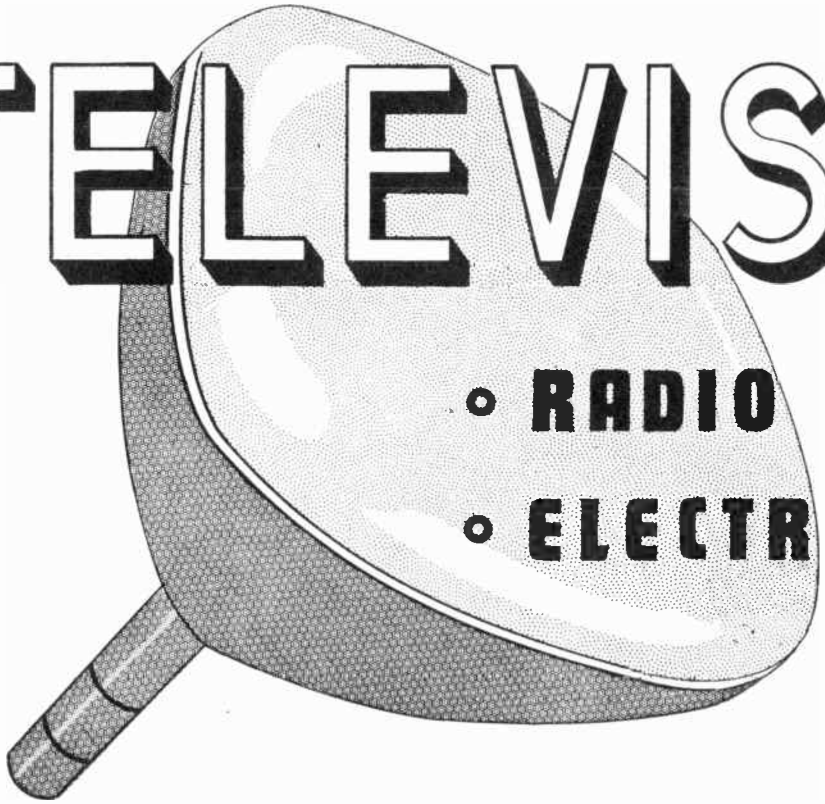
TELEVISION



LESSON 100 — COLOR TELEVISION — PART FIVE

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practical home training

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Lesson 100

COLOR TELEVISION — PART FIVE

Fig. 1. A Chromatron color picture tube in which is a single electron gun.

In a receiver having a color picture tube with a single electron gun, instead of the three guns with which we have become familiar, there are major changes in all circuits beyond the color amplifiers, or beyond the demodulators when no color amplifiers are used. The single-gun tube whose performance is to be explained is the Chromatron, a development of Chromatic Television Laboratories, which is an affiliate of Paramount Pictures. It is called also the Lawrence color tube because it was originated by Professor Lawrence of the University of California.

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A Chromatron picture tube is illustrated by Fig. 1. It appears much like a rectangular monochrome picture tube except for features near the face. The neck is of the same size, and five base pins, numbers 1, 2, 10, 11, and 12, are for the same elements as in a monochrome tube. The shell is metal, and the high-voltage anode connection is at a metal flange near the face. A magnetic deflection yoke and magnetic focusing coil, similar to those for monochrome tubes, mount around the tube neck. Tilt of the focus coil is adjustable, as an auxiliary centering control in addition to electric centering by yoke currents.

In addition to having only one electron gun, the differences between this and other color tubes are chiefly in the phosphor screen and a color grid structure mounted within the tube just back of the glass face. These are shown, somewhat simplified, by Fig. 2.

Color phosphors on the viewing screen are in the form of horizontal strips, each about 1/100 inch wide and extending all the way across. The order of the phosphor strips is red-green-blue-green-red-green, and so on all the way from top to bottom. Red and blue strips alternate with each other, but always there is a green strip in between them.

Any three adjacent phosphor strips extend vertically over a distance of about 3/100 inch, so that on each vertical inch of viewing screen there are about 33 complete color groups. Each complete color group is of about the width of a horizontal trace line on a 21-inch monochrome picture tube.

About 1/3 inch behind the phosphor screen is the color grid structure. This grid consists of a great number of horizontal wires, each about 6/1000 inch in diameter, separated by spaces. Every alternate grid wire is almost directly back of a red phos-

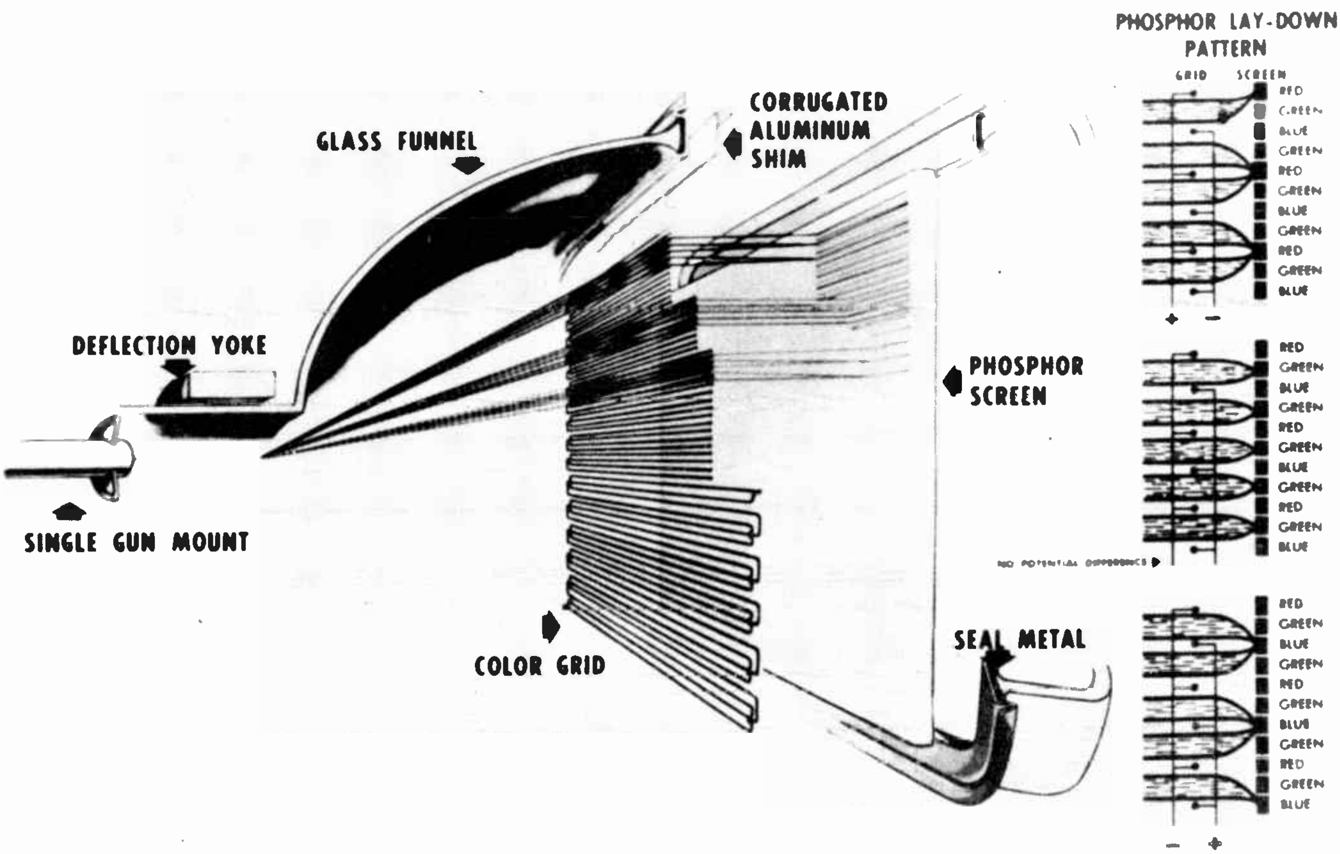

Fig. 2. How the electron beam is deflected and focused in the single-gun picture tube.

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phor strip, and the wires in between are almost directly back of the blue strips. All red grid wires back of red phosphor strips are connected together at their outer ends and to one external terminal just back of the face plate. All wires back of blue phosphor strips are connected together at their ends, and to a second external terminal. These connections are illustrated at A of Fig. 3.

The precise positions of color grid wires with respect to phosphor strips are such as to maintain focusing of the electron beam onto the strips as the beam is deflected. Deflection angles somewhat in excess of 70 degrees may be used.

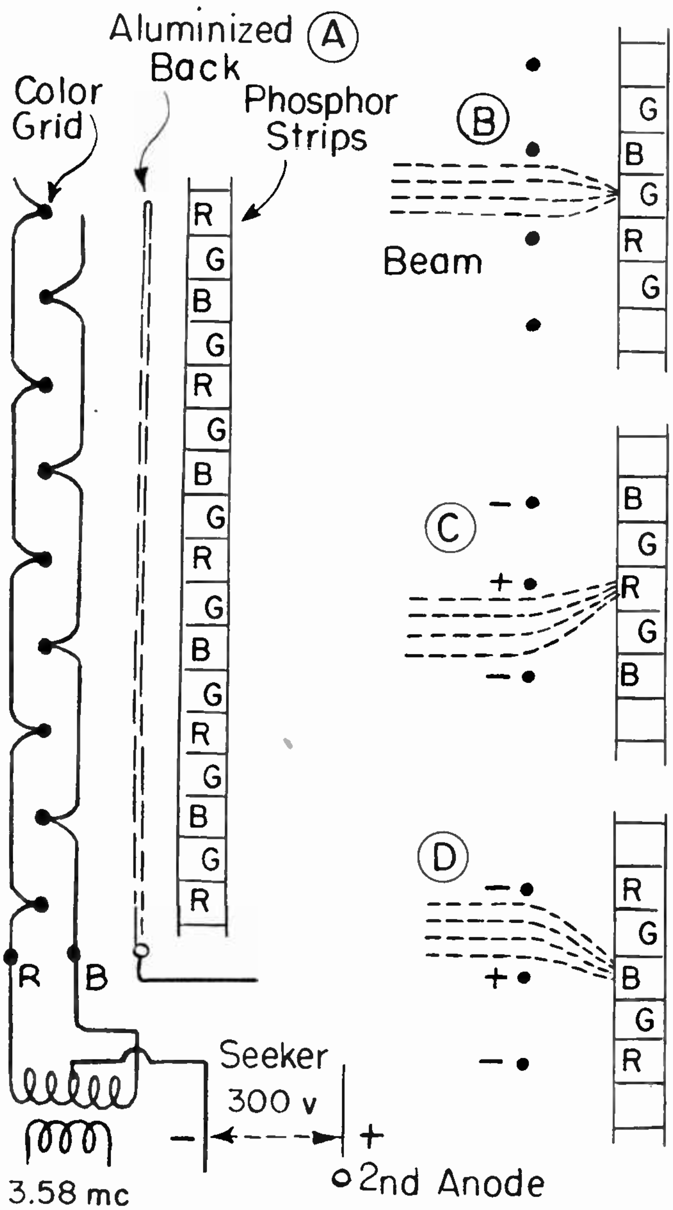

Fig. 3. The color grid and how it acts on the electron beam.

On the back of the phosphor screen is a conductive aluminized coating connected to a recessed cap terminal on the forward end of the flare. This aluminized coating makes an ion trap and magnet unnecessary, as on other color picture tubes, since ions are caught by the backing before they can reach the phosphors.

Between the aluminum backing and the grid wires considered as a unit assembly is applied a d-c potential difference of 12,000 to 14,000 volts. This potential difference forms an electrostatic lens which, while no other potential is applied to the grid, focuses the electron beam sharply onto green phosphor strips that lie midway between grid wires. This is illustrated at B of Fig. 3. No matter on what part of the screen the beam is tracing horizontal lines, electrons are thus focused onto green phosphor strips.

To the primary of the transformer in diagram A of Fig. 3 is applied an alternating voltage at 3.58 mc, derived from the color oscillator circuit of the receiver. Induced voltage at this frequency appears in the secondary winding, whose outer ends are connected to the two sets of color grid wires. The center tap on the secondary allows maintaining a d-c potential difference of 300 volts between the color grid assembly and the second anode in the picture tube. This is called the seeker voltage.

While one end of the transformer secondary goes positive the other end goes negative with reference to their average potential. Consequently, during one half-cycle of 3.58-mc voltage the red grid wires are made positive and the green wires are made negative. On intervening half-cycles the red wires are made negative while the green ones are made positive.

While grid wires back of red phosphor strips are positive the electron beam is focused onto the red strips, as at C of Fig. 3. While grid wires back of blue strips are positive the beam is focused onto blue strips, as at D. Sharp focusing is maintained by the high voltage between the color grid assembly

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and the backing on the phosphor screen no matter onto which of the phosphor strips the beam is directed. This is called post-deflection focusing, abbreviated PDF.

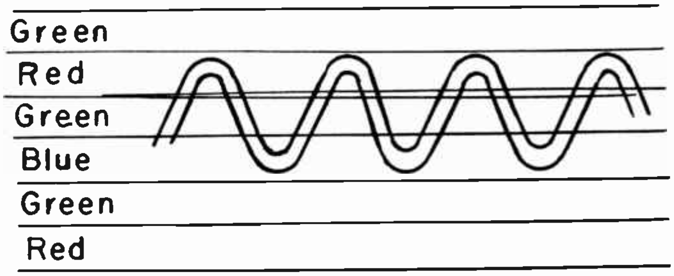

Fig. 4. The beam follows a sine-wave path over the three color phosphors.

The electron beam is deflected horizontally and vertically by magnetic fields of the yoke, just as in any picture tube. While the beam travels horizontally across one trace line the alternating 3.58-mc voltage on the sets of color grid wires causes the beam to follow a sine-wave path, as shown by Fig. 4.

During each cycle of 3.58-mc voltage applied to the grid wires the beam moves upward over phosphor strips of three colors, then downward over the three colors. The phosphors are excited in such rapid succession that persistence of the phosphors and persistence of vision make all three primary colors appear simultaneously.

Which color is produced at any instant depends only on relative potentials on the two sets of grid wires. Colors are not affected by where the beam may be traveling between top and bottom of the screen. There need be no particular relation between horizontal trace lines and the positions or number of phosphor strips.

SEQUENTIAL OPERATION. Now we come to the problem of changing the simultaneous NTSC color signal into a sequential signal. The NTSC signal is simultaneous because all three primary colors are transmitted all the time, simultaneously. The single-gun Chromatron color tube produces the three primary colors one after another, or in sequence, as the beam moves up and down on the phosphor strips, and consequently requires a sequential color signal.

Simultaneous received signals are changed to sequential signals in this manner:

While the single electron beam is focused onto a red phosphor strip the grid-cathode circuit of the electron gun must be acted on only by signal voltage from the red color amplifier or red matrix. While the beam is on blue strips the gun must receive signals voltage only from the blue amplifier or blue matrix. Every time the beam crosses a green phosphor strip the gun must be affected only by green signal voltage.

The process of selecting a color signal voltage corresponding to the phosphor on which the beam acts at the moment usually is called color sampling. Directing the beam onto the three color phosphors one after another usually is called color switching.

Sampling is accomplished by connecting a gating tube between each of the three color amplifiers or matrixes and the input to the grid-cathode circuit of the single electron gun. The red gate is opened, by making that gate tube conductive, only while the beam is on a red phosphor. Similarly, the blue gate is opened only while the beam is on a blue phosphor, and the green gate opens only while the beam is traversing green phosphors.

To gate a tube means merely to make it conductive during certain intervals, and non-conductive at all other times. During gating intervals the plate may be made positive, the screen may be made positive, the control grid less negative, or the cathode more negative. These polarities are made opposite during periods in which the gate is to be closed.

Fig. 5 shows grid-voltage gating for red and blue color signals delivered from red and blue color amplifiers to grid circuits of the gate tubes. These color signal voltage are continuous or simultaneous from the amplifiers. The amplifier signals reach the grid of the red gate through transformer winding La, and the grid of the blue gate through winding Lb.

Located between them and coupled to the grid windings of the transformer is primary winding Lc, which is furnished with current

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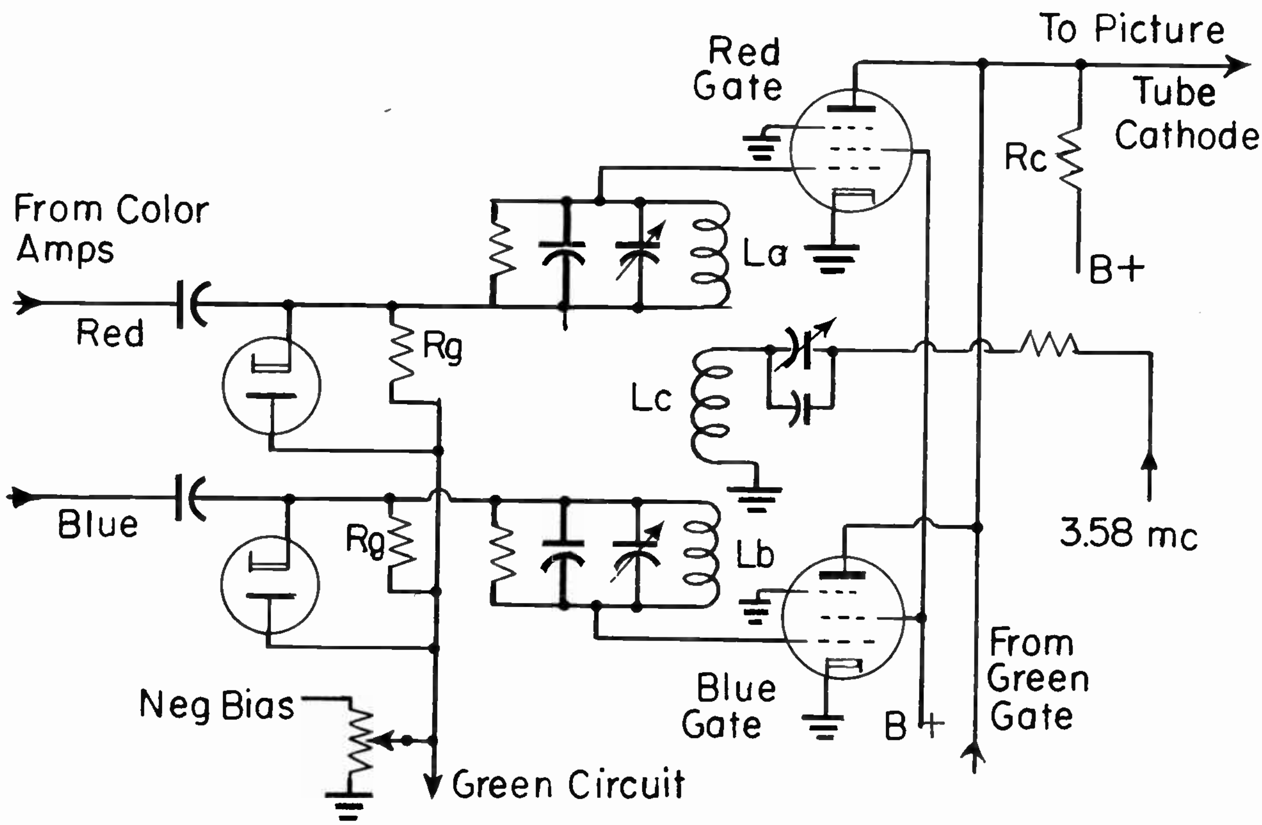

Fig. 5. Circuits for the red and blue gates which sample the simultaneous color signals.

at 3.58 mc from the color oscillator system of the receiver. During one alternation in each cycle of 3.58-mc current the voltage induced in winding La is of polarity tending to make the grid of the red gate more positive, or actually less negative, so that this gate conducts the red signal voltage. The red signal goes from the plate of the red gate to the picture tube cathode.

While the red gate is conducting, voltage induced from the opposite end of winding Lc into winding Lb makes the grid of the blue gate more negative, and this gate is held non-conductive while the red gate conducts.

During the following alternation of 3.58-mc current there is reversal of polarity in winding Lc, and reversal of grid voltage polarities at the two gates. Then the blue gate conducts, while the red gate is held non-conductive. Outputs of the gate tubes feed into a single line which goes to the picture tube cathode, with color signal voltages developed across resistor Rc.

Grid circuit couplings are phased, with respect to the 3.58-mc supply, in such manner that the red gate conducts while the single electron beam is on a red phosphor strip. The same 3.58-mc current or voltage that does the gating is also doing the color switching shown by Fig. 4. Gating or sampling and color switching remain in synchronisism when circuits are properly adjusted.

Proper phasing is brought about by adjustment of variable capacitors connected to transformer windings La, Lb, and Lc. Incorrect phasing allows color sampling and color switching to get out of step, and pictures will have wrong coloring.

Because the gate tubes provide rather small gains they are operated with maximum permissible color signal voltages on their grids, and are biased nearly to cutoff. Signal amplitudes from the color amplifiers are prevented from exceeding the bias limit by diode "clampers" across grid return resistors Rg in both grid circuits. The grid returns go to an adjustable negative bias voltage.

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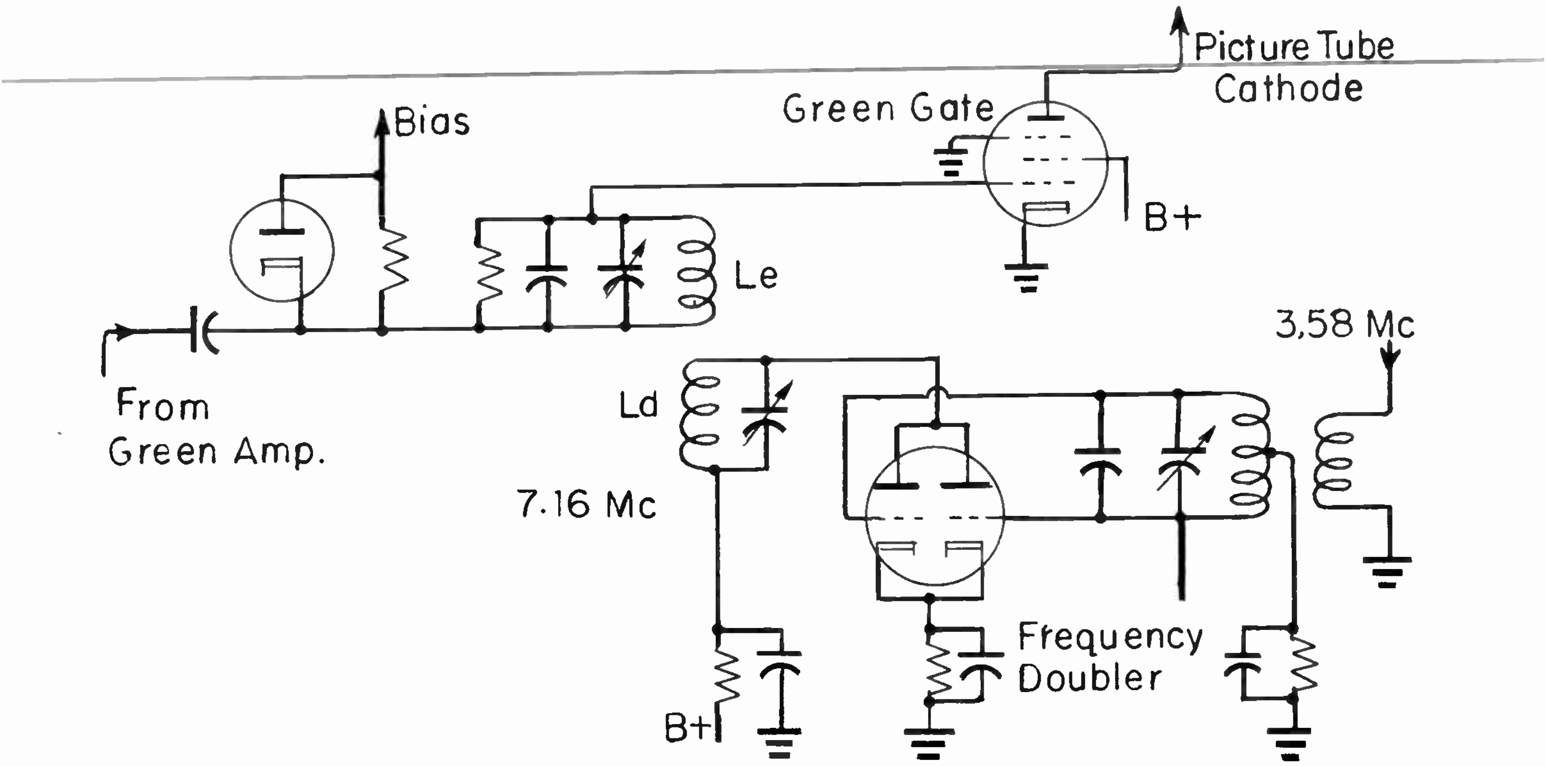

Fig. 6. The green gate and its frequency doubler.

Examination of Fig. 4 shows that the electron beam passes over green phosphor strips twice as often as over either red or blue during any given time. Therefore, the green gate must open twice as often as either the red or blue gate. This is accomplished by using a frequency doubler, of which one type is shown in Fig. 6.

This frequency doubler utilizes a twin triode with grids connected to the two ends of a transformer secondary tuned to resonance at 3.58 mc by a variable capacitor. The transformer primary is supplied with current at 3.58 mc. In the doubler plate circuit is the primary of another transformer which is tuned to twice 3.58 mc, or to 7.16 mc. This double frequency is coupled into secondary winding Le, which is in the grid circuit of the green gate tube.

The remainder of the grid circuit for the green gate is like the grid circuits for the red and blue gates, but is connected to the output of the green color amplifier. Output from the plate of the green gate goes to the picture tube cathode through the same line as output from the red and blue gates. The green gate opens twice during each cycle of 3.58-mc voltage that does the color switching.

Fig. 7 shows relations between color switching of the electron beam on the phosphor strips and color signals coming through gate tubes to the grid-cathode circuit of the electron gun. At the top of this diagram is represented color switching, as shown earlier by Fig. 4. Below are color signals passing through the three gates during reception of red, blue, green, white, and yellow. At the bottom are the combined or composite color signals going to the electron gun.

Signal pulses are shown negative because plate voltages go negative when gate grid voltages go positive for opening the gates. Negative pulses are required because the color signals are applied to the picture tube cathode while the luminance or Y-signal goes to the picture tube grid.

The red gate will be opened by the 3.58-mc voltage on its grid every time the electron beam is on a red phosphor. If there is red in the signal then being received, the red signal voltage will pass to the picture tube through the open gate. If no red is on the

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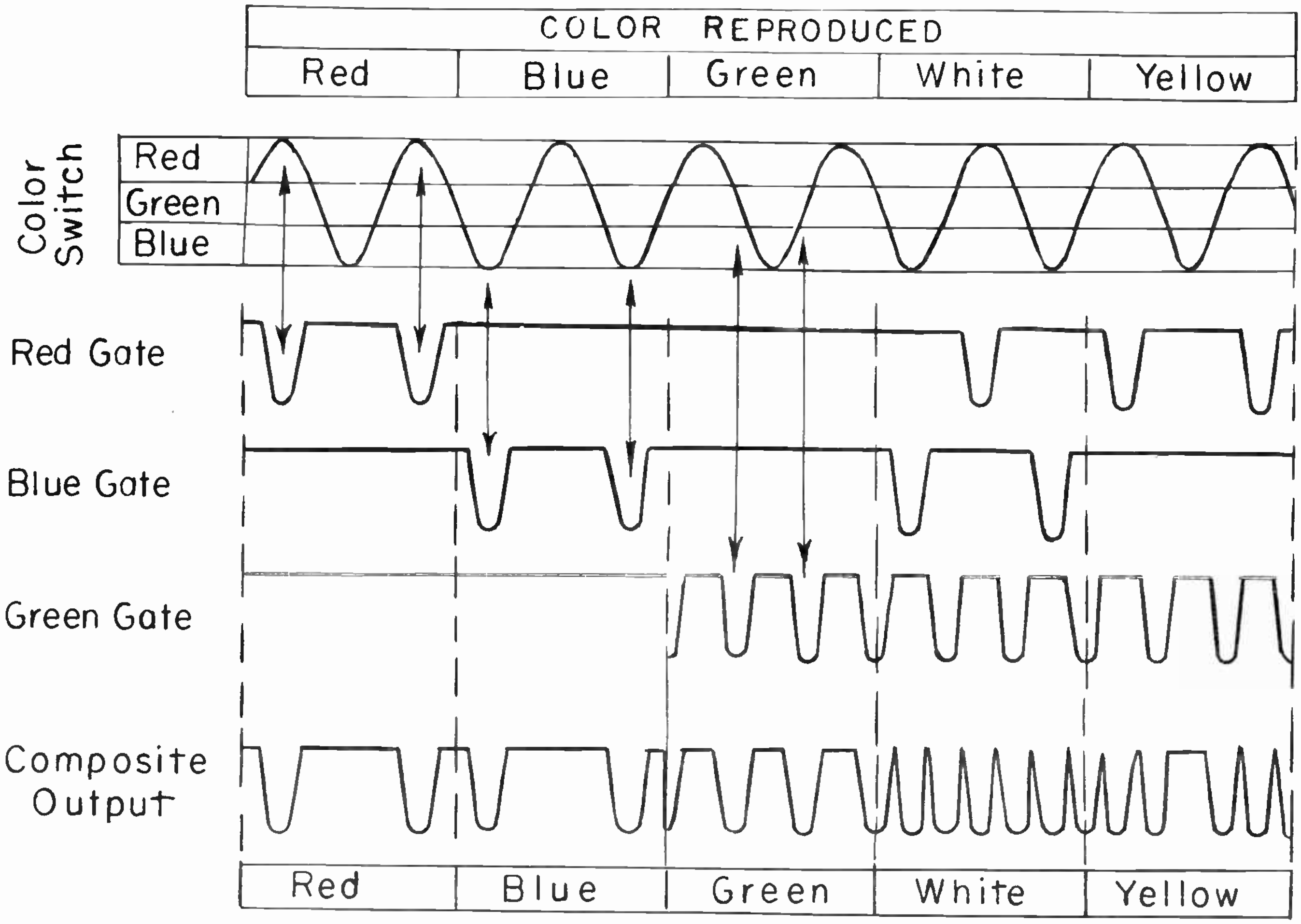

Fig. 7. Relations between color switching, at the top, and signal voltages passing through the three gates to form the composite output for the single electron gun.

received signal, as in columns for blue and green in Fig. 7, there will be no red signal voltage even though the red gate is open.

Similar actions occur at the blue and green gates. When white or gray is received, the red, green, and blue voltages will come through their respective gates. During reception of yellow there will be no blue voltage, but there will be red and green voltages.

The time during which each gate remains open depends on relations between negative grid bias on that gate tube and the amplitude of 3.58-mc or 7.16-mc gating voltage induced in the grid windings of the transformer. If gating time is too brief, there will be insufficient color illumination in pictures, while gating time too long reduces the saturation of colors. Adjustment of bias on gate tubes and of amplitude of 3.58-mc voltage in the gating circuits will remedy such faults.

POWER SUPPLY. Fig. 8 shows typical operating voltages, also power connections, for the type PDF 22-4 Chromatron tube. All voltages are with reference to the tube cathode. The brightness control is capable of making the control grid 33 to 77 volts negative for a dark raster.

Note relations between voltages on elements near the face plate of the picture tube. The highest potential, 18,000 volts, goes through a recessed cap on the tube to the aluminized backing of the phosphor screen. The second anode, whose external terminal is the metal flange, is at 3500 to 6000 volts with reference to the cathode. The difference between the aluminized backing and second anode potentials is called post deflection focusing voltage. Average voltage on the color grid structure is 300 volts negative with reference to the second anode, this being the seeker voltage.

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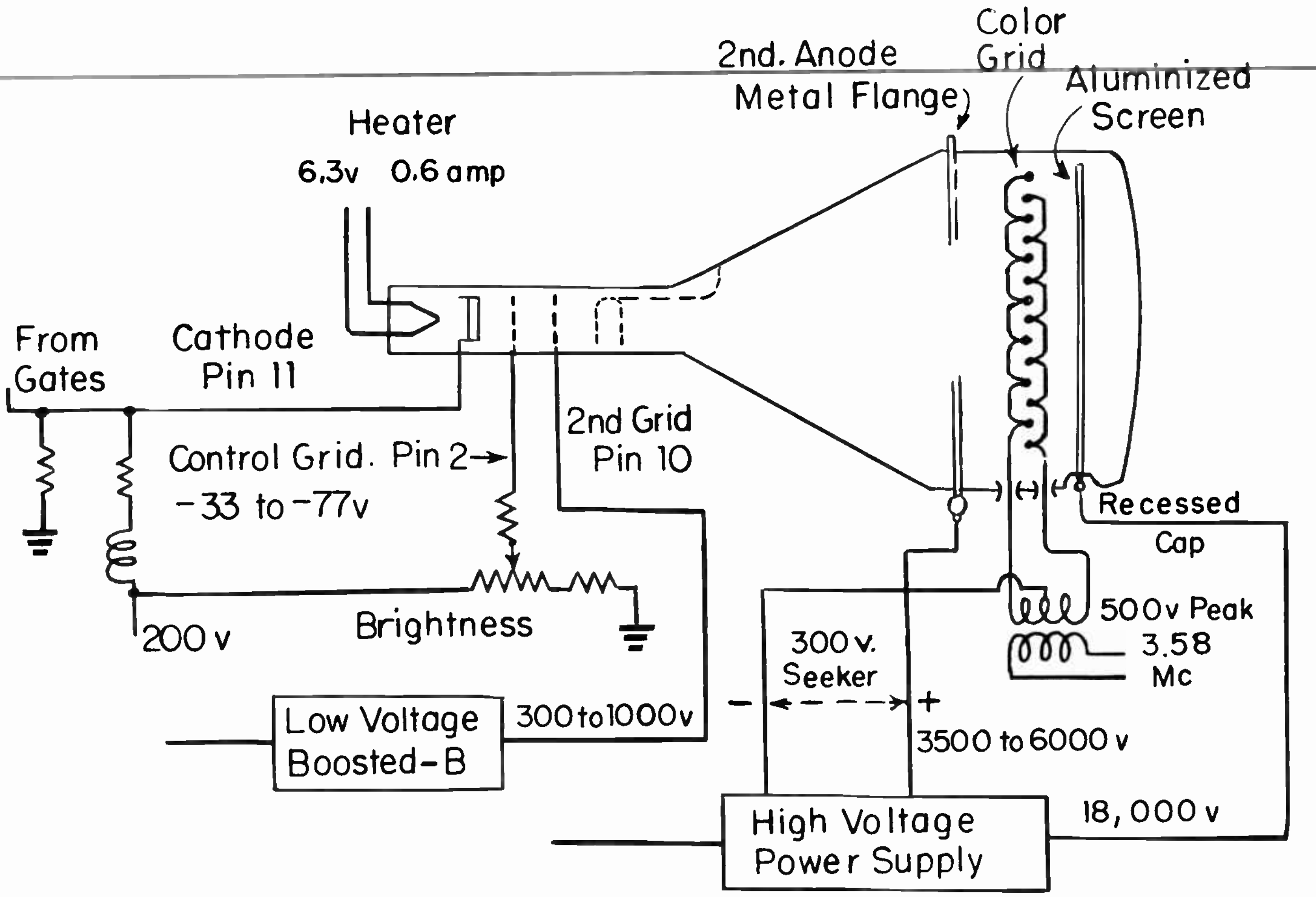

Fig. 8. Power supply voltages and their connections to elements in the Chromatron color tube.

High-voltage power supplies are of the usual flyback type. Changes of high voltage up to plus or minus five per cent, due to line fluctuations or other causes, should not affect picture reproduction after all voltages are correctly adjusted to begin with. Automatic voltage regulation may or may not be used.

The center-tapped transformer secondary whose ends connect to the two sets of color grid wires is part of a circuit resonant at 3.58 mc. Inductance is in the winding, while resonating capacitance is that between the two sets of color grid wires. Each set acts like a capacitor plate, with vacuum between them as the dielectric.

In one of its forms the 3.58-mc secondary consists of 3/8-inch diameter copper tubing with four turns on a circle diameter of 3 3/4-inches. The tap is clamped midway along the tubing. The primary is copper wire insulated with polyethylene, passed through the secondary tubing.

Because of high focusing voltage and small spacing between color grid and aluminized backing on the phosphor screen, considerable a-c power is needed to turn the electron beam onto the red and blue phosphors, and away from a straight path toward the green phosphors. The transformer circuit has high Q-factor, and at resonance there are circulating currents of 10 amperes or even more.

<u>PURITY ADJUSTMENTS.</u> Before commencing service adjustments on Chromatron circuits make sure that the deflecting yoke is pushed closely against the flare or cone of the tube, and that the focusing coil is concentric with the neck of the tube. Check all voltages shown by Fig. 8. Voltage on the second grid, base pin 10, should be low

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enough to allow a dark raster with the brightness control at minimum.

A pure green raster should appear while the 3.58-mc color switching voltage is temporarily cut off from the transformer connected to the color grid wires, since this allows the electron beam to pass straight through as at B of Fig. 3.

Purity of the green raster depends on the following adjustments.

1. Ratio of potentials on the aluminized screen backing and on the second anode. One or the other of these voltages will be adjustable.

2. Value of seeker voltage. With this voltage too low there will be white contamination at the center of the green raster.

3. Proper tuning, and phasing, in plate and grid circuits of the frequency doubler.

4. Slight tilting of the focusing coil may be necessary.

With 3.58-mc switching voltage applied, the beam will be switched across all the color phosphors and the raster should be white or gray with no color signals received. A red raster should appear while blue and green gate tubes are biased to cutoff. A blue raster should appear while red and green gates are biased to cutoff. Purity of red and blue rasters is affected by these adjustments.

1. Amplitude of 3.58-mc color switching voltage applied to the primary of the color grid transformer.

2. Value of negative grid bias on the gate tubes.

3. Proper tuning, and phasing, in grid circuits for red and blue gate tubes.

INSTRUMENTS FOR COLOR TV SERVICING

For servicing color TV receivers you will use all test instruments regularly employed for work on monochrome sets, plus a color-bar generator and a dot generator.

COLOR-BAR GENERATOR. This instrument is a practical necessity for making rapid and accurate color adjustments independently of transmitted signals. The color-bar generator allows obtaining correct colors by adjustments in 90° phase-shift circuits and in all other circuits which control phasing and thereby determine the hues reproduced from demodulator output signals. This generator also allows making correct adjustments in matrix and color amplifier circuits.

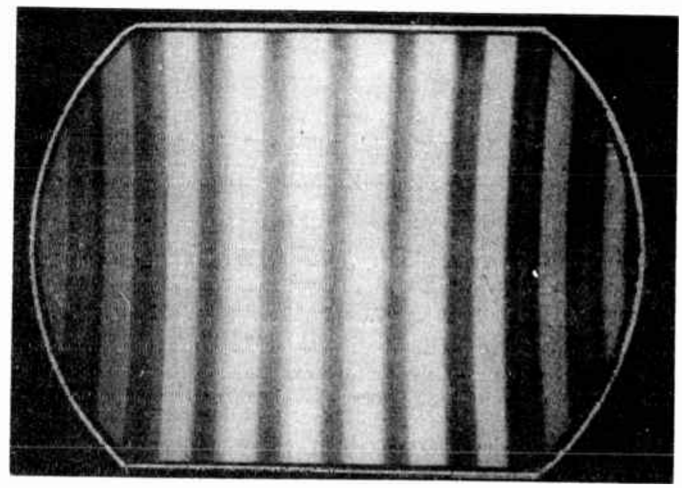

Fig. 9. The test pattern produced by an RCA color-bar generator.

An RCA color-bar generator will produce on the viewing screen of a color tube a series of vertical bars shown by Fig. 9. When receiver phasing and phase-shift circuits are properly adjusted, certain of the bars will be of the following hues when counting the bars from left to right.

2nd bar.	Positive I	6th bar.	Positive B-Y
3rd bar.	Positive R-Y	8th bar.	Negative I
5th bar.	Positive Q	9th bar.	Negative R-Y

The 1st, 4th, 7th, and 10th bars will be of hues intermediate between those of adjacent bars on either side. The generator delivers signals for an 11th bar and a 12th bar, but they disappear during horizontal blanking. The 11th bar would produce the hue for negative Q. The 12th bar would produce the hue for negative B-Y, which means it is in phase with the reference or burst voltage.

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Color bars appear in the same order as colors or hues on the color phase chart, as you follow the phase positions clockwise around the chart. This makes for convenient checking of demodulators, phase splitters, and matrix circuits, as well as color amplifiers. Here is an example: Removing or disabling an I-demodulator should remove color from positive and negative I-color bars, the 2nd and 8th from the left. This would leave the Q-demodulator operating, and adjustments could be made for correct hue on the 5th bar, produced from the positive Q signal.

Similarly, removing or disabling an R-Y demodulator should remove color from the 3rd and 9th bars from the left, and allow adjustments in the B-Y circuits for correct hue on the 6th bar, produced from the B-Y signal.

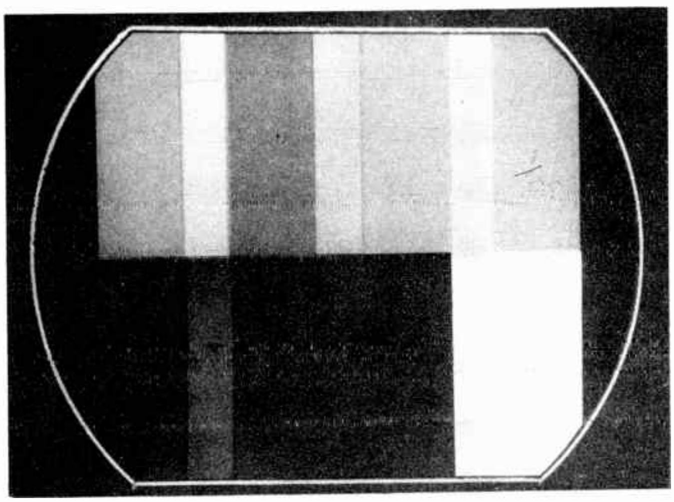

Fig. 10. Another style of color-bar test pattern.

Another type of color-bar generator produces a pattern shown by Fig. 10. Across the top are the three fully saturated primary colors and their complementary colors. White, black, and hues for demodulator outputs appear across the bottom of the pattern. Obviously, to make tests and perform adjustments while using any one type of color-bar generator, you must follow detailed instructions for that particular instrument.

Hues for color-bar patterns are formed by vector addition of suitable percentages of I- and Q-signals or of R-Y and B-Y signals. Complementary colors are formed by opposite polarities of a given signal voltage. For example, to form yellow (the complement of blue) percentages of I, Q, R-Y and B-Y voltages which are positive for blue would be negative for yellow, and those negative for blue would be positive for yellow.

In addition to furnishing chrominance signals for formation of the color-bar pattern, a generator may furnish a luminance or Y-signal for adjustment of luminance circuits and for checking monochrome reception. The generator may furnish still other signals needed for color servicing, such as video carrier frequencies, a 3.58-mc frequency, and sync pulses.

Color-bar signals may be observed on a high-quality oscilloscope connected through a frequency compensating probe to the outputs of demodulators, to demodulator amplifiers, to plates or cathodes of phase splitters, or to the picture tube grid-cathode input. Waveforms will depend on the type of color-bar generator and on the point of observation.

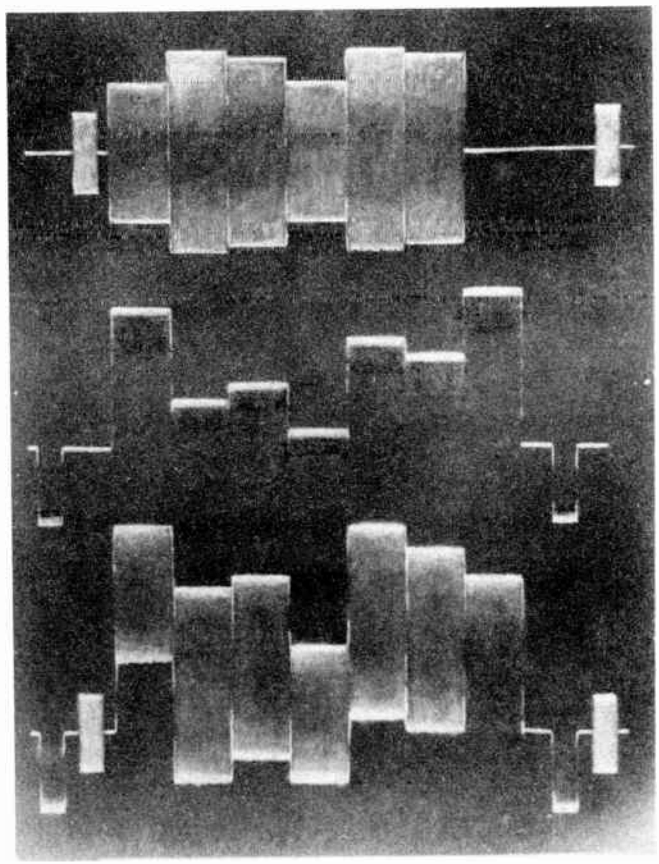

Fig. 11. How chrominance and luminance signal voltages are combined to form color-bar signals in a generator.

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A series of chrominance signals such as used to form color bars might appear as at the top of Fig. 11. These signals would be preceded and followed by bursts. Voltage changes for a luminance or Y-signal, preceded and followed by horizontal sync pulses, might appear as across the center of the diagram. The combined chrominance and luminance signals then would appear as across the bottom, preceded and followed by a sync pulse and a burst. From left to right the hues are yellow, red, magenta, blue, cyan, green, and finally white.

DOT GENERATOR. A dot generator will produce on the raster area of a picture tube a pattern of regularly spaced dots or spots useful while making convergence adjustments for three-gun tubes. At A of Fig. 12 is a dot pattern as it appears with correct convergence. The three electron beams strike together on corresponding phosphors, and the three primaries combine for white or gray dots.

When static or d-c convergence adjustment is incorrect the three beams will not meet at the phosphor screen but will spread after passing through the aperture mask. Then the pattern will have dots in clusters of three, as at B. In each cluster will be a red dot, a blue dot, and a green dot. If parts of the three colors overlap, a small central area will be white or gray.

If static convergence is correct, but dynamic convergence adjustments are wrong, single white or gray dots will appear at the center of the raster area. But dots at sides, top, and bottom of the raster area will have colors around their white or gray centers.

Some dot generators produce dots which are round or approximately round, as in Fig. 12. Others produce dots of square or rectangular outline. Most generators provide, in addition to dots, a choice of several other patterns. One pattern may be straight horizontal lines or bars, another may be straight vertical lines or bars, and still another may be a combination of horizontal and vertical lines called a crosshatch. A crosshatch pattern appears as in Fig. 13.

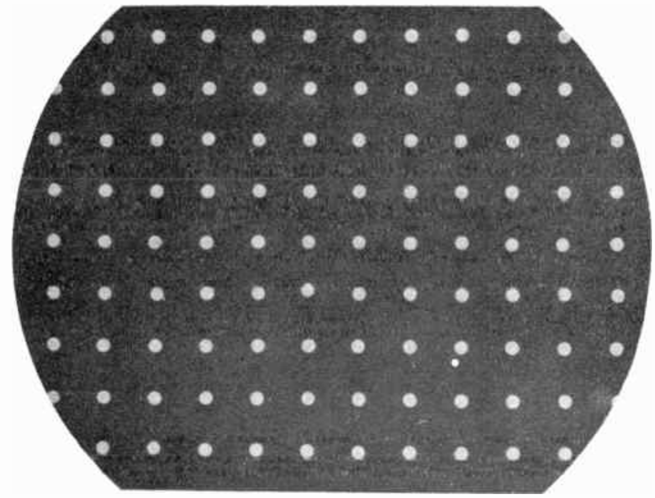

Fig. 12-A.

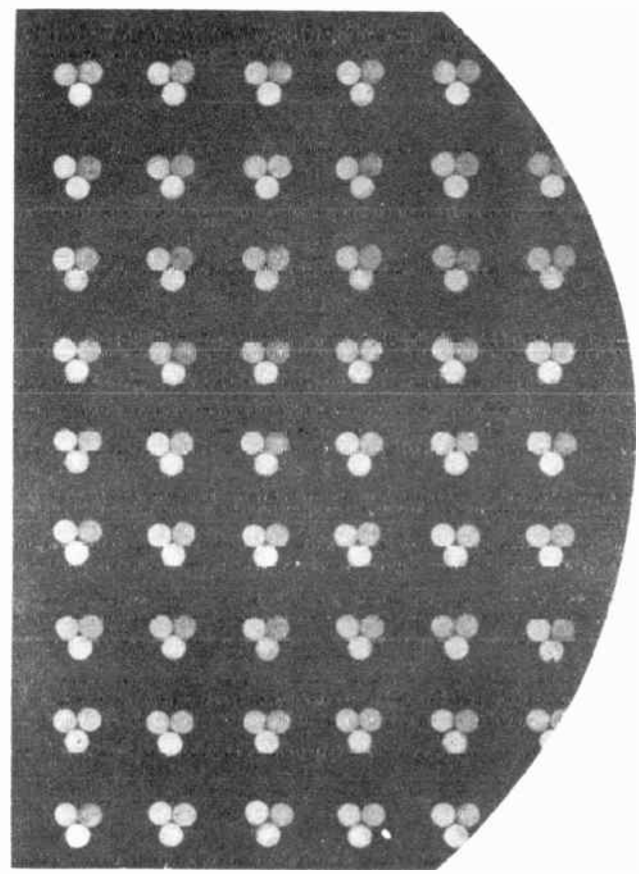

Fig. 12-B.

Fig. 12. A dot pattern as it appears with perfect convergence, and with the three electron beams acting separately before convergence adjustments are completed.

A horizontal line pattern is useful while adjusting vertical linearity and size controls of both color and monochrome receivers. A vertical line pattern helps with adjustments of horizontal linearity and size. The cross-

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hatch pattern allows simultaneous check of both vertical and horizontal linearity and size.

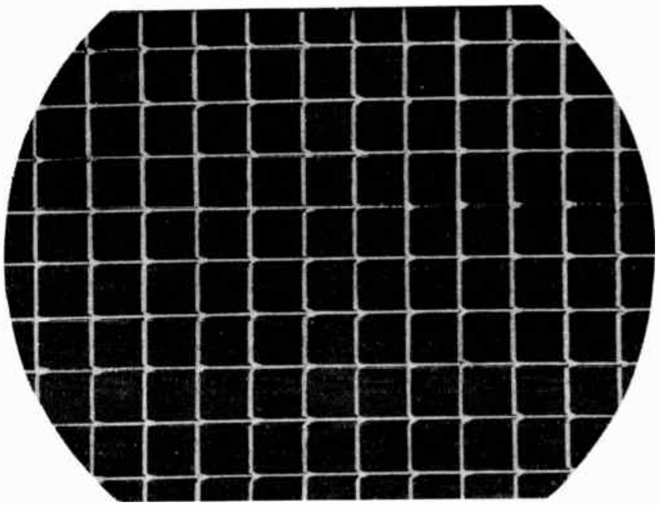

Fig. 13. A crosshatch pattern as produced by a pattern generator.

Output of a dot or pattern generator may be applied to a video amplifier grid through a cable and bias isolating capacitor in the same way as any other signal. Otherwise the generator output may be connected to receiver antenna terminals, in which case the instrument must contain an r-f oscillator which may be tuned to some one channel or else to any of several channels, usually those in the vhf low band. The pattern signal voltages are modulated onto the r-f voltage.

A generator which produces dots or narrow lines, rather than broad bars, requires a polarity reversing switch on its output when connected to a video amplifier. This is because polarity of pattern signals must be adapted to the number of video amplifier stages and to whether signal input goes to grid or cathode of the picture tube. This is the same requirement as for output polarity from a video detector. With one polarity there will be white dots or lines on a dark background, and with opposite polarity the dots or lines will be dark on a light background. White dots or lines are necessary for color convergence adjustments.

Pattern lines result from the same actions which produce sound bars and interference lines on picture tubes. Generator frequencies above 60 cycles and below 15,750 cycles produce various numbers of horizontal lines, while frequencies above 15,750 cycles per second produce various numbers of vertical lines. Adjustments allow varying the number of lines, or rows of dots, in either or both directions.

Dots usually are formed by applying to a tube in the generator output section pulses of such frequency as would form either vertical or horizontal lines. Then the same tube is gated or keyed by pulses which, by themselves, would form lines in the other direction. Gating allows conduction in the tube only at intervals which result in spaced dots.

If your pattern generator will produce a crosshatch of fairly narrow lines, but not a true dot pattern, the approximate equivalent of a dot pattern may be had by reducing brightness to a point which leaves visible only the intersections of crosshatch lines. The intersections appear like spaced dots.

OSCILLOSCOPE, SWEEP, AND MARKER. Servicing of color receivers imposes certain requirements on the oscilloscope, the sweep generator, and the marker generator which are more exacting than for ordinary work on monochrome sets. In particular, the vertical amplifier of the scope should have practically flat response to at least 4 mc. This is necessary for observation of burst signals and of signals at 3.58-mc frequency anywhere in the color oscillator section. Unless response is flat within 10 or 15 per cent at worst, it is impossible to make reasonably accurate measurements of peak and peak-to-peak voltages by any of the usual calibration methods.

As a rule, sensitivity of a scope having flat response over a range so wide as 4 mc is decidedly less than that of instruments having flat response only to about 500 kc. The lowered sensitivity should cause no difficulty, since 3.58-mc signals normally are quite strong. The vertical amplifier of the oscilloscope should have no serious frequency or phase distortion. A properly designed or adjusted frequency compensating probe is a necessity.

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The sweep generator should satisfy all the usual requirements, such as operating on fundamentals, having flat output through any one range of swept frequencies, furnishing a sweep practically linear with respect to frequency, and having an effective attenuator and shielding.

In addition, the sweep generator should sweep a range as low as from 50 or 100 cycles up to about 5 mc. This is necessary for observing frequency responses of video amplifiers, luminance amplifiers, bandpass amplifiers, and of demodulators after their output filters. All such responses are observed in the same way as those of video amplifiers. Methods are explained in the lesson on "Oscilloscope Alignment of Special Circuits". Unless you recall the procedure it will be well to review those instructions before going ahead with this lesson.

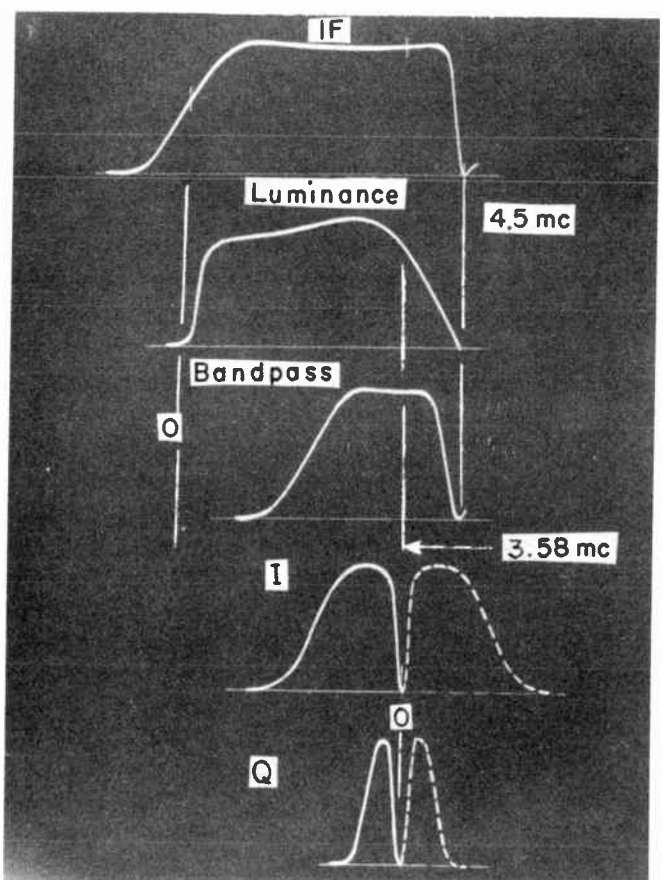

Fig. 14. Frequency responses of the i-f amplifier section and of other amplifiers and demodulator circuits in a color receiver.

Fig. 14 shows the general form of some color receiver frequency responses as they are related to the i-f response observed at the output of a video detector. Note first that the i-f response of a color receiver must extend with nearly full gain almost to the sound intermediate on the high-frequency side of the curve. The reason is that all chrominance information and fine details for luminance are carried by video frequencies between about 2.5 and 4.1 mc.

All other responses of Fig. 14 are observed with a sweep signal applied at video amplifier inputs or beyond, and with sweep widths extending from 50 to 100 cycles to whatever frequency includes the required band width of circuits checked. Response of a luminance or Y-amplifier is shown as cutting off at 4.5 mc, and as having 2/3 to 3/4 of peak response at 3.58 mc. Response of a bandpass amplifier remains zero up to about 2.0 mc, rises to half its peak value at about 2.5 mc, peaks from about 3.0 to 4.0 mc, and cuts off at 4.5 mc.

Responses of I- and Q-demodulators, after their filters, are shown as centering at 3.58 mc with respect to the i-f response up above. However, when observing these demodulator responses with the sweep extending from zero to about 2.0 mc, zero frequency on the observed curve is at the dip between full-line and broken-line curves. The I-demodulator response peaks, then drops to about half the peak value at 1.5 mc. Response of the Q-demodulator peaks, then drops to about half at 0.5 to 0.6 mc.

Frequency responses of Fig. 14 are merely illustrative, they do not apply to any particular receiver. Actual frequency responses will vary with make and model of receiver, and requirements must be learned from service instructions applying to each set.

Precise measurement of frequencies at various points on responses are important in color servicing. Therefore, the marker generator should have better accuracy than might be satisfactory for some monochrome alignments. It is especially important to accurately mark the burst and color oscil-

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lator frequency of 3.58 mc, also the sound and trap cutoff frequency of 4.5 mc.

Marker indications may be of the pip type as produced by an oscillator in the generator, or else may be dip or absorption markers resulting from connection of accurately calibrated resonant circuits. You will recall that there is less likelihood of incorrect indications when using absorption markers than when using oscillator markers.

ADJUSTING THE COLOR RECEIVER

When placing a color receiver in operation or when commencing a complete check of adjustments and alignments, all controls which affect reproduction of both monochrome and color transmissions should be adjusted before controls which affect only color. Monochrome controls include those for focus, for second anode or ultor voltage, for size, linearity, centering, and horizontal drive.

Electrostatic focus in three-gun picture tube is adjusted by varying the high voltage on a focusing electrode by means of a potentiometer on the high-voltage power supply. Magnetic focus for a single-gun tube is adjusted in the same manner as magnetic focus for monochrome picture tubes.

Where there is automatic regulation of the high-voltage supply, voltages for second anode or ultor and for phosphor screen backings is adjusted by a potentiometer on the regulator circuit. This adjustment should be made so that varying a master brightness control has least possible effect on high voltage.

Linearity and size adjustments must be correct for monochrome pictures or patterns before color adjustments are undertaken. Otherwise color reproduction will be upset by later readjustments of these controls.

Color adjustments most often are made in this order: First, purity. Second, static or d-c convergence. Third, dynamic convergence. Fourth, color balance for monochrome reception. The work is easier on some receivers when making convergence adjustments before purity adjustments. For the single-gun picture tube there are no convergence adjustments, although purity and color balance require adjustment.

PURITY ADJUSTMENTS. Purity adjustments for the single-gun picture tube have been explained earlier in this lesson. The following applies to three-gun tubes having either magnetic or electric convergence. Each gun should produce its own pure primary color when the other two guns are made inactive. Wrong purity adjustments allow objects to change color as they move over the viewing screen during a color program, and during monochrome programs allow color tints to appear at points away from the raster center. Fig. 15 shows purity control elements on the tube neck.

Purity coil adjustments change directions of the electron beams so that each strikes

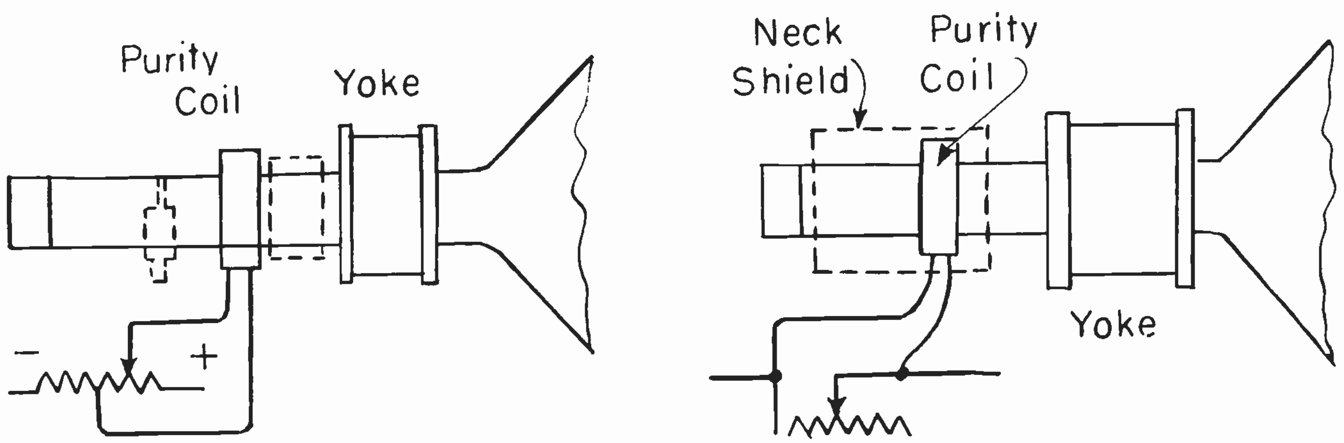

Fig. 15. Locations of purity control elements on a tube employing magnetic convergence (left) and on one employing electrostatic convergence (right).

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only phosphor dots of corresponding color. Rotation of the coil around the tube neck determines the direction in which the beam positions are changed. Varying d-c current through the purity coil determines how far the beams are shifted. Adjustments are made as follows.

Before turning on the power.

1. On tubes with magnetic convergence place the yoke about 2 inches back from the flare. With electric convergence place the yoke about 3/8 inch back of flare.

2. Beam positioning magnets turned or screwed out, for least effect on beams.

3. Contrast control at minimum.

4. Master brightness control about 2/3 to 3/4 of maximum.

5. Purity control potentiometer at mid-position.

6. Screen or second grid controls for blue and green at minimum.

7. Screen or second grid control for red at maximum.

8. Turn on power.

9. Make following adjustments a, b, and c for purest and largest red area at center of raster. There will be green and blue toward the outside.

a. Rotate purity coil on tube neck. With three beam positioning magnets on the coil shield, do not move shield or magnets while rotating coil.

b. Slide coil forward or back along tube neck.

c. Vary coil current control to obtain best red purity out as far as possible from raster center.

10. Move the deflecting yoke forward, or back if already close to flare, to obtain most uniform red over entire raster.

11. Repeat adjustments of steps 9 and 10.

12. Observe blue raster with blue screen control at maximum and other two at minimum. Observe green raster with green screen control at maximum and other two at minimum.

13. Try varying position of purity coil to improve blue and green fields, or to obtain best compromise of purity for fields of all three colors.

14. Adjust rim coil control, if used, to improve purity of the three colors.

CONVERGENCE ADJUSTMENTS. Convergence adjustments are made most easily with a dot generator, although it is possible to use a crosshatch pattern with the receiver brightness control turned low enough to leave visible only the intersections of horizontal and vertical lines.

Static or d-c convergence adjustments bring the three primary colors onto single dots which are white or gray at the raster center. Separated colors will show at the raster edges. Dynamic convergence adjustments bring the three colors together to form white or gray dots at top, bottom, and sides of the raster area.

Electron beams are converged in some three-gun picture tubes by magnetic fields, in others by electric or electrostatic fields. Adjustments for the two methods are summarized as follows.

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	MAGNETIC CONVERGENCE	ELECTRIC CONVERGENCE
STATIC OR D-C CONVERGENCE	Vary a direct current in three electromagnets or coils around the tube neck. Also vary location of a permanent magnet for blue beam position.	Vary a direct voltage on a convergence electrode in the tube. Also shift location and polarity of three permanent magnets for positioning the three beams.
DYNAMIC CONVERGENCE	In the three coils, vary amplitude and phase of alternating current derived from horizontal and vertical deflection circuits.	On the convergence electrode, vary amplitude and phase of alternating voltages derived from horizontal and vertical deflection circuits.

Preliminary steps for any kind of convergence adjustments are as follows.

1. Contrast control at or near maximum.

2. Master brightness high enough to make dots clearly distinguishable, but not so high that background is illuminated.

3. Vertical and horizontal dynamic convergence controls at minimum.

4. Turn or screw all beam positioning magnets out, for least effect on electron beams.

5. If purity has not yet been adjusted, set picture tube screen or second grid controls for equal sizes of red, blue, and green dots.

6. Work where there is a minimum of surrounding or external light.

Locations of adjustments for magnetic and electrostatic convergence are shown by Fig. 16.

MAGNETIC CONVERGENCE, STATIC OR D-C. Instructions for magnetic convergence adjustment apply to the CBS Colortron tube.

1. Vary d-c current through red and green convergence coils to make red and green dots overlap at the center of the raster area.

2. Vary d-c current in the blue convergence coil, and at the same time alter the position of the blue-beam positioning magnet until blue dots overlap the red and green dots at the center of the raster area.

MAGNETIC CONVERGENCE, DYNAMIC. Steps 1 and 2 are for horizontal dynamic convergence. Steps 3 and 4 are for vertical dynamic convergence.

1. Adjust amplitude or strength of alternating current derived from horizontal deflection circuits to make all color triads of the same size along a horizontal row passing through the raster center.

2. Vary d-c current (the static adjustment) to bring all triangles along this central horizontal row into proper convergence as single dots.

3. Adjust amplitude of alternating current derived from vertical deflection circuits to make all triads of the same size along a vertical row passing through the center of the raster area.

4. Vary d-c current (the static adjustment) to properly converge all dots along this central vertical row, making single white or gray dots.

5. There is some interaction between vertical and horizontal dynamic adjustments. Therefore, repeat these adjustments alternately for best possible convergence.

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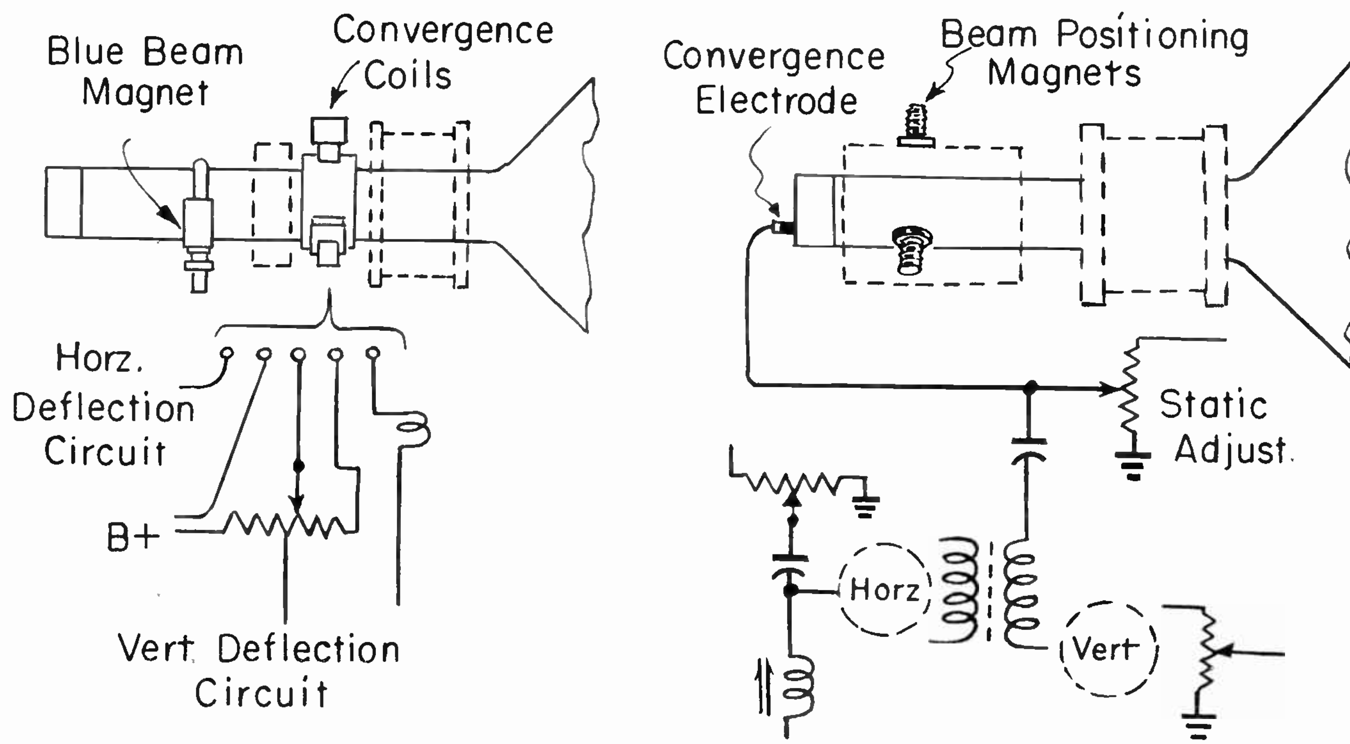

Fig. 16. Locations of adjustments for magnetic convergence (left) and for electrostatic convergence (right).

ELECTRIC CONVERGENCE, STATIC OR D-C.

1. If at the center of the raster area the color dots are not equally spaced with reference to one another, to form equilateral triangles, adjust the three beam positioning magnets to secure such triangles. Each magnet shifts dots of one color.

2. Adjust the static or d-c convergence control to make the color dots at the center of the raster area converge into single white or gray dots.

3. If necessary, readjust the three beam positioning magnets for perfect convergence at the center of the raster area.

ELECTRIC CONVERGENCE, DYNAMIC.

1. Adjust vertical amplitude and shaping controls so that dots in each triangle at top and bottom of raster area, as well as at center, come together into single white or gray dots, or are equally displaced.

2. Adjust the static or d-c convergence control for best possible convergence from left to right through the center of the raster area.

3. Adjust horizontal amplitude and phase controls so that dots at both sides as well as at the center of the raster area come together into single white or gray dots, or have equal displacements.

4. Readjust the static or d-c convergence control for best possible convergence from top to bottom through center of raster area.

5. Since horizontal and vertical adjustments may interact, repeat steps 1 through 4 to obtain most uniform white or gray dots over the entire raster area.

MONOCHROME ADJUSTMENTS (COLOR BALANCE). The object of monochrome adjustments is to so balance the red, green, and blue signal voltages at the picture tube input that monochrome transmissions produce pictures in white, gray, and black, without any color regardless of any normal settings of contrast and master brightness controls.

World Radio History