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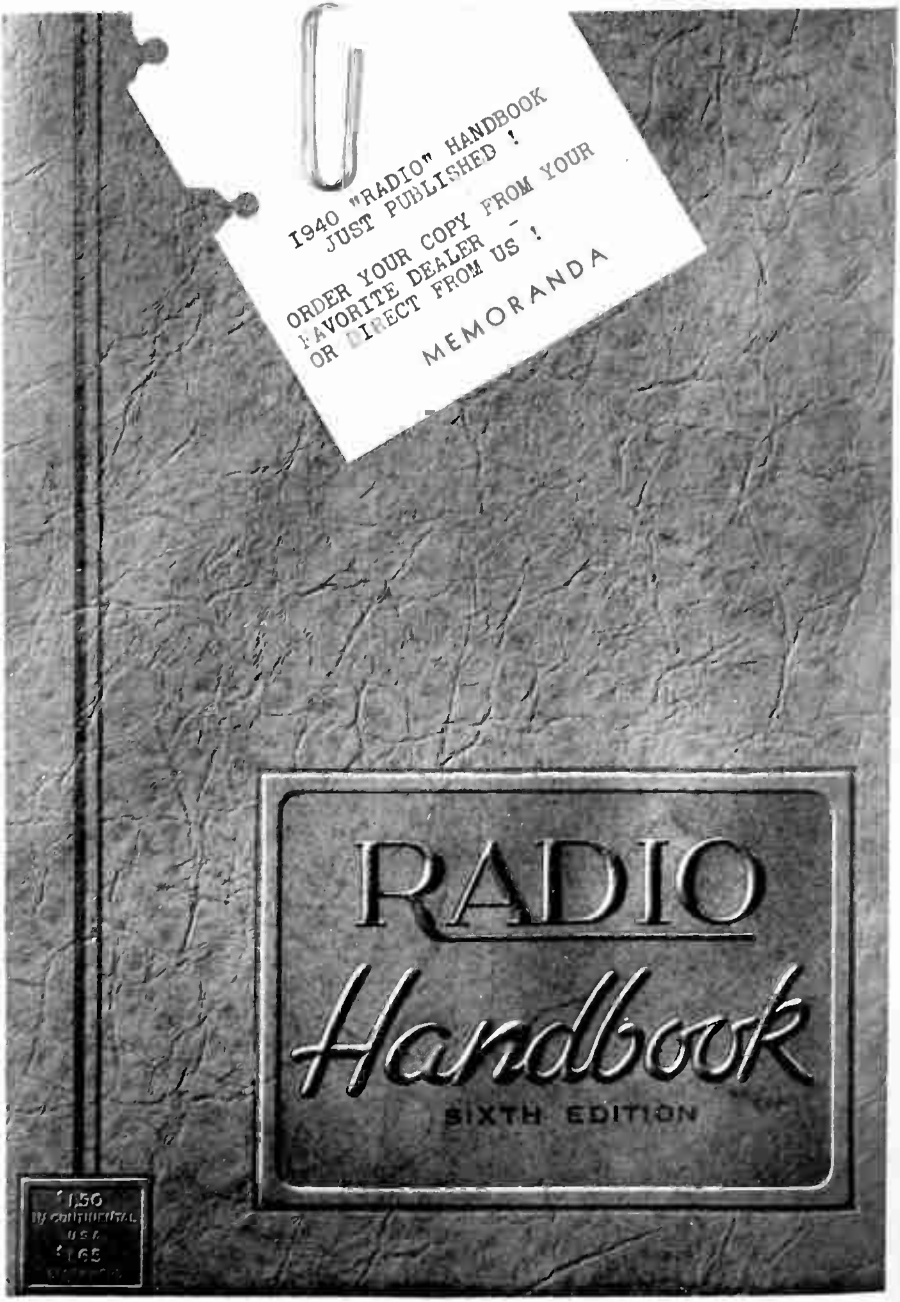
MARCH AND
APRIL, 1940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RADIO
Technical Digest

● MARCH - APRIL, 1940 NUMBER 16 ●

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¶ From Service, January, 1940

