PRICE 25c

# Visual Alignment Techniques for FM SERVICING

**GENERAL ELECTRIC**

# Visual Alignment Techniques

# FOR FM SERVICING

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# Introduction

In May 1947 the Specialty Division of the General Electric Company published a booklet entitled "Servicing FM Receivers" which was intended to acquaint radio servicemen with the new techniques required in FM service work.

The response to this publication was so overwhelming that we have decided to completely revise and enlarge the original edition to include the latest circuits and methods of alignment and, in brief, to give the serviceman a thorough treatise on the latest time-saving FM techniques. To this end there has been included brief but important sections on the theory of the oscilloscope and sweep frequency signal generator — plus detailed information on practical applications of these essential instruments which will enable you to turn out a better FM service job in less time. An entire section on basic FM circuits has been added, together with information on special circuits such as double conversion, squelch circuits, etc.

A complete understanding of the principles and practices described in this publication will result in faster service, better receiver performance and a reputation for reliability among good customers. It all adds up to more profits and personal satisfaction.

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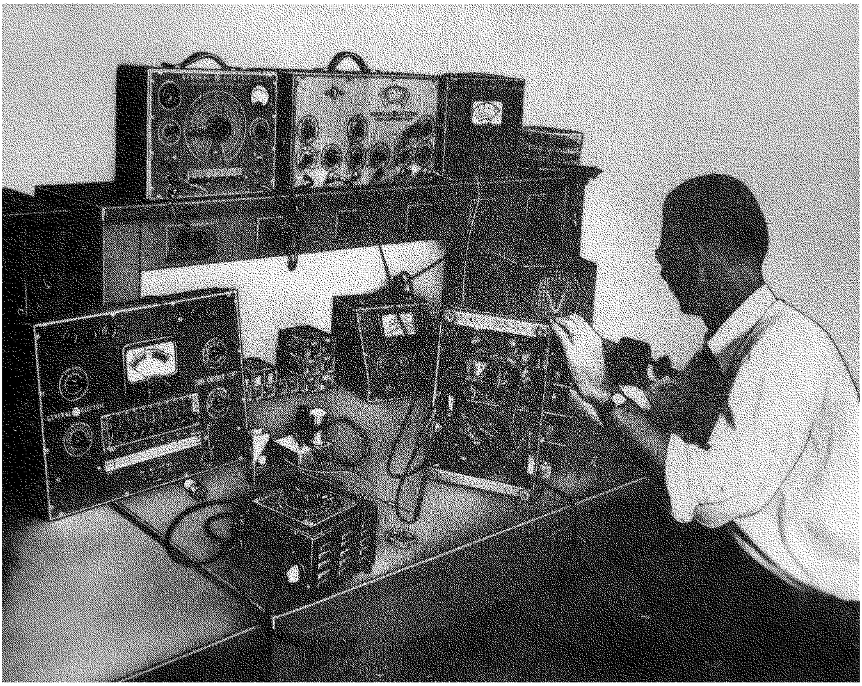


A Typical Radio Service Bench Set-up Illustrating One Phase of the Visual Alignment Procedure.

# SECTION 1

## THEORY OF THE CATHODE RAY OSCILLOSCOPE

### The Cathode Ray Tube

The cathode ray tube is essentially a vacuum tube which contains a cathode, a control grid, focusing electrodes, deflection plates, and a special translucent screen which fluoresces or gives off light when struck by an electron beam.

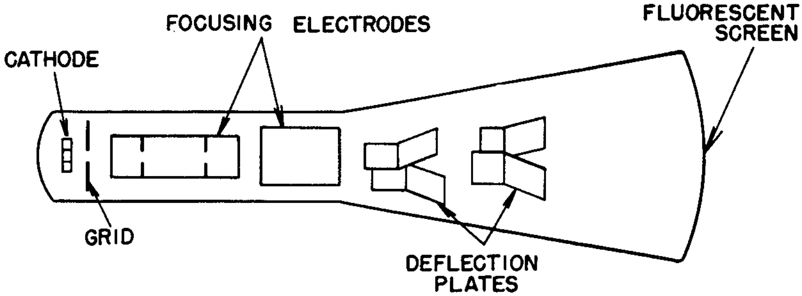
Figure 1 illustrates the general construction of a typical cathode ray tube. Electrons emitted by the hot cathode are first accelerated to considerable velocity and then formed into a beam which strikes the fluorescent screen. As in an ordinary vacuum tube, the control grid controls the intensity of the current flow. In the case of the cathode ray tube, the intensity of the electron stream and hence the brightness of the electron trace on the screen is controlled by varying the grid voltage. This grid voltage control is usually available on the operating panel of the oscilloscope so that the operator can adjust the intensity to the desired level.

Since the electrons emitted by the cathode fly off in all directions, it is necessary to control and shape them into the desired narrow beam. This is done by the focusing electrodes which act in much the same manner as the optical lens in a camera, only in this case we focus electrons rather than light. By adjusting the voltage applied to the focusing electrodes, the necessary control is achieved and this control is brought out to the front panel where adjustments can be made by the operator.

After passing the focusing electrodes and before reaching the fluorescent screen, the electron beam passes between two sets of deflecting plates which are at right angles to each other. If a voltage difference is applied between one set of plates the electrostatic field will deflect or move the electron beam in a direction perpendicular to the electron stream. The same action will take place if a voltage is applied to the other set of deflection plates but this time the electron beam will be deflected in a direction perpendicular to the previous motion. Since the face of the CR tube is often blocked off into small squares resembling graph paper, horizontal deflections of the beam are often referred to as deflections along the X-axis while Y-axis deflections correspond to vertical movements of the beam.

Since the electron beam has very little weight, it can be deflected very rapidly. Because of this, the cathode ray oscilloscope can respond faithfully to very rapid voltage variations.

Figure 1. Arrangements of elements in a typical cathode-ray tube.



## Amplifiers and Sweep Generators

The amount of voltage which must be applied directly to the horizontal and vertical deflection plates to result in a useable swing of the electron beam is fairly large, 10 to 50 volts being required to obtain one inch of deflection. For this reason, amplifiers are usually incorporated in the complete oscilloscope to permit observation of relatively small voltages. Two separate amplifiers are required, one for the horizontal plates and one for the vertical plates. Gain controls are normally provided for each amplifier so that the required vertical and horizontal deflection can be obtained.

In most cases in the study of electrical phenomenon, the electrical quantities under consideration are plotted as some function of time. Normally, the horizontal axis is used as the time base which requires that the electron beam or spot on the CR tube sweep linearly across the screen and then return almost instantly to the starting point. An internal timing or sweep oscillator accomplishes this by applying a saw-tooth voltage to the horizontal plates. This action is illustrated in figure 2. If an a-c voltage is now applied to the vertical plates, the horizontal trace will be pulled up and down by the variations in the applied a-c voltage. A continuous picture of these variations is thus presented on the screen of the CR tube as illustrated in figure 3.

A complete cathode ray oscilloscope then, consists of a cathode ray tube which produces the traces, two amplifier circuits to amplify small signal voltages for application to the deflecting plates of the cathode ray tube, a timing or sweep oscillator, and the necessary electronic power supplies. A picture of a typical oscilloscope is shown in figure 4.

## Oscilloscope Specifications for Visual Alignment

Oscilloscopes to be used for visual alignment work must possess certain features and characteristics if satisfactory and accurate results are to be obtained. These specifications, together with explanatory reasons are listed below for the benefit of the serviceman who is contemplating the purchase of an oscilloscope.

## Sensitivity

In general, the sensitivity of the oscilloscope through the amplifiers

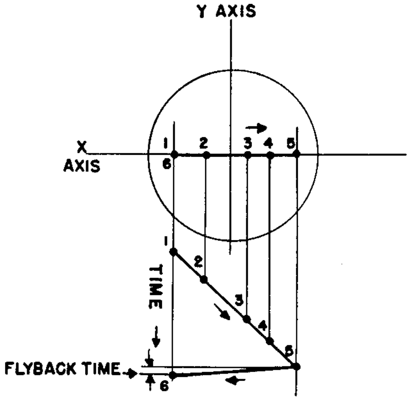


Figure 2. How a sawtooth voltage applied to the horizontal plates sweeps the electron beam linearly across the CR tube screen. The portion of the sawtooth voltage between points 5 and 6 acts to return the beam to the original starting point (1). The return or flyback takes but a very small fraction of the total time required for one sawtooth.

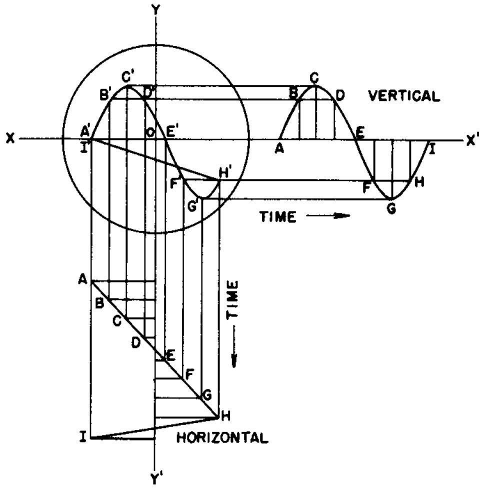


Figure 3. Illustrating the formation of the pattern from horizontal and vertical sweep voltages.

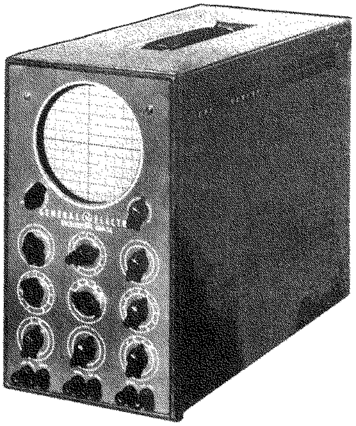


Figure 4. A typical oscilloscope: General Electric CRO-5A.

should not be less than 30 millivolts (.03 volts) rms/inch for the vertical plates and 200 millivolts (.2 volts) rms/inch for the horizontal plates. This means simply that if .03 volts rms is applied to the vertical amplifier, a maximum deflection of one inch will be obtained on the screen of the cathode ray tube. The required sensitivity of the horizontal amplifier is much less than the vertical amplifier because it is relatively easy to obtain sufficient sweep voltage (internal or external) for the horizontal plates. In normal practice, the external voltage to be plotted with respect to horizontal deflection is applied to the vertical amplifier and since this voltage is often very small, greater sensitivity is required.

**Linearity**

As explained earlier, a saw-tooth voltage is applied to the horizontal plates causing the electron spot to trace a horizontal line on the screen of the CR tube (with no signal applied to the vertical plates). Since this horizontal trace is a direct function of time, it can be seen that the speed of the spot as it moves across the face of the tube should be as uniform as possible. Should the spot move faster or slower in one particular section of the screen, the trace which would result upon the application of a vertical signal would be distorted and would cause misleading interpretations of the pattern or waveshape being studied. A non-linear sweep, therefore, is one whose speed is not constant with respect to time.

A satisfactory maximum limit is ±15% non-linearity over 80% of the forward sweep.

Similarly, amplifier non-linearity should be held to a minimum and should never be more than 10% over a range equal to 75% of the total deflection.

### Provisions for External Synchronization and Sweep

Ordinarily the internal sweep generator acts as a self-excited or "free-running" oscillator to provide the saw-tooth voltage which is applied to the horizontal plates. In visual alignment work, however, it is desirable to be able to control the exact timing of the internal oscillator so that the trace on the screen of the CR tube will remain steady and stationary. This can be accomplished by applying an a-c voltage of the proper frequency to the internal oscillator circuit and thus tying down or synchronizing the sweep rate of the internal oscillator with the applied a-c voltage. When a sweep generator is also used, phase relationships must also be considered, as pointed out in Section 2.

Although the linear or saw-tooth sweep generally is most useful, other sweep waveshapes are often desirable for visual alignment work. A sinusoidal wave is widely used in conjunction with the sweep frequency signal generator. From our discussion of linearity, it would at first appear that the use of a sine wave for the horizontal sweep would result in distortion because the speed of the sweep would not be constant. If, however, the a-c voltage applied to the vertical plates is of the same frequency and phase as that applied to the horizontal plates, the relationship will be linear. This is taken up in detail in Section 2.

A good oscilloscope then, should include a flexible input circuit to the horizontal plates which is capable of selecting either an internal saw-tooth sweep voltage or an external voltage. Provisions should be made for connecting an external synchronization voltage to stabilize the saw-tooth sweep and a control should be provided which will permit the operator to adjust the amplitude of the external or internal synchronization voltage.

### Summary of Oscilloscope Specifications

From the above brief discussion of oscilloscope characteristics it can be seen that just any type of oscilloscope cannot be pressed into service for visual alignment. A thorough study of the specifications of available instruments should be made to insure that the oscilloscope finally selected is capable of fulfilling the necessary requirements.

A good quality oscilloscope, properly used, is a paying investment for the serviceman because it means more jobs handled per day — hence more profits.

# SECTION 2

## THEORY OF THE SWEEP FREQUENCY SIGNAL GENERATOR

As every serviceman knows, the ordinary amplitude modulated signal generator is really a small transmitter which is used to test the response of AM receivers. The sweep frequency generator is used in exactly the same manner, supplying frequency modulated test signals which can be used to adjust and align both AM and FM receivers. Generally speaking, the AM signal generator cannot be used for FM alignment purposes if accurate results are to be obtained. On the other hand, the use of a sweep frequency generator for visual alignment of AM as well as FM receivers has consistently been recommended by leading manufacturers as the quickest and most accurate alignment method possible.

In its simplest form, the sweep frequency signal generator consists of a frequency modulated oscillator tuned to the desired frequency. One of the earliest systems of frequency modulating an oscillator employed a motor driven capacitor to swing the frequency of the oscillator back and forth across the center frequency at a rate dependent upon the speed of the motor. This system has since been superseded by an electronic method of frequency modulating the oscillator with a reactance tube. The reactance modulator consists of a vacuum tube connected to the frequency determining circuit of the oscillator in such a way as to act as a variable inductance or capacity, thereby changing the frequency of the oscillator. A simplified diagram illustrating this system is shown in figure 5. The amount of change or frequency modulation depends primarily upon the amplitude of the audio signal applied to the grid of the reactance tube. Thus, by varying the audio input to the reactance tube it is possible to control the frequency sweep or *Bandwidth* of the FM test signal. Since it is extremely difficult to design a reactance tube modulated oscillator which will operate properly over the wide range of frequencies encountered in AM and FM work, it is common practice to design the frequency modulated oscillator to work at only two or three *fixed* frequencies. The frequency modulated signal is

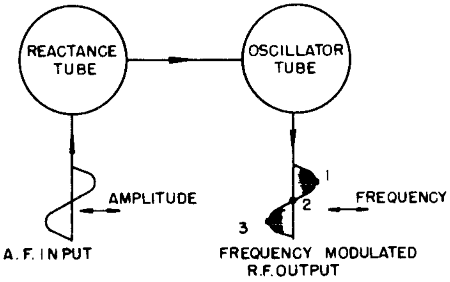


Figure 5. Simplified frequency modulated oscillator. The RF output of the oscillator is swung back and forth across its center frequency (point 2) in accordance with the audio waveshape applied to the reactance tube. The amount of swing or deviation of points 1 and 3 depends upon the amplitude of the AF voltage applied to the reactance tube.

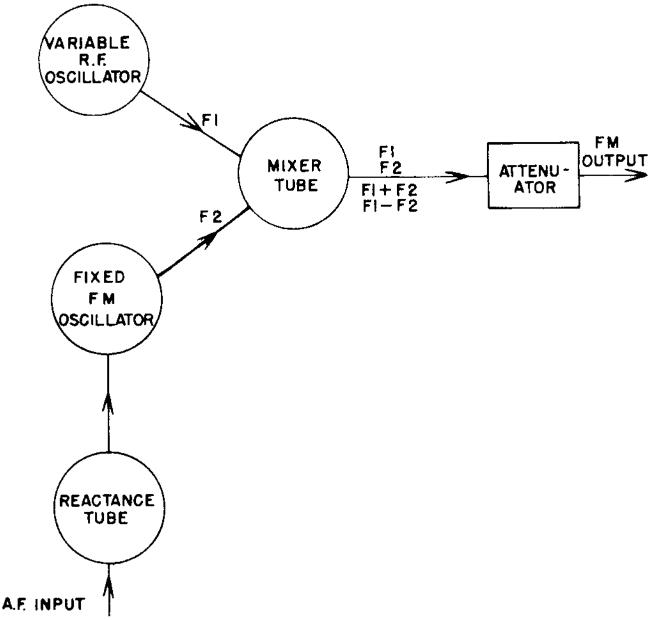


Figure 6. How a fixed, frequency modulated signal and a variable, unmodulated signal are combined to produce an FM signal of the desired frequency. This system is used in the General Electric Type YGS-3 Signal Generator.

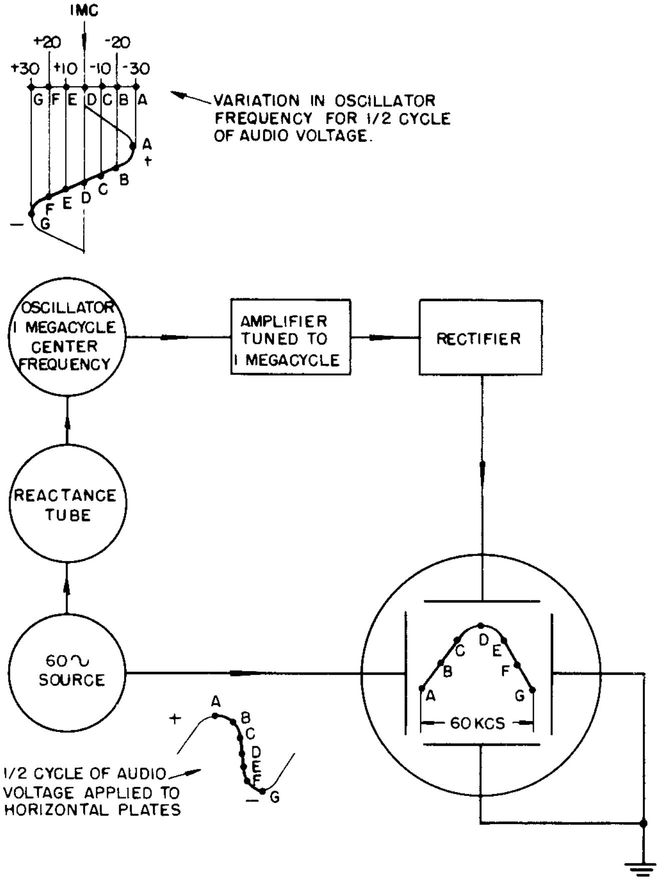
then mixed or hetrodyned with a variable frequency oscillator to produce the desired output frequency as shown in figure 6. A review of the principles involved in the hetrodyning process will clarify the operation.

The combination of two voltages of different frequencies gives rise to beat frequencies equal to the sum and difference of the two frequencies. For example, if two frequencies, F1 and F2, are mixed or combined, the following *new* frequencies will result: F1 + F2 and F1 — F2. If either frequency is modulated, amplitude or frequency, the sum and difference frequencies will retain the modulation component. As an illustration, if a 20 MC signal with a frequency deviation of ±10 kcs is mixed with an unmodulated 30 MC signal, the sum of the two frequencies will equal 50 MC with a frequency deviation of ±10 kcs. This phenomena, commonly referred to as hetrodyning enables a fixed frequency oscillator of known frequency deviation to control the modulation characteristics of the sum or difference frequency resulting from the combination of a modulated and unmodulated signal. In practice, either the sum or difference frequency may be used to obtain the desired output signal. A typical circuit embodying this principle is illustrated in block form in figure 6.

From our discussion of the oscilloscope it will be remembered that a sweep voltage was applied to the horizontal deflection plates of the CR tube to swing the electron beam back and forth across the screen of the tube. If a sweep voltage is applied to the reactance tube which frequency modulates the oscillator somewhat the same action will take place, the difference being that we are now swinging the *frequency* of the *oscillator* back and forth. If the *same* sweep voltage is simultaneously applied to the horizontal plates of the oscilloscope *and* to the FM oscillator, the two instruments will be in exact synchronization, disregarding for the moment slight phase shift effects. This practice of using the same sweep voltage for both the FM signal generator and the horizontal plates of the oscilloscope is an extremely important point to remember because it forms the basis for practically all visual alignment operations. A simplified visual alignment circuit is shown in figure 7.

Here we have a 60 cycle sine wave applied to the horizontal plates of the oscilloscope and also to the reactance tube which frequency modulates the oscillator. The FM oscillator, operating at a center frequency of one megacycle, feeds into an amplifier also tuned to one megacycle. A rectifier demodulates the RF coming out of

Figure 7. Simplified visual alignment circuit.



the amplifier and the resultant audio frequency voltage is applied to the vertical plates of the oscilloscope.

Assume that the audio input to the reactance tube is adjusted so that the frequency deviation of the oscillator is 30 kilocycles either side of the one megacycle center frequency or a total deviation of 60 kilocycles. Let us now follow the action which takes place if we simultaneously apply one half cycle of audio frequency voltage to the reactance tube and the horizontal plates of the oscilloscope.

At the extreme positive half of the cycle (point A) the reactance tube has swung the frequency of the oscillator 30 kilocycles lower than the one megacycle center frequency. At the same instant, this same positive voltage on the horizontal plates of the oscilloscope pulls the beam to the extreme left of the screen to point A. Since the oscillator is 30 kilocycles away from the resonant frequency of the amplifier, amplification is very low and relatively little voltage is fed into the rectifier and the vertical plates of the oscilloscope. The vertical plates therefore have very little effect upon the position of the beam. Following the audio cycle to point B, we find that the reactance tube has shifted the oscillator frequency back toward the center frequency or 20 kilocycles away from one megacycle. At the horizontal plates of the oscilloscope the less positive voltage draws the beam to point B on the screen. Since the oscillator is nearer the resonat frequency of the amplifier, amplification increases, more voltage is applied to the vertical plates and thus the beam is also drawn upward. At point C the oscillator is still closer to the resonant frequency of the amplifier while at the same time the changing voltage on the horizontal plates deflects the beam further to the right. Amplification in the amplifier increases and the vertical plates exert more pull on the beam which is thus drawn further upward. At point D, the oscillator is exactly at the resonant frequency of the amplifier, horizontal deflection moves the beam to the center and since amplification is now at a maximum, the vertical plates pull the beam to the top of the pattern. At points E, F, and G, the oscillator swings away from the resonant frequency of the amplifier while at the same time the horizontal deflection resulting from less positive or now negative voltage continues to pull the beam to the right. Amplification decreases, less voltage is applied to the vertical plates and thus the beam drops as it moves to the right.

On the other half of the cycle the same action occurs in reverse and an almost identical curve is again traced on the screen of the CR tube. This second curve may not follow precisely the same path as the first curve because of phase shift effects. This condition can usually be corrected by the addition of a simple phase shifting network connected to the horizontal plates. Typical constants and connections are shown in figure 8. The potentiometer should be adjusted so that the two curves merge into one.

It can be seen from the preceding explanation that the *actual* response curve of the amplifier is traced on the screen of the CR tube. It is this feature which makes visual alignment so valuable for FM work. The ear alone cannot distinguish between steep and slowly rising curves during the

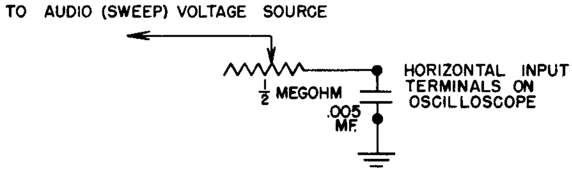


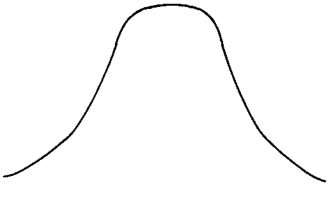
FIGURE 8.

Figure 8. Phase shifting network used to eliminate double trace.

alignment process and rule-of-thumb alignment methods are accordingly equivalent to "working in the dark". Peak FM receiver performance requires that the IF response curve have a wide, flat-top and steep-sided skirts as illustrated in figure 9. This type of response curve rules out simple aural alignment methods because it would be practically impossible to determine the actual width of the curve or the steepness of the skirts.

Although earlier FM visual alignment systems made use of separate sweep frequency oscillators used in conjunction with standard AM signal generators, current commercial practice is to include the FM oscillator as an integral part of an over-all equipment. Such an instrument must necessarily possess certain flexible features if the full advantages of the sweep frequency generator are to be enjoyed. Provisions must be made for audio voltage switching from the variable RF oscillator to the FM oscillator; mixer circuits must be included; bandwidth, output and percentage of modulation indicators must be provided, and yet, the entire equipment must not be so cumbersome and complicated that a special course of instruction is required before it can be operated. It is apparent then, that the design of an AM-FM signal generator capable of being operated effectively by the average serviceman is a big order.

Figure 9. Typical over-all response curve of FM-IF channel.



Specifications for a good AM-FM signal generator are listed below, together with explanatory notes:

**Frequency Range:**

RF Oscillator 100 KC to 125 MC, fundamental coverage.

FM Oscillator: Sufficient fixed frequencies to supply deviations from zero to ± 500 KCS or higher.

If the signal generator is to be used for both AM and FM service work, the RF oscillator must necessarily cover the entire frequency spectrum for both these ranges, together with intermediate frequencies and short wave bands. Less expensive generators sometimes employ RF oscillators with a top frequency range of around 60 megacycles and then depend upon second harmonic coverage to fill in on the new FM band frequencies. If the beat frequency system is employed to obtain FM output, it is desirable to have fundamental rather than second harmonic coverage to avoid the possibility of spurious and confusing responses.

The FM oscillator should be capable of continuously variable deviations from zero to ± 500 KCS or more with extremely low amplitude modulation and good linearity. These figures may appear extreme until it is realized that the bandwidth of a single, broadband IF stage on 10.7 MCS often stretches out to a megacycle or more at the base. It would be impossible to "look" at the entire response curve of such a stage unless this order of deviation were available. Good linearity requires that the frequency deviations on either side of the FM oscillator center frequency be equal so that a true response picture of the channel under test will be obtained.

**Output:**

At least .1 volt throughout the entire frequency range.

Mixed FM output should be great enough to permit observation of a *single*, broad-band IF stage response curve so that stage-by-stage alignment can be carried out. Insufficient output requires that the FM alignment signal be applied directly to the front end of the set in order to obtain enough gain to produce a sizable picture — hence most of the advantages of visual alignment would be lost.

**Audio Output:**

Low distortion, preferably continuously variable, capable of modulating either RF or FM oscillator.

Several volts of audio voltage with less than 10% total distortion should be available for internal modulation and also for audio test purposes. The audio circuit should include provisions for simultaneously supplying the modulating voltage for the FM oscillator and the horizontal amplifier for an external oscilloscope. A continuously variable frequency source of audio voltage will permit fidelity checks on audio amplifiers and is therefore a desirable feature.

**Output Indication**

Unless amplitude modulation levels and FM bandwidths remain fixed, some method of indicating these factors must be provided. Meters which read output in microvolts, amplitude modulation in percent and FM bandwidth in Kilocycles are, of course, the ideal answer. However the inclusion of such circuits in service test equipment would raise the selling price beyond the average serviceman's pocketbook and a less expensive method is generally employed.

While the exact output voltage of the generator is not too important in alignment work, it is essential that a fairly accurate indication of the bandwidth of the FM oscillator be provided. Without knowing the bandwidth of the oscillator it would be impossible to determine the bandwidth of circuits under alignment and the response curve obtained would be practically meaningless.

Under amplitude modulation conditions, a method of determining the standard 30% modulation depth should also be provided since this modulation figure is usually specified by manufacturers in AM alignment instructions.

**Miscellaneous Considerations**

In addition to the features described above, the AM-FM signal generator should also have an effective attenuator system which will control the output voltage without too seriously affecting the frequency of the generator. If the attenuator is to be effective, the generator itself must be well shielded and filtered so that stray voltages will not leak through the power cord or small openings in the equipment case.

While not essential, the inclusion of a crystal calibrator for internal and external calibration purposes would prove a useful adjunct and would round out the over-all versatility of the equipment. A one thousand kilocycle crystal standard, for instance, would prove invaluable for rapid checking of dial calibration on short wave bands.

Figure 10. A typical AM-FM signal generator: General Electric YGS-3.

# SECTION 3

## BASIC FM CIRCUITS

### General

Probably one of the easiest ways to understand FM receivers is to compare typical AM and FM receivers in block form. Such a comparison is given in figure 11. With the exception of the waveshapes at the stages, the only apparent differences in the AM and FM receivers are the blocks representing the limiter and discriminator stage of the FM receiver. However, in addition, there are other modifications in circuit characteristics which makes an FM receiver considerably different. The principle differences are as follows:

1. The FM receiver uses a different type of 2nd detector, known as a discriminator which responds to frequency modulated signals and when perfectly balanced eliminates amplitude modulated signals.

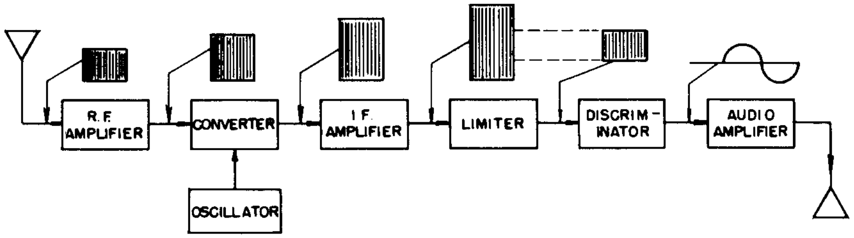
2. The use of one or two modified stages in the intermediate frequency amplifier just preceding the discriminator (2nd detector) which act as voltage limiting stages and are known as limiters.

3. The over-all gain of the receiver from antenna to the input of the 2nd detector (discriminator) is usually greater than in an ordinary AM receiver.

4. The intermediate frequency is considerably higher than that used in AM receivers, being in most cases above 4 MC.

5. Since the bandwidth requirements of an FM signal are much wider than that used in AM, the frequency response of the inter-

Figure 11. Block diagrams of FM and AM receiver.



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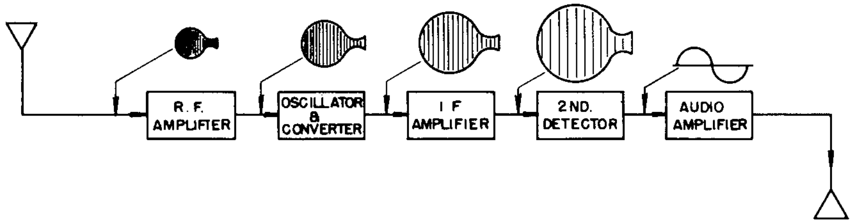


A.M. RECEIVER

mediate frequency amplifier must be wide enough to pass the total range through which the FM signal deviates.

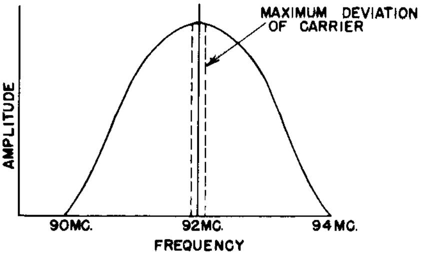
6. The amount of gain in the radio frequency stage is relatively small, due to the comparatively high frequencies at which it operates.

### Radio Frequency Circuits

The antenna and RF circuits used in FM receivers perform the same general functions as those used in the ordinary AM receiver, i.e., to improve selectivity, increase the sensitivity and to reject the image frequency.

One of the most important requirements of the RF circuit for an FM receiver is that its frequency response be broad enough so that uniform amplification of all deviation frequencies due to modulation is obtained as shown in figure 12. At the radio frequencies used for FM broadcasting, this requirement presents no special problem and it is not necessary to take any special precautions. It will be recalled that the intensity or amplitude of the audio level in FM depends upon the amount of frequency deviation of the carrier. If all the frequencies over which the carrier deviates are not amplified an equal amount by the RF circuits then it is obvious that the variations in the audio level in the output of the receiver will not be the same as those transmitted. This results in distortion of the audio output of the receiver.

Figure 12. Typical response of RF stage in FM receivers.



A majority of the receivers in use are connected to a dipole antenna by a balanced transmission line system. When this system is used, the antenna input circuit makes use of a low impedance primary winding on the antenna transformer which is balanced to ground by means of a center tap on this winding. Another system uses an unbalanced coaxial or a parallel line with one conductor connected to RF ground. The other conductor is then tapped directly to the RF coil at a point which represents optimum coupling.

### Mixer and Oscillator Circuits

Mixer and oscillator circuits, like the RF circuit, are very similar to those used in the conventional superhetrodyne receiver. However, stability of the oscillator circuit is of much greater importance as the operating frequency is raised and careful design must be used if continuous retuning during operation is to be avoided. To keep drift to a minimum, some precautions include the use of low loss insulation on the gang condenser and coil forms, the use of an air condenser for trimming, careful placement of parts and, in addition to this, the use of a temperature compensating capacitor to bring the total drift to as near zero as possible. A temperature compensating capacitor changes in a direction opposite to that of the other components and if properly chosen will keep drift to a minimum.

### Double Conversion

One of the most serious problems encountered in the design of early FM receivers was frequency instability of the local oscillator. Such instability caused receiver drift, poor immunity to physical shocks and made the use of pushbuttons for FM impractical. Since the signal frequencies of the old FM band ranged from 42 to 50 MC, the lowest frequency range at which the oscillator could operate to produce the intermediate frequency of 4.3 MC was 37.3 to 45.7 MC. The design of a stable oscillator at these frequencies is difficult and requires extremely rugged mechanical construction which in turn increased production costs and selling prices.

To overcome these disadvantages, an ingenious "double-conversion" design was evolved by General Electric engineers which permitted the local oscillator to operate at a much lower frequency with greatly improved frequency stability characteristics.

As the words "double-conversion" imply, the incoming signal is converted or mixed with the local oscillator signal twice, the same oscillator frequency being used twice during this conversion process. The incoming signal is mixed in the usual manner in the first converter stage — however, along with the difference frequency formed by conversion, the first converter tube also passes the original oscillator signal. Thus the difference frequency and the original oscillator voltage are fed into the second converter tube and mixed again to form the final intermediate frequency.

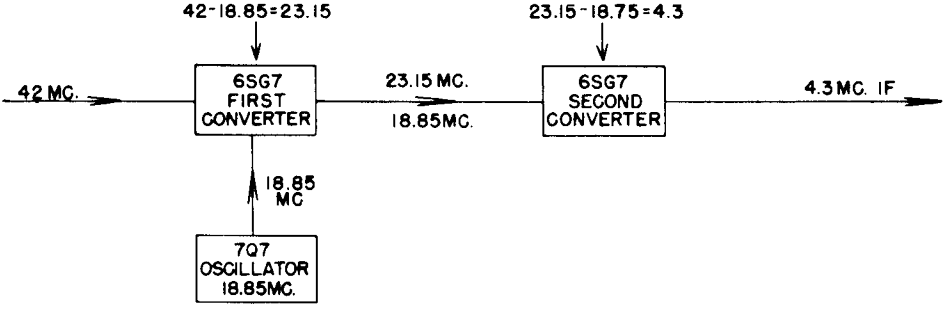
The General Electric Model 40, AM-FM receiver employs this system of double conversion and portions of the circuit are reproduced here in figure 13 to illustrate the functioning of this type of circuit.

To illustrate the action, consider an FM signal of 42 MC to which the receiver is tuned. The oscillator frequency for this setting of the tuning control is 18.85 MC and it hetrodynes or beats in the first converter tube with the 42 MC signal to form 23.15 MC (42 — 18.85). The original oscillator signal of 18.85 also passes through the first converter and thus two frequencies are fed into the second converter. Hetrodyning action again takes place in the second converter which mixes 23.15 MC and 18.85 MC to produce the 4.3 MC intermediate frequency (23.15 — 18.85).

### Requirements of the IF Circuits

The intermediate frequency amplifier of an FM receiver must have a broader response than that used in AM receivers and it should have a uniform response over the entire range of frequencies contained in the transmitted signal.

Figure 13. Simplified diagram of double conversion circuit used in the General Electric Model 40 AM-FM receiver.



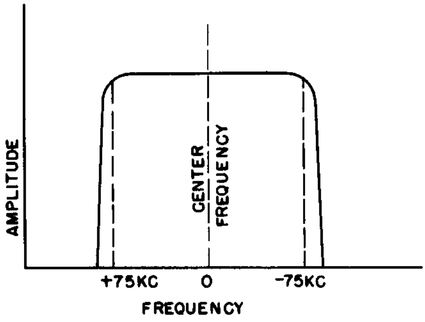


Figure 14. Ideal IF selectivity curve.

In other words, the ideal frequency response to the IF amplifier should be flat topped for about 150 KCS and then drop off rapidly beyond this range as shown in figure 14. However, such an ideal response is not practicable and is compensated for as shown later when we take up the action of the limiter. Due to the comparatively high intermediate frequency used in FM receivers, the stage gain is rather low and also there is a tendency toward regeneration unless particular care is taken in the design of the IF circuits.

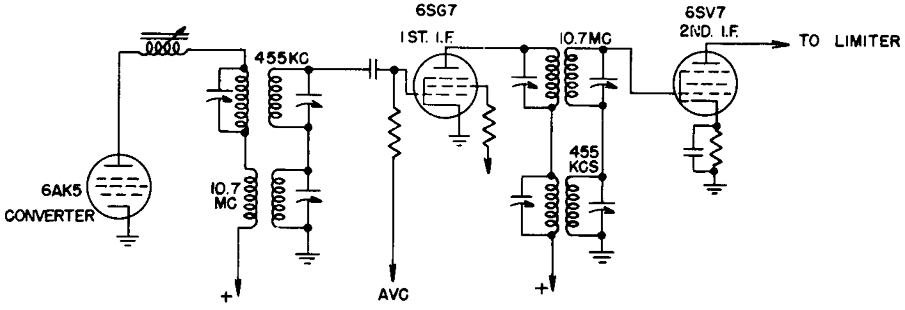
The IF amplifier in FM receivers must also be able to reject interfering signals just as in AM receivers and therefore, its response should not be any broader than is necessary to pass the band of frequencies necessary for satisfactory reception of FM signals.

It has been general practice to employ three IF stages including the limiter. This is a greater number than is used in AM receivers and is due to the fact that a high signal level is required for efficient operation of the limiter and also because of the lower gain per stage at the higher IF frequencies used in FM receivers.

The center frequency of the IF should be as low as possible, since the voltage gain per stage of an IF amplifier is reduced as the frequency is raised. It should not, however, be reduced to the point where image difficulties are encountered. There are many considerations involved in the selection of a suitable IF. For the new high frequency FM band of 88 to 108 megacycles, an intermediate frequency of 10.7 MCS is usually employed. However, quite a few FM receivers were earlier manufactured with an IF of 2.1 and 4.3 megacycles.

Modern combination FM-AM receivers usually use the same tubes as far as possible for both services. The IF transformer for both FM and AM are connected in series, as shown in figure 15. This is

Figure 15. Partial IF circuit of General Electric Model 417-A AM-FM receiver.



possible since the IF transformers are resonant circuits and the resonant frequency of the IF transformers used for the FM channel is much higher than that used in the AM channel. The IF section resonated at 455 KCS will offer practically no impedance to currents at 10.7 MC, and likewise, the IF section resonated at 10.7 MC offers very little impedance to currents at 455 KCS.

### The Limiter Stage

Thus far, the various circuits that we have covered in the FM receiver have been pretty much the same as those used in the ordinary AM receiver except for the special requirements mentioned above. However, the limiter stage is considerably different from anything used in conventional receivers, although it is part of the FM IF system.

The limiter is part of the final IF amplifier stage and its main function is to remove all amplitude variations that might be present in the IF signal up to the input of the limiter and to feed a signal to the discriminator circuit that is constant in amplitude. In other words, it limits or shaves off any peaks that might be present in the IF signal due to noise or undesired signals. This is necessary since any amplitude variations in the signal reaching the discriminator would result in distortion and noise in the output of the receiver.

A good example of this action is shown in figure 16, which compares the limiter to a gate which removes all amplitude variations in the signal above a certain level as determined by the gate, and passes a signal that is constant in amplitude.

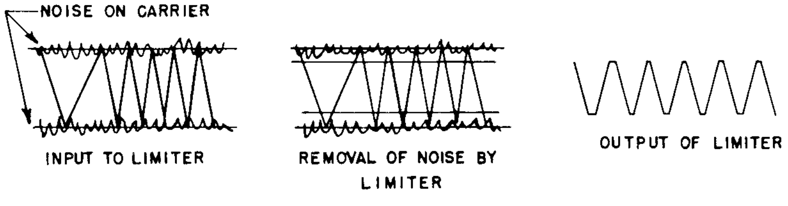
At first, it would seem that the action of the limiter in flattening the plate current peaks would introduce severe distortion in the ouput of the receiver, since the plate current variations are not exact reproductions of the grid voltage variations. This would be true in an AM receiver; however, in FM the modulation component is contained in the frequency deviations of the signal rather than in amplitude variations of the signal. Flattening of the plate current waveform will therefore not introduce audio distortion.

An important point to bring out in connection with satisfactory limiter action is in the amount of signal voltage that is required at the imput to the limiter. If the signal at the limiter grid is too low for satisfactory limiter action, it will cause two undesirable effects. First of these is that any amplitude variations in the signal due to noise will not be clipped off, and the second is that the dynamic range of the signal as transmitted is not duplicated in the receiver.

### The Discriminator Stage

The second point at which the

Figure 16. Limiter operation.



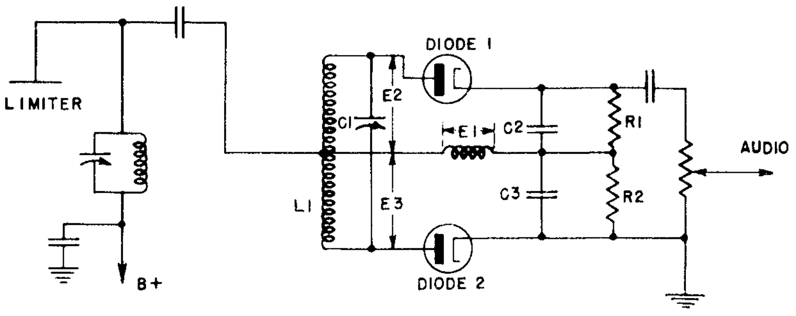
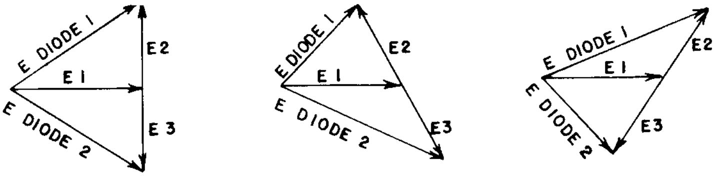


Figure 17. Conventional discriminator circuit.

FM receiver is considerably different from an AM receiver is in the method used to demodulate the IF signal. Since in FM the modulating voltage or audio component is contained in frequency deviation of the signal, some means of converting these frequency changes back to voltage changes that vary in accordance with the audio or modulating voltage must be employed. The circuit used for this purpose is known as a discriminator because of its ability to discriminate between frequency deviations above and below those of the center frequency. Fundamentally, the discriminator performs the same function as the 2nd detector in an ordinary superhetrodyne but its action is quite different. Whereas the ordinary diode detector converts amplitude changes into audio voltage, the discriminator converts *frequency* changes into audio voltage.

Figure 17 illustrates a conventional discriminator stage which consists essentially of two diode rectifiers differentially connected so that the d-c potentials across their respective load resistors are subtractive. These two d-c voltages (across R1 and R2 in figure 17) are proportional to the a-c voltages applied to the diodes. The a-c voltage applied to each diode is the vector sum of E1 and the voltage across that half of L1 which is connected to the diode plate, as shown in the diagrams in figure 18. E1 has practically the same amplitude and phase as the voltage across the tank in the limiter plate circuit. The current in this tank induces a voltage in L1, which causes a cir-

Figure 18. Vector representation of discriminator action (A, B, C).



A- CARRIER FREQ. AT I.F.   B-CARRIER FREQ. ABOVE I.F.   C-CARRIER FREQ. BELOW I.F.

culating current to flow in the resonant circuit composed of L1 and C1. E2 and E3 are the voltage drops which occur across each half of L1 as a result of this circulating current. When the carrier frequency is equal to the frequency at which the discriminator transformer is tuned (figure 18A), the a-c voltage applied to diode 1 equals that applied to diode 2, therefore the rectified voltages are equal and since they are bucking voltages, the output of the discriminator is zero.

When the carrier frequency increases during a half cycle of modulation, the phase relations between E1, E2 and E3 change in accordance with figure 18B, and it is evident that the vector sum of the voltages applied to diode 2 exceeds the vector sum of the voltages applied to diode 1; this results in a higher rectified voltage across R2 than R1. The instantaneous difference of the rectified voltages appears as a negative voltage in the discriminator output. Figure 18C shows the condition occuring when the carrier frequency swings below the resonant frequency of the discriminator transformer, the end result being a positive voltage at the output of the discriminator.

The important fact in discriminator action is that the output voltage is proportional to the difference between E diode 1 and E diode 2. This is true because the d-c voltages appearing across R1 and R2 vary directly with E diode 1 and E diode 2, respectively, and the instantaneous output voltage is the difference between the rectified voltage drops.

In considering the effect of amplitude variations on the discriminator output, refer again to the vector diagrams of figure 18. An increase in the amplitude of the voltage applied to the discriminator would increase all the vectors in the diagram proportionately. In other words, the effect would be as though the vector diagrams were enlarged photographically. It can be seen that while the phase relationships would remain the same, the difference between E diode 1 and E diode 2 would increase, so long as the frequency of the applied voltage differed even slightly from the receiver IF. Thus, components of amplitude modulation would be detected and passed on to the audio amplifier. Ordinarily, discriminators are preceded by limiters which remove most of the amplitude variations as shown in the preceding pages, but the discriminator itself is not a device capable of rejecting amplitude modulation, except when the instantaneous frequency of the applied carrier is exactly equal to the resonant frequency of the discriminator transformer. This condition occurs only twice in every modulation cycle.

### The Ratio Detector

A new device now appearing in post-war FM receivers is the ratio detector. This circuit also converts a frequency modulated carrier into an audio signal but has the additional advantage of being inherently insensitive to amplitude modulation. This characteristic enables the ratio detector to be used without the usual preceding limiter stage, thus affording the use of a high gain IF stage instead of the low-gain limiter.

A schematic of the fundamental ratio detector is shown in figure 19. C3, C4, and C7 have very little reactance at the intermediate frequency, so it is evident that the parallel resonant circuit L2-C2 is the true load for the driver stage, this stage being shunt fed. A driver stage, in this case, is nothing more than a conventional IF amplifier preceding the ratio detector. L2 is inductively coupled to L1, therefore a comparison of figures 17 and 19 will show that as far as the a-c voltages applied to the diodes are concerned, these circuits are almost exactly similar and the same vector diagrams used in the analysis of figure 17 can be used to portray the a-c voltages across the diodes of figure 19.

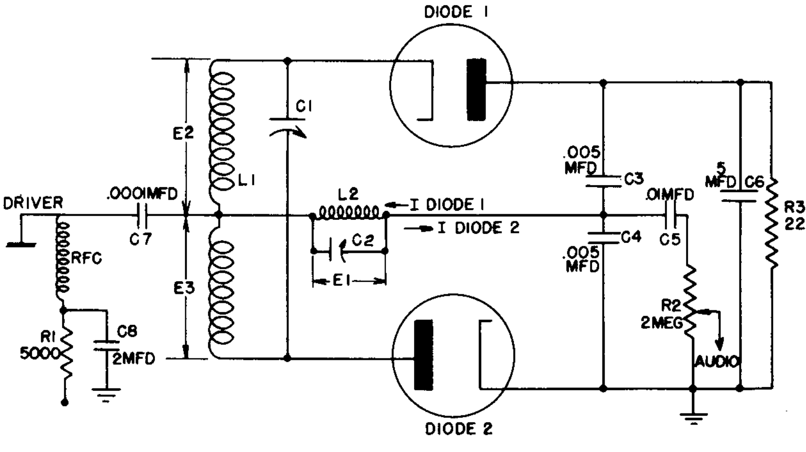
Here the similarity ends, because the ratio detector method of extracting intelligence from the FM carrier differs greatly from previously used methods. Diode 1, R3, and diode 2 complete a series circuit fed by the a-c voltage across L1. Since the two diodes are in series, they will conduct on the same half cycle, and the rectified current through R3 will cause a negative potential to appear at the plate of diode 1. The time constant of R3-C6 is usually about .2 second, so that the negative potential at the plate of diode 1 will remain constant even at the lowest audio frequencies to be reproduced.

C3 will be charged by the rectified current through diode 1 to a voltage proportional to the voltage represented by vector E diode 1 (figure 18), and C4 will be charged through diode 2 in proportion to the vector E diode 2. Since the magnitudes of these vectors differ according to the instantaneous frequency of the carrier, the voltages across C3 and C4 will differ proportionately, the voltage across C3 being the larger of the two voltages at carrier frequencies below the IF and the smaller at frequencies above the IF.

Note that the voltages across C3 and C4 are additive and that their sum is fixed by the constant potential across R3. Therefore, while the ratio of these voltages will vary at an audio rate, their sum will always be constant and equal to the voltage across R3. The potential at the junction of C3 and C4 will vary at an audio rate when an FM carrier is applied to the detector, hence audio voltage is extracted at this point and fed into the audio amplifier.

The rejection of amplitude modulation in the ratio detector may be

Figure 19. Schematic diagram of fundamental ratio detector.



explained as follows: A rapid increase in the amplitude of the carrier applied to the ratio detector will tend to increase the d-c voltages across C3 and C4. The sum of these voltages must always be equal to the voltage across C6. The voltage across C6 cannot change with a rapid increase in the amplitude of the carrier, due to the large time constant of R3 and C6. Therefore, this constant potential across C6 prevents the voltages across C3 and C4 from rising with an increase in the strength of the carrier. A reduction in carrier amplitude is prevented from appearing as a reduction in the voltage across C4 in the same way. The constant voltage across C6 can be considered to be a stabilizing voltage, i.e. it stabilizes the ratio detector output against amplitude modulation of the applied carrier.

The time constant of R3-C6 is not too large to prevent average changes in carrier level from appearing as changes in voltage across R3; in other words, the voltage across R3 is proportional to the average strength of the received carrier. Thus, this voltage serves as an excellent AVC voltage.

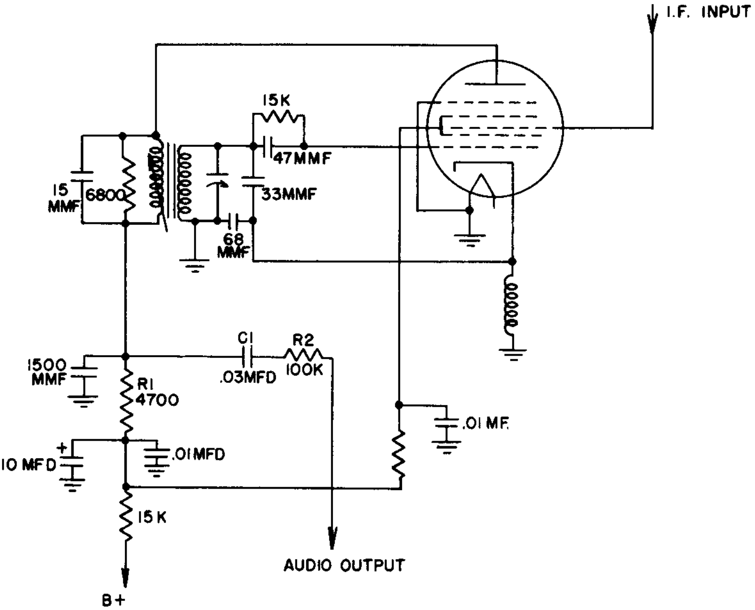
There is no "threshold" effect apparent in the ratio detector. That is, there is no minimum carrier level which must be applied to the detector to cause noise attenuation as in other types of FM detectors requiring the use of a limiter stage.

### The Locked Oscillator Detector

Another postwar development in FM second detectors is the locked oscillator circuit which is also inherently insensitive to amplitude impulses and, therefore, does not require the conventional limiter stage.

Figure 20 shows the schematic diagram of a typical locked oscil-

Figure 20. Locked oscillator type 2nd detector



lator circuit. A special tube is used, one section of which operates as a modified Colpitts oscillator at the intermediate frequency. The IF amplifier output is fed into the injection grid of the same tube and the coupling between the two circuits causes the oscillator to lock in and follow the variations in frequency of the IF signal. As the oscillator frequency decreases, the plate current through R1, the audio load resistor increases, and as the oscillator frequency increases, the plate current decreases. These current variations are linear with respect to the frequency deviation of the applied IF signal and the plate current therefore reproduces the same wave shape as the modulation of the incoming FM signal. This audio signal is then fed into the audio stages through the de-emphasis network consisting of C1 and R2.

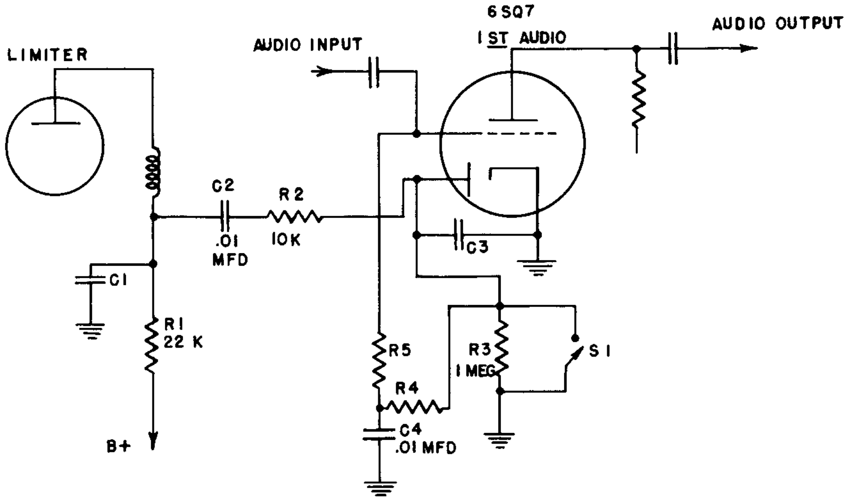
### Squelch Circuits

As pointed out previously, the limiter circuit of an FM receiver will only remove noise when an FM signal of sufficient strength is present at the input of the limiter to provide good limiting action.

Since the noise limiter circuits only operate when an FM carrier is present, noise between stations will ride through with undiminished amplitude. In order to remove this undesirable effect, some FM receivers make use of an FM station silencer circuit or simply a squelch circuit which operates on the amplitude-modulated noise signals present between stations to produce squelch or quieting of the audio amplifier.

A breakdown of a typical squelch circuit used in several FM receivers is shown in figure 21. The noise signal appears in the limiter plate circuit and develops a voltage across R1, which is in series with the primary of the discriminator transformer. This voltage is applied to one diode of the 6SQ7 tube through C2 and R2, and is rectified

Figure 21. Typical squelch circuit.



by the diode. The current due to rectification of this noise voltage flows from the diode to the cathode which is grounded, through R3, and back to the diode, thus developing a voltage across R3 with the grounded end positive with respect to the end connected to the diode plate. This rectified voltage is applied to the grid of the 6SQ7 1st audio tube through R4 and R5, making the grid more negative than the cathode by an amount equal to the rectified voltage developed across R3. This rectified voltage is sufficient to completely bias off the 6SQ7 so that no audio signal is passed.

When an FM signal is received that is strong enough to satisfactorily operate the limiter, the noise or amplitude-modulated signal is removed altogether or greatly reduced by the operation of the limiter as previously described. Therefore, the voltage developed across R2 due to a noise signal is removed or greatly reduced so that little or no current flows in the diode circuit containing R3, and consequently, the cut-off bias previously applied to the grid of the 6SQ7 is removed and the tube amplifies the audio signal and passes it on in the normal manner.

If it is desirable to receive FM stations that are too weak to satisfactorily operate the limiter, the squelch voltage can be manually removed by closing switch S1, which simply shorts out R3 and places the diode plate of the 6SQ7 at ground potential. However, considerable noise is likely to be present when receiving such weak signals.

## SECTION 4

# PRACTICAL APPLICATIONS OF THE OSCILLOSCOPE AND SWEEP FREQUENCY SIGNAL GENERATOR

### General Considerations

Before proceeding directly to a step-by-step visual alignment process on a typical FM receiver, it would be well to examine, in general terms, the objectives and advantages of visual alignment.

**First,** *what is visual alignment?*

Visual alignment is a method of aligning AM and FM receivers that enables the serviceman to actually see the response curves of various circuits as they are tuned. It is the quickest, most accurate system of alignment possible. It can be applied advantageously to almost any make or type of receiving circuit now in existence.

**Second,** *why use visual alignment?*

Any system which enables the serviceman to turn out *better* work in *less* time means more profits. Such a system is visual alignment.

FM alignment methods employing an AM signal generator and a vacuum tube voltmeter have been described in the past. However, such methods usually require the use of external loading resistors which must be carefully soldered into place with short leads, disconnected after one stage is aligned, reconnected to the next stage and so on. This is a time-consuming and tedious process and is even more exasperating when the points to which the loading resistors are to be connected are buried under two or three layers of by-pass capacitors and resistors. At best, such systems of alignment leave much to be desired because there is *no positive way* of determining if the job has been done correctly. Visual alignment circumvents these difficulties because the basic circuits of the receiver are not disturbed and a true picture of the actual operating conditions is obtained. Alignment is simply a matter of connecting the instruments and adjusting the trimmers until the correct trace is observed on the oscilloscope — and this can be done in a matter of minutes. Furthermore, the visual alignment system can be used right up to and *including* the front end of the receiver.

**Third,** *how is visual alignment used?*

In the conventional FM receiver, using a limiter and a discriminator, the vertical plates of the oscilloscope are connected to the grid of the limiter stage which acts as a rectifier as shown in the simplified diagram in figure 7. The a-c voltage which modulates the FM oscillator is fed into the horizontal plates. The FM signal is then applied to the input of each IF stage, working forward as the correct response curve is obtained upon manipulation of trimmers or slugs. Upon completion of IF and front end alignment, the vertical plates of the oscilloscope are connected to the discriminator output and this stage is aligned, completing the job.

Receivers employing ratio detectors require a slightly different approach, since a limiter tube is not available to furnish rectified voltage to the vertical plates of the oscilloscope. In this case, ratio detector alignment is carried out first, after which the IF stages are aligned, one by one, with the output of the ratio detector serving as the observation point. The typical discriminator curve obtained at the output of the ratio detector depends critically upon the correct alignment of the IF stages which are therefore tuned for maximum amplitude and linearity of the discriminator curve.

### Visual Alignment of Locked Oscillator FM Receivers

Visual alignment procedure for FM receivers employing the locked oscillator type of second detector is similar to the procedure used for ratio detector receivers.

The vertical amplifier of the oscilloscope is connected to the audio output of the locked oscillator. The signal generator, set to sweep across the center of the intermediate frequency, is first fed into the grid of the last IF tube. Tuning adjustments on the locked oscillator are then set to result in the typical discriminator trace as illustrated in figure 27. The trace at this point may not slope as much as the conventional discriminator trace, and if the signal input is low, the trace may appear almost vertical. The locked oscillator should be adjusted, however, for maximum amplitude and symmetry. It will be found that tuning adjustments on the locked oscillator will affect the frequency which will result in a more or less horizontal shift of the trace across the screen. The trace should, of course, be centered on the screen so that the midpoint of the curve falls on the center frequency point. The trimmers or inductive slugs in the last IF transformer should then be adjusted for maximum symmetry and amplitude. In general, IF trimmer adjustments should affect only the symmetry and amplitude of the trace. If, however, regeneration or undesirable coupling is present in the IF stages, small frequency changes may be observed.

The signal generator output is then shifted successively to the preceding IF amplifier input grids and the trimmers or inductive slugs adjusted for symmetry and amplitude of the detector trace. In any case where there is a choice between maximum amplitude and symmetry, adjustments should be made which favor symmetry. The reason for this is that over-coupled IF transformers are usually employed with this type of detector and it is therefore possible to obtain more gain by tuning to one side rather than to the center of the double-peaked response curve. Such misalignment, while resulting in more gain, will result in serious distortion of the output signal as evidenced by the non-symmetrical output trace.

It can be seen, as in the case of the ratio detector, that the final output curve depends critically upon the correct alignment of the IF channel, hence this method of alignment will quickly reveal even slight inaccuracies in IF tuning adjustments.

### Visual Alignment of the General Electric Model 417-A AM-FM Receiver

Figure 22 (p. 29) illustrates the schematic diagram for the General Electric Model 417A, combination AM-FM receiver which covers two FM bands, two short wave bands and the standard broadcast bands.

The circuit consists of a 6AG5 RF amplifier, 6AK5 converter, 6AK5 oscillator, 6SG7 1st IF amplifier, 6SV7 2nd IF amplifier, 6SH7 FM limiter and AM detector, 6AQ7 FM discriminator and audio frequency amplifier, 6V6 power output, 6SC7 phono preamplifier and 5Y3 rectifier. The standard intermediate frequency of 455 KCS is employed on the broadcast and short wave bands while an intermediate frequency of 10.7 MC is used for the two FM bands.

Alignment is carried out in the following order:

1. FM channel of IF amplifier (10.7 MC)
2. AM channel of IF amplifier (455 KCS)
3. FM oscillator [dial calibration (FM band No. 2)]
4. FM converter and RF amplifier (FM band No. 2)
5. FM Oscillator [Dial calibration (FM band No. 1)]
6. FM converter and RF amplifier (FM band No. 1)
7. SW oscillator [Dial calibration (SW band No. 2)]
8. SW converter and RF amplifier (SW band No. 2)
9. SW oscillator [Dial calibration (SW band No. 1)]
10. SW converter and RF amplifier (SW band No. 1)
11. BC oscillator (HF dial calibration)
12. BC converter and RF amplifier
13. BC oscillator (low frequency dial calibration)
    (Repeat steps 11 and 13)

Since alignment procedures for the two FM and two SW bands are identical except for the use of different alignment frequencies, the alignment process for one FM band and the BC band only will be described in detail.

### Visual Alignment — FM IF Channel 10.7 MC

Set the signal generator controls to produce an output signal of 10.7 MC, frequency modulated by 60 cycles with a total deviation of 600 KCS. Connect the audio output of the signal generator (60 CPS) to the horizontal amplifier of the oscilloscope and set the oscilloscope controls to external sweep.

Remove the 6AQ7 discriminator and 6AK5· oscillator tubes from their sockets. Set receiver band switch to FM band 1. Connect vertical amplifier of oscilloscope to the grid of the 6SH7 limiter through a 200,000 ohm resistor. A shielded lead should be used for this connection. Connect the RF output from the signal generator to the grid of the 6SV7 second IF amplifier through a .01 mfd. condenser. Figure 23 illustrates these connections.

Trimmers C28 and C94 on IF transformer T9 are now adjusted for maximum amplitude on the oscilloscope. Figure 24 illustrates the approximate shape of the IF curve for this stage. Increasing the RF output of the signal generator will tend to broaden the overall curve.

Shift the signal generator output to the grid of the 6SG7 1st IF amplifier through the .01 mfd. condenser. Adjust trimmers C26 and C93 on IF transformer T8 for maximum amplitude on the oscilloscope. Figure 25 illustrates the approximate pattern for *two* stages. The signal generator output level will again affect the overall shape of the pattern.

Shift the signal generator output lead to the grid of the 6AK5 converter tube through the .01 mfd. condenser and adjust trimmer C24 on IF transformer T7 and the slug in peaking coil L10 for maximum amplitude. The over-all IF curve should approximate figure 26 but depends to a great extent upon the signal level fed into the converter grid.

Regeneration in the IF stages will result in a non-symmetrical or

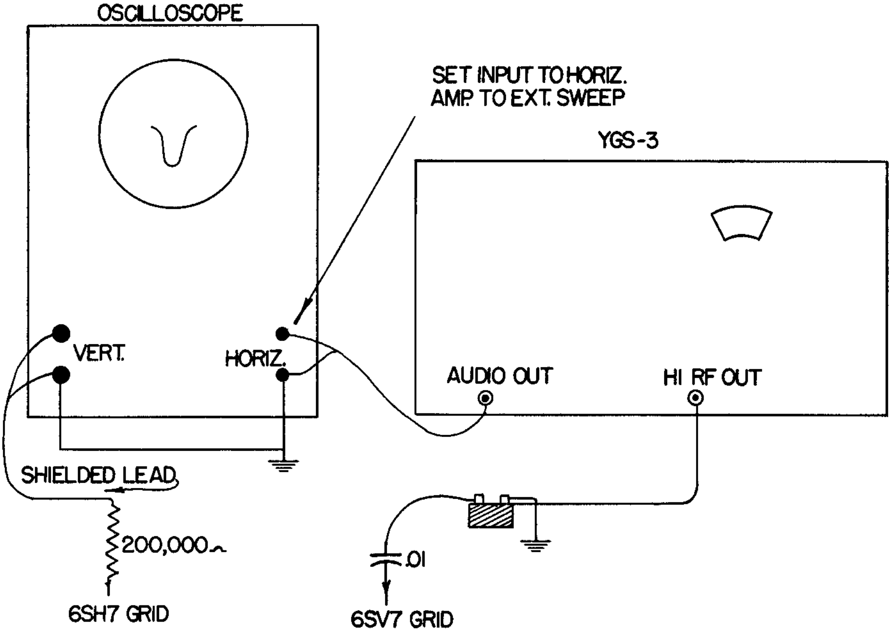
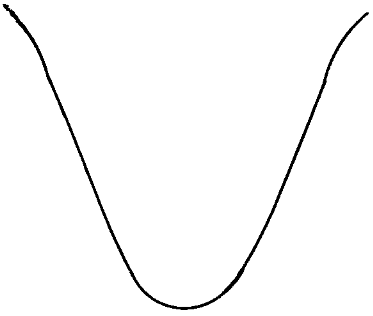
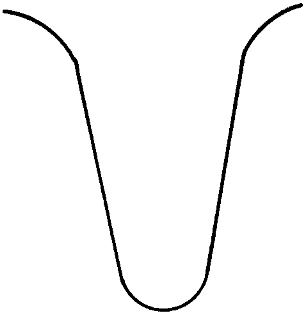


Figure 23.

Figure 24.

Figure 25.





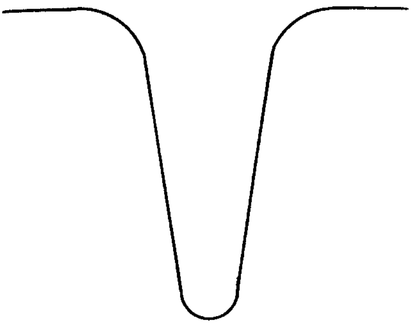


Figure 26.

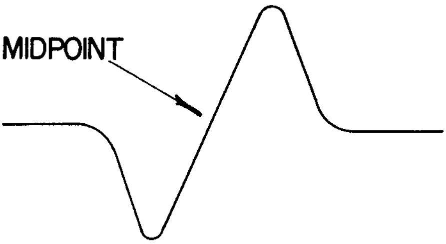


Figure 27.

sharply peaked curve which will be immediately evident on the response curve. If the signal generator sweep has been set for a total deviation of 600 KCS, the total horizontal trace will also represent 600 KCS on the oscilloscope screen. If at 70% of maximum amplitude the IF curve occupies one quarter of the total horizontal space, bandwidth is ¼ of 600 KC, or 150 KC. The accuracy of these figures depend, of course, upon the accuracy of the sweep calibration of the signal generator and also upon the linearity of the oscilloscope. In general, however, this method of determining bandwidth is sufficiently accurate for most purposes and can, of course, be done in a matter of seconds.

Discriminator alignment is carried out by replacing the 6AQ7 tube and connecting the vertical amplifier of the oscilloscope to the junction of R21 and C29 (discriminator output). The signal generator output should remain on the converter grid. Adjust trimmer C48 (primary) in Transformer T10 for maximum amplitude. Then adjust C49 (secondary) for vertical symmetry with respect to the midpoint horizontal traces. Readjust C48 for straightest possible slope. Figure 27 represents the approximate pattern which should be obtained. It is essential that the oblique portion of this reponse curve be as straight as possible because any irregularities will result in distortion of the audio signal. At the same time, the amplitude, or length should be as great as possible so that maximum output will be obtained. This completes the IF alignment.

### Visual Alignment — Front End, FM Band 1 (42 to 50 MC)

The usual nuisance of "rocking-in" padders, especially on the short wave and FM bands (in front end alignment) is entirely eliminated when visual alignment is used. This method "rocks-in" the padders electronically, results in a symmetrical response curve, and yields an overall picture of circuit performance which can be very valuable. For example, regeneration in a stage, as well as spurious responses, are missed when older techniques are used. These are immediately apparent on a scope and can be corrected without waste of time.

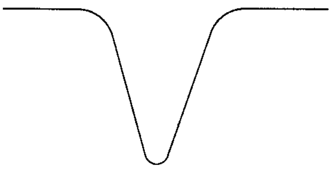
The vertical amplifier of the oscilloscope is connected to the 6SH7 limiter grid through a 200,000 ohm resistor. The RF output of the signal generator is connected to the antenna input terminals of the receiver through a dummy antenna consisting of a 250 to 700 ohm carbon resistor and the 6AK5 oscillator tube is replaced. Audio output from the signal generator is left connected to the horizontal amplifier of the oscilloscope. Set the receiver dial to 43 MC and adjust the signal generator to obtain 43 MC output *amplitude* modulated by 60 cycles. If the receiver dial calibration is correct, an oblique, straight trace will be obtained on the screen of the scope. If this is not obtained, the oscillator padder C45 should be adjusted until this trace is present on the scope. The dial calibration point is now correct.

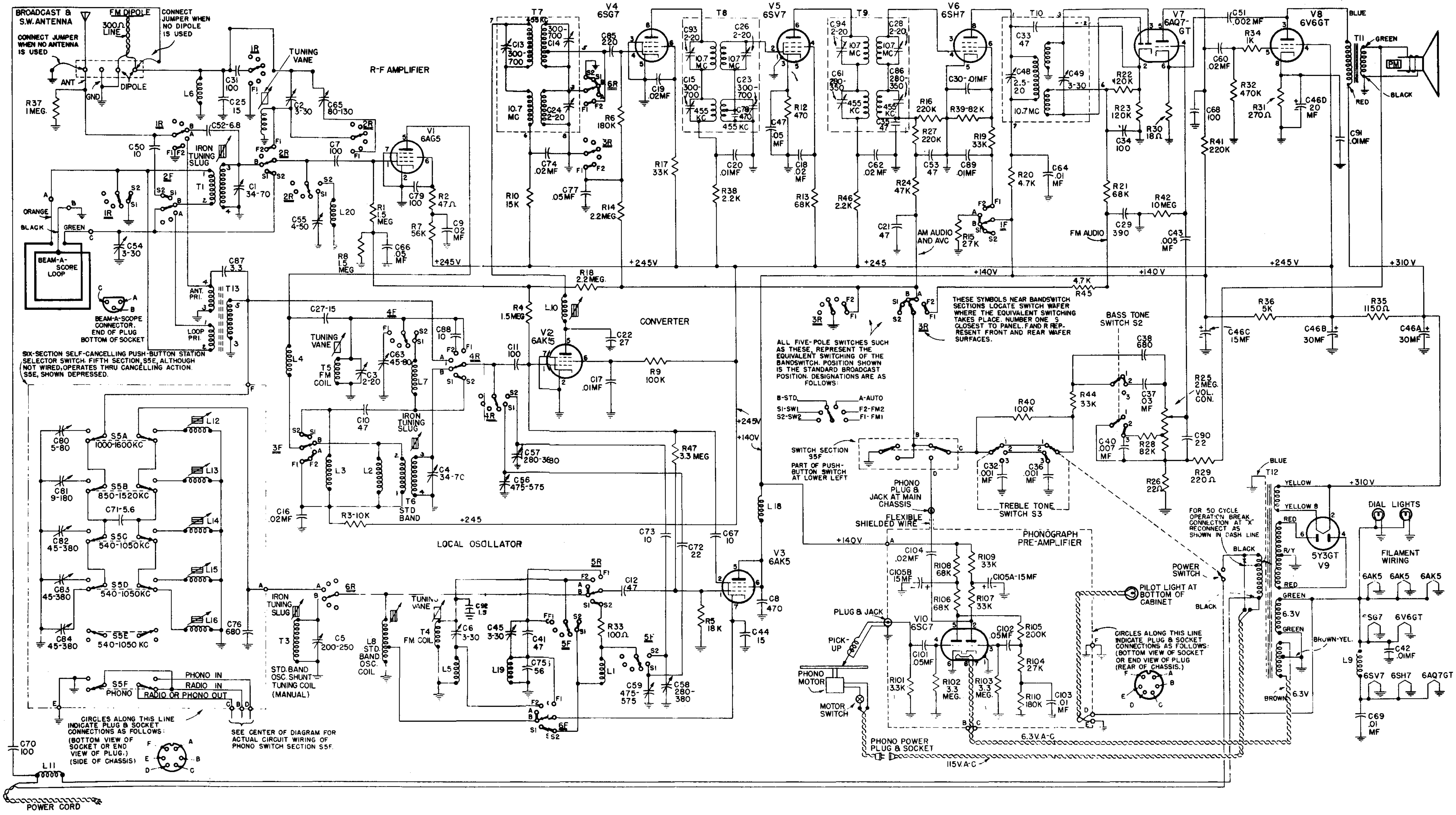
Alignment of the converter and antenna circuits is carried out at 46 MC, to which the receiver is next tuned. All connections remain the same and the signal generator is set to produce a frequency modulated signal with a center frequency of 46 MC and a deviation of ± 300 KCS. A response curve similar to figure 26 should now be present on the scope and if the receiver dial is tuned, the curve should move across the screen. After centering the response curve on the screen, adjust converter trimmer C63 for maximum amplitude. This adjustment is usually accompanied by a slight frequency shift which will be indicated by horizontal movement of the response curve on the scope. The important feature at this point is that the setting for C63 which produces maximum amplitude can be quickly determined despite small frequency shifts or oscillator "pulling". The RF amplifier circuit is peaked for maximum amplitude by adjusting trimmer C65. This completes the front end alignment for FM band 1. The identical procedure is used on FM band 2 with the exception that the alignment frequencies will be different. This same system can be used for front end alignment of the short wave and broadcast bands. It will be found that "electronic rocking" is most advantageous on the higher frequencies where the oscillator "pulls" more readily with the converter.

### Visual Alignment — BC-IF Channel 455 KCS

Connect the vertical amplifier of the scope to the junction of R24 and C21 (second detector output) and switch the receiver bandswitch to the BC position. Audio output from the signal generator remains connected to the horizontal amplifier of the scope and the signal generator controls are set to produce a 455 KC output signal frequency modulated ± 20 KCS. Connect the RF output from the signal generator to the grid of the 6AK5 converter tube through a .01 mfd. condenser. Adjust the IF trimmers in the following order for maximum amplitude: C86, C61, C23, C14, C13. The signal generator output should be maintained as low as possible consistent with a clearly defined pattern. Figure 28 illustrates the approximate over-all IF curve which should be obtained upon completion of IF alignment.

Figure 28.





BROADCAST & S.W. ANTENNA

CONNECT JUMPER WHEN NO ANTENNA IS USED

CONNECT JUMPER WHEN NO DIPOLE IS USED

SIX-SECTION SELF-CANCELLING PUSH-BUTTON STATION SELECTOR SWITCH. FIFTH SECTION, S5E, ALTHOUGH NOT WIRED, OPERATES THRU CANCELLING ACTION. S5E, SHOWN DEPRESSED.

BEAM-A-SCOPE CONNECTOR. END OF PLUG BOTTOM OF SOCKET

CIRCLES ALONG THIS LINE INDICATE PLUG & SOCKET CONNECTIONS AS FOLLOWS: (BOTTOM VIEW OF SOCKET OR END VIEW OF PLUG.) (SIDE OF CHASSIS)

SEE CENTER OF DIAGRAM FOR ACTUAL CIRCUIT WIRING OF PHONO SWITCH SECTION S5F.

ALL FIVE-POLE SWITCHES SUCH AS THESE, REPRESENT THE EQUIVALENT SWITCHING OF THE BANDSWITCH. POSITION SHOWN IS THE STANDARD BROADCAST POSITION. DESIGNATIONS ARE AS FOLLOWS:

B-STD — A-AUTO
S1-SW1 — F2-FM2
S2-SW2 — F1-FM1

THESE SYMBOLS NEAR BANDSWITCH SECTIONS LOCATE SWITCH WAFER WHERE THE EQUIVALENT SWITCHING TAKES PLACE. NUMBER ONE S CLOSEST TO PANEL. F AND R REPRESENT FRONT AND REAR WAFER SURFACES.

SWITCH SECTION S5F PART OF PUSH-BUTTON SWITCH AT LOWER LEFT

FOR 50 CYCLE OPERATION BREAK CONNECTION AT "X". RECONNECT AS SHOWN IN DASH LINE

CIRCLES ALONG THIS LINE INDICATE PLUG & SOCKET CONNECTIONS AS FOLLOWS: (BOTTOM VIEW OF SOCKET OR END VIEW OF PLUG (REAR OF CHASSIS.)

Figure 22. Schematic diagram of General Electric Model 417-A Radio Phonograph.