TUBES

By JOHN H. POTTS

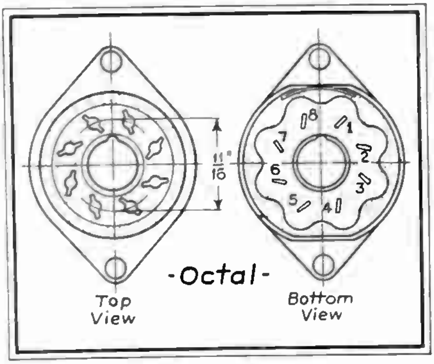
OCTAL, loktal, octalox, miniature tubes, bantam tubes, glass and metal tubes—tubes in radically different sizes and shapes and with assorted filament voltages and operating characteristics have emerged from the laboratories and plants of tube manufacturers during the past year. Many of these types were described in *Service*[1]; since then, however, over 70 types have crashed the market to the unconfined dismay of jobbers, servicemen and tube checker manufacturers.

• Portables

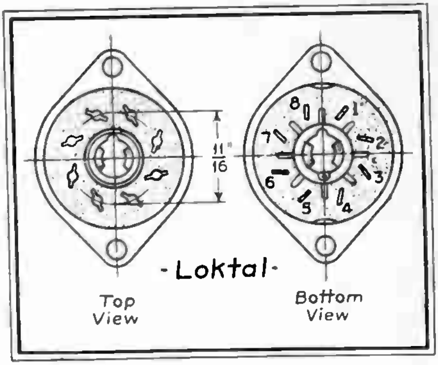
Time was when a battery-operated portable receiver required the services of a hardened piano-mover to transport it. Not so the new ones, with 1.4 volt tubes, which may be carried without inconvenience by a child. While a great deal of the reduction in weight in the new portables has been achieved through the increased efficiency of tube and circuit design, practically all the receivers now in use employ a 90-volt B battery. This B supply usually consists of two 45-volt units and, to render reasonably long service, they must have a certain size and weight. In this year's portables, this weight generally exceeds that of all the rest of the receiver, including the A battery. In many portables the latter is of insufficient ampere-hour capacity to give economical service. The unholy appetite of these portables for A-battery juice has been no unmixed blessing for dealers and servicemen. Since it is not usual to fit receivers of this type with pilot lights, it is easy for the user to forget to turn the receiver off when it is not being used. As a result, the A battery is quickly exhausted—and replacements are not cheap. Too often the battery replacement cost discourages the use of the receiver and has a deterring effect on sales.

A step forward in overcoming these limitations is represented in the new miniature battery tubes, just announced by RCA. These tubes are smaller than any of the more conventional types. The maximum overall length is 2⅛ inches

[1] Tubes, by D. Bee, SERVICE, Feb. 1939, p. 62. Also New Tubes, SERVICE, March, 1939, p. 133.



The metal, G, and GT types use the familiar octal base which fits the socket shown. RMA pin numbers are indicated on the bottom view.



Loktals, identified by heater voltage rating, employ an 8-pin base. A metal guide locks into the socket shown. RMA pin numbers on bottom view.

and the maximum diameter but ¾ inch—just about the size of a dime. The decrease in size has been made possible by eliminating the conventional base and bringing the heavy wires from the seal directly through a 7-pin glass button base so that they serve as pin connections to the socket, which is a special miniature type.

Due to this method of construction, it is possible to retain the same length of filament, grid and plate elements as are employed in conventional 1.4-volt tubes, yet the amount of space taken by the complete tube is less than that required by a standard GT type. This makes possible the design of a still more compact portable chassis.

Of particular note, however, is the fact that these new tubes are designed to operate efficiently on but one-half the B voltage usually employed in portable receivers. Since the limiting factor in the design of such receivers to achieve compactness is the space taken by the batteries, efficient operation on 45 volts means a considerable saving in size and weight. While the A battery requirements are the same, it is still possible to increase the size of the A battery to acquire more economical operation and yet make a smaller and lighter receiver.

These new miniature tubes are available in four types and permit the design of an efficient four-tube receiver with a total B-current drain of about 10 ma at 45 volts, with an output power of 65 milliwatts.

The four tube types are the 1R5 pentagrid converter, 1S4 power amplifier pentode, 1S5 diode-pentode and 1T4 super-control r.f. amplifier pentode. All these tubes are single-ended types; that is, there are no top caps.

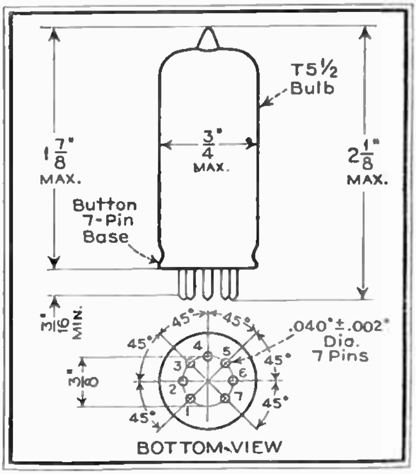
As compared with the standard

1N5GT r.f. pentode, the new miniature 1T4 has a mutual conductance of 700 micromhos with a plate and screen voltage of 45 at zero grid bias, while the mutual conductance of the 1N5GT is 750 at zero grid bias and twice the plate and screen voltages. In other words, the new miniature 1T4 will provide about 93 per cent as much amplification with but 50 per cent of the B voltage required by the 1N5GT. However, the plate current and screen current drain of the 1T4 at 45 volts amount to 2.6 ma, while the total B-current drain of the 1N5GT is but 1.5 ma at 90 volts. To summarize, then, the 1T4 will provide substantially the same gain at 45 volts as the 1N5GT at 90 volts, but the 1T4 will require more B current at the lower voltage. The filament voltage and current for each of these tubes are the same, 1.4 volts at 50 ma.

The type 1R5 converter is designed to give much better performance at 45 volts than other battery type converters at 90 volts. However, the only data available show its operation as a mixer, with a separate oscillator, so that direct comparison with standard types used as converters cannot be given at the present writing.

The voltage gain of the pentode section of the 1S5, with a plate and screen supply voltage of 41 is rated at 30, when the plate load resistor is 1 meg, and the screen resistor 3 megs.

The 1S4 power amplifier pentode has a maximum undistorted output at 45 volts of about one-fourth that



The decrease in size has been made possible, in the new miniature tubes, by eliminating the conventional base and bringing the wires from the seal directly through a 7-pin glass-button base.

of an equivalent pentode of the conventional type at 90 volts. This means that the *sound volume* will be about one-half that obtained at 90 volts with a larger output pentode, both requiring the same filament voltage and current.

These new tubes should work out well in hearing aids and other devices where efficiency, compactness and light weight are prime considerations.

There is a growing tendency toward combining a.c., d.c. operation along with battery operation of small portables. Accordingly, a new rectifier has been announced—the 117Z6GT—which is designed to operate directly from the line supply. As shown in figure 1, this new tube may be installed to provide both A and B supply for the portable, thus greatly extending the life of the batteries when the receiver is used in the home. Each of the sections of the 117Z6GT is designed to supply a maximum of 60 ma. Thus, as shown, one section may be filtered to supply the 50-ma drain of the filaments in series, while the other section may be used in the same manner for the B supply. Since the B-current drain is normally low, it is possible to use resistance-capacity filtration in this section without appreciable voltage drop. The high drain of the filaments is filtered through a choke, though in some cases the choke might be omitted and a resistance-capacity filter likewise used here. The voltage-dropping resistor R will be necessary if the choke is used to limit the filament current to 50 ma. This resistor may be used as part of the filter, if desired.

The heater of the 117Z6GT is center-tapped. Therefore, the heater sections may be connected in parallel and operated at 58.5 volts, if desired. If this is done, one or more additonal heater-type tubes may be employed in conjunction with the 117Z6GT to enable greater power output when the portable is operated from the power lines.

This new tube should prove handy and simple to adapt as a source of field excitation for dynamic speakers used in conjunction with p.-a. systems, "ham" receivers, etc. With cathodes and plates, respectively, tied together the total rated output is 120 ma.

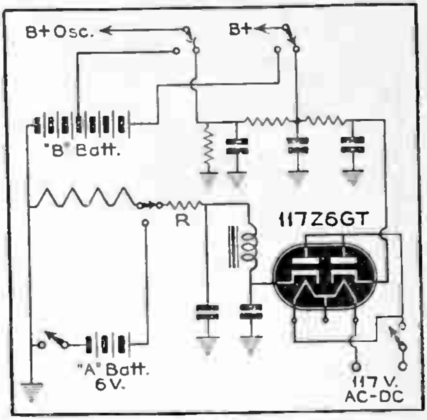


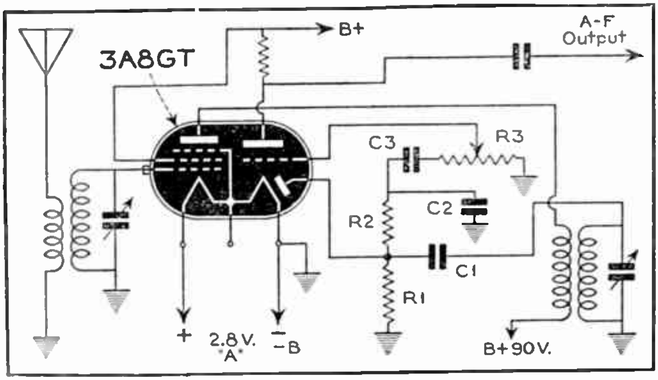
Figure 1. In accordance with the growing tendency toward combining a.c., d.c. operation of small portables, along with battery operation, a new 117-volt rectifier has been announced.

- Multi-Purpose Types

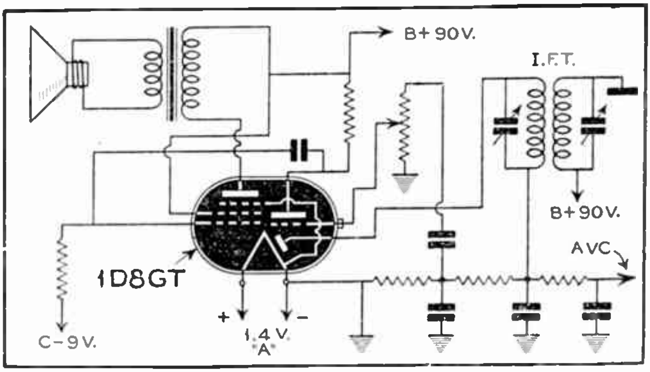
We have had double-purpose tubes for some time; now they come three in one envelope. Witness the 3A8GT and the 1D8GT, shown in circuit applications in figures 2 and 3.

The 3A8GT is a diode-triode-pentode detector-amplifier. The pentode section is designed for use as an r.f. amplifier and the triode section as an a.f. amplifier to follow the diode detector. The filament requires 50 ma at 2.8 volts, or, since it is mid-tapped, the two filaments may be connected in parallel and operated at 1.4 volts and 0.1 amp.; the latter is also the voltage and current rating of the 1D8GT.

The diagram, figure 2, shows the 3A8GT in an operating circuit in which the pentode section is connected to a tuned antenna trans-



Figures 2 (above) and 3. We have had double purpose tubes for some time but now they come three in one envelope. The 1D8GT and the 3A8GT are combination diode-triode-pentodes. The pentode section of the latter is designed with a remote-cutoff grid for r.f. applications. The pentode section of the 1D8GT is for power output applications.



former. The output of the pentode section is fed to the diode detector through a tuned stage. The demodulated a.f. voltage is developed across the diode load resistor R1 and the r.f. is filtered by the resistance-capacity filter R2-C2. The audio voltage then appears across the volume control, R3, the blocking condenser C3 preventing the d.c. component developed across the diode-load resistor from biasing the triode section. All returns are made to ground as is the negative filament. This means that all grids are at zero potential, neglecting such bias as will result from contact potential.

The G. E. HB412 employs the 3A8GT as an i.f., detector-audio-avc stage, and provides an excellent circuit application.

The 1D8GT is likewise a diode-triode-pentode, but the pentode section is a power amplifier type. Consequently, with this tube, we have a complete detector-a.f. system for a portable receiver. The pentode provides a power output of 200 milliwatts at 10-per cent distortion when operated with 90 volts on the plate and screen and a 9-volt negative grid bias.

The circuit shown in figure 3 represents a suggested application in a superheterodyne receiver, whereby a.v.c. voltage is supplied in addition to the other functions.

- Television Types

Sylvania has announced the 1232, a loktal-type triple-grid amplifier somewhat similar to the 1231 but with improved shielding. This tube is designed to be used in television video amplifiers and other applications where a tube with high mutual conductance (4500 micromhos) is desirable.

The 1232 is a single-ended tube, with low inter-electrode capacitance for a tube of this type. The grid-plate capacitance is .007 $\mu\mu$fd., input capacitance, 9.0 $\mu\mu$fd. and output capacitance is 7.0 $\mu\mu$fd. This tube should work out well in u.h.f. and frequency modulation receivers as well as in television applications. It is small and highly efficient.

RCA has a new video beam-power amplifier, the 6AG7. This is a special purpose tube for use in the final stage of a video amplifier to modulate a picture tube. It is capable of giving a voltage output of approximately 70 (peak to peak). A typical video amplifier circuit incorporating the 6AG7 is shown in figure 4. This amplifier, having a band width of 4 Mc., will undoubtedly find many other useful applications.

Most of us know that the suffix G after a tube type number usually indicates that it is a glass tube with an octal-type base; some of the other suffixes are not so familiar.

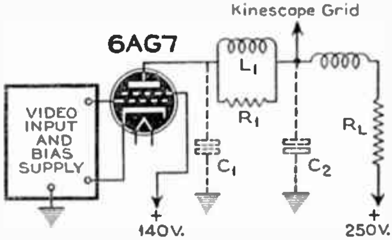
When the G tubes were made with a smaller tubular bulb, the initial T for the tubular form was added to the G, thus making the total suffix GT. These tubes are designed to fit an octal socket.

The designation 7 for the heater voltage indicates that the tube is designed to fit a loktal socket, and has a glass bulb. Other loktal-glass types are the 1231 and 1232. A suffix LM is used by RCA for octalox-metal tubes and LT for octalox-glass types. All fit the loktal socket.

The T bulb is tubular and bears a number which indicates its height. T7 has an overall height of 1-1/16 inch, T8 is 3-5/16 inches. The battery tubes bear an additonal letter to indicate the bulb height and shape. For instance, the T9A, T9B, T9C bulbs are all 1-3/16 inches in diameter and vary in height; the —A type is 4-3/16 inches, —B, 4 inches and —C 4-5/16 inches.

• TYPICAL VIDEO VOLTAGE AMPLIFIER •

Having Bondwidth of 4 Megacycles



C_1 = 16 Mmfd.= Tube output capacitance + socket capacitance + wiring capacitance + coil capcitance.

C_2 = 16 Mmfd.= Kinescope input capacitance + socket capacitance + wiring capacitance + coil capacitance.

L_1 = 94 μh Filter inductor.

L_2 = 47 " " "

R_1 = 30,000 ohm, non-reactive resistor.

R_L = 1700 ohm, 10 Watt, non-reactive resistor.

(Circuit from RCA booklet)

Figure 4. The 6AC7 video amplifier is especially designed for use in the final stage to modulate the picture tube in a television receiver.

• Testing New Tubes

In testing tubes, we need to know the operating voltages, first and foremost. Also, we want to know what function it is designed to perform, if it is being tested in the receiver. All these data, together with other design characteristics, are tabulated on the charts provided by the various manufacturers.

With regard to the socket types, the only new one is the miniature type used for the 1R5, 1S4, 1S5 and 1T4, and the same one is used for all four. The octalox type of base fits the loktal socket, so there is nothing to worry about on that score. In general, too, the characteristics of the new GT types listed, correspond closely to those of their larger predecessors in glass and metal. If your tube checker does not list settings for testing these tubes, check over the characteristics of the GT or loktal type and compare them with one of the fore-runners of the same general type. If the characteristics are substantially the same, then no new test data will be required in order to check the tubes.

The 1.4-volt tubes are designed to operate directly fom a 1.5-volt battery, while the 7-volt series operates equally well at 6.3 or 7 volts.

Standard bases are of eight types, designed to fit 4, 5, 6, small 7, large 7, loktal, octal and miniature types. The last listed are used for the new RCA miniature tubes—a 7-prong type. There are, of course, special types, such as the acorn, and junior bantam which are not in large production. The main types as listed above, meet the requirements for tube checker use. In fact, the miniature 7-prong might well be omitted for the present, since there are only four new tubes using this type of socket.

• Tube Ratings

A new system of rating receiver tubes has recently been adopted by the Radio Manufacturers Association and will be followed generally by tube manufacturers. Formerly all tubes were rated at maximum operating voltages but designers usually made their calculations on the basis that the maximum operating voltages would be obtained at an average line voltage, in the case of a.c. operated receivers, of 117 volts or less. However, the line voltage varies at different times of the day in the same location and in different locations. As a result, the receiver often operates at voltages both above and below that for which the design calculations were made. For instance, we may note that the maximum operating plate voltage of a 6L6 is 400 volts under a given set of conditons. If this maximum point is reached when the line voltage is 117, it will be exceeded if the line voltage increases with a resulting decrease in the life of the tube.

Many tubes are designed with a factor of safety so that the maximum rated operating voltages may be slightly exceeded without serious decrease in length of service; others are not. To standardize these ratings, all tubes are now to be rated according to the "design maximum" rather than to the "absolute maximum" as heretofore. As applied to the various electrodes and types of service, the following conditions will be observed:

Cathode: The heater or filament voltage is given as the normal value unless otherwise stated. This means that transformers or resistances in the heater or filament circuit should supply the full rated voltage to the heater or filament under average supply-voltage conditions. The cathode design is such that a moderate drop in heater or filament voltage will not cause a decided falling off in response, nor will moderate increases in heater or filament voltage above the design maximum cause a marked reduction in the life of the cathode.

Plate and screen: For a.c. and d.c. power lines, equipment should be so designed that the maximum rated operating plate and screen voltages do not exceed the values specified when the line voltage is 117 volts. (Note that this is the new design maximum—it does not apply to ratings published prior to the introduction of this system except in instances where a wide safety factor was included in such prior ratings.) When so designed, the equipment may be used over a range of 105-125 volts with satisfactory performance and serviceability.

Automobile storage batteries: The average voltage value of automobile batteries has been established as 6.6 volts. In practice this value varies over a greater proportionate range than power line voltages, both above and below the average value. Therefore, the plate and screen operating voltages, as well as the plate and screen dissipation, and the rectified load current should not exceed 90 per cent of the design maximum at 6.6 volts and this should be taken into consideration in the design of the equipment.

B batteries: Equipment operated from B batteries should be so designed that under no condition of operation will the plate voltage, the screen voltage, the plate dissipation or the screen dissipation exceed the

NEW MAXIMUM RECEIVING-TUBE RATINGS ACCORDING TO RMA SYSTEM

POWER AMPLIFIERS

TYPE	NAME	MAXIMUM Plate Voltage Volts	Screen Voltage Volts	Plate Dissipation Watts	Screen Dissipation Watts
6F6 6F6-G	AS PENTODE	375	285	11.0	3.75
	AS TRIODE	350	-	10.0	-
6G6-G	PENTODE	180	100	2.75	0.75
6K6-G	PENTODE	315	285	8.5	2.8
6L6 6L6-G	AS BEAM TUBE	360	270	19.0	2.5
	AS TRIODE	250	-	10.0	-
6V6 6V6-G	BEAM POWER AMPLIFIER	315	250	12.0	2.0
6Y6-G	BEAM POWER AMPLIFIER	200	135	12.5	1.75
25A6 25A6-G	PENTODE	160	135	5.3	1.9
25B6-G	PENTODE	200	135	12.5	2.0
25L6-G	BEAM POWER AMPLIFIER	117	117	4.0	1.25

CONVERTERS AND MIXERS

TYPE	NAME	MAXIMUM									MINIMUM
		Plate Voltage Volts	Screen Supply Volts	Screen Voltage Volts	Anode-Grid Supply Volts	Anode-Grid Voltage Volts	Dissipation: Plate Watts	Dissipation: Screen Watts	Dissipation: Anode-Grid Watts	Total Cathode Current Milliamperes	External Signal-Grid Bias Volts
6A8 6A8-G	PENTAGRID CONVERTER	300	300	100	300	200	1.0	0.3	0.75	14	0
6D8-G	PENTAGRID CONVERTER	300	300	100	300	200	1.0	0.3	0.75	13	0
6K8 6K8-G	TRIODE-HEXODE CONVERTER	300*	300	150	-	125#	0.75**	0.7	0.75##	16	0
6L7 6L7-G	AS MIXER	300	-	150	-	-	1.0	1.5	-	-	-

* Hexode plate voltage. # Triode plate voltage. ** Hexode plate dissipation. ## Triode plate dissipation.

TUNING INDICATORS

TYPE	NAME	MAXIMUM Plate Supply Volts	MAXIMUM Target Voltage Volts	MINIMUM Target Voltage Volts
6E5	ELECTRON-RAY TUBE	250	250	100
6N5	ELECTRON-RAY TUBE	180	180	100
6U5/6G5	ELECTRON-RAY TUBE	250	250	100

VOLTAGE AMPLIFIERS

TYPE	NAME	MAXIMUM					MINIMUM
		Plate Voltage Volts	Screen Supply Volts	Screen Voltage Volts	Dissipation: Plate Watts	Dissipation: Screen Watts	External Grid Bias Volts
6B6-G	DUPLEX-DIODE HIGH-MU TRIODE	250	-	-	-	-	-
6B8 6B8-G	DUPLEX-DIODE PENTODE	300	300	125	2.25	0.3	0
6C5 6C5-G	DETECTOR AMPLIFIER TRIODE	300	-	-	2.5	-	0
6C8-G	TWIN TRIODE AMPLIFIER	250	-	-	*1.0	-	0
6F8-G	TWIN TRIODE AMPLIFIER	300	-	-	*2.5	-	0
6J5 6J5-G	DETECTOR AMPLIFIER TRIODE	300	-	-	2.5	-	0
6J7 6J7-G	AS PENTODE	300	300	125	0.75	0.1	0
	AS TRIODE	250	-	-	1.75	-	0
6K7 6K7-G	TRIPLE-GRID SUPER-CONTROL AMPLIFIER	300	300	125	2.75	0.35	0
6L7 6L7-G	AS CLASS A_1 AMPLIFIER	300	-	100	1.5	1.0	-
6S7 6S7-G	TRIPLE-GRID SUPER-CONTROL AMPLIFIER	300	300	100	2.25	0.25	0
6SQ7	DUPLEX-DIODE HIGH-MU TRIODE	250	-	-	-	-	-
6U7-G	TRIPLE-GRID SUPER-CONTROL AMPLIFIER	300	300	100	2.25	0.25	0
6W7-G	TRIPLE-GRID DETECTOR AMPLIFIER	300	300	100	0.5	0.1	0
12SQ7	DUPLEX-DIODE HIGH-MU TRIODE	250	-	-	-	-	-

* For each plate.

RECTIFIERS

TYPE	NAME	MAXIMUM			CONDENSER INPUT TO FILTER			CHOKE INPUT TO FILTER		
					MAXIMUM		MINIMUM	MAXIMUM		MINIMUM
		Peak Inverse Voltage Volts	Steady-State Peak Plate Current per Plate # Milliamperes	D-C Heater-Cathode Potential Volts	A-C Plate Voltage* Volts (RMS)	D-C Output Current Milli-amp.	Total Effective Plate-Supply Impedance* Ohms	A-C Plate Voltage* Volts (RMS)	D-C Output Current Milliamperes	Value of Input Choke Henrys
5T4	FULL-WAVE	1550	675	-	450	225	150	550	225	3
5U4-G	FULL-WAVE	1550	675	-	450	225	75	550	225	3
5V4-G	FULL-WAVE	1400	525	-	375	175	65	500	175	4
5W4 5W4-G	FULL-WAVE	1400	300	-	350	100	25	500	100	6
5X4-G	FULL-WAVE	1550	675	-	450	225	75	550	225	3
5Y3-G	FULL-WAVE	1400	375	-	350	125	10	500	125	5
5Y4-G	FULL-WAVE	1400	375	-	350	125	10	500	125	5
5Z4	FULL-WAVE	1400	375	-	350	125	30	500	125	5
6X5 6X5-G	FULL-WAVE	1250	210	450	325	70	150	450	70	8
6ZY5-G	FULL-WAVE	1250	240	450	325	40	225	450	40	13.5
25Z4	HALF-WAVE	700	710	350	235	125	100	-	-	-
25Z6 25Z6-G	VOLTAGE-DOUBLER	700	450	350	117	75	0	-	-	-
	HALF-WAVE	700	450	350	235	75	100	-	-	-

\# When a filter input condenser larger than 40 µf is used, it may be necessary to use more plate-supply impedance than the minimum value shown.

* Per plate.

0 Zero ohms for full-wave voltage-doubler circuit. 15 ohms for half-wave voltage-doubler circuit (in which one d-c terminal is connected to one side of a-c line).

recommended respective maximum values by more than 10 per cent.

Other electrodes: When a tube is of the multi-grid type, the voltages applied to the additional electrodes, when positive, will be subject to the same considerations as those stated for the plate and screen.

Typical operation: Typical operating conditons are not to be considered as ratings; they are intended merely to serve as a guide for the use of each type. The tube can be used in any circuit or under any operating conditions providing its rating limitations are not exceeded.

RCA has just issued an application note (No. 105) which gives charts showing the new design maximum (and minimum) ratings as applied to a group of standard tubes.

It can be seen from these charts, which we reproduce herewith, that the new design maximum ratings for many power-amplifier and rectifier types have been reduced from the former absolute maximum values. For some other tube types, the design maximum ratings are the same as those previously specified as absolute maximum ratings.

• • •

At left: The new design maximum ratings for many power-amplifier and rectifier types have been reduced from former absolute maximum values. For some other types design maximums are the same as previously specified as absolute values; for still others the rating has actually been increased.

By maintaining the same rating, under the new basis of interpretation, the result is, in effect, an increase in the rating. For instance, in some of the voltage-amplifier types, the previous absolute maximum of 250 volts has been retained as a design maximum under the new system. Further, in a number of other voltage amplifier types, the rating has been increased to 300 volts as a design maximum in place of the former 250-volt absolute maximum.

With reference to the 6L6 and 6L6G, note that the new design maximum rating is 360 volts for the plate and a screen maximum of 270 volts, as compared with the former ratings of 400 and 300 volts, respectively. However, the new design maximum for the plate voltage of the 6V6 has been increased from 300 to 315 volts, while the screen maximum has been reduced from 300 to 250 volts. It would be a good idea, in servicing receivers which use these tubes at their former maximum ratings, to alter the voltages to correspond with the new ratings. This applies likewise of course, to p.a. systems and ham transmitters.

The 25B6G must be standing the gaff unusually well; we note under the new listing that the design maximum for the plate voltage has been jacked up from the previous absolute maximum rating of 135 to the new listing of 200. The screen voltage rating remains the same at 135.

The 25L6G seems to be doing better in the field if we are to judge by the new ratings. As listed, the plate and screen design maximums are now 117 volts as compared with previous absolute maximum ratings of 110 volts.

For the popular 6F6, the plate maximum under the new rating remains unchanged at 375 volts for the pentode application and 350 volts, when used as a triode. The design maximum for the screen is 285 volts, as compared with the previous absolute maximum of 315 volts. The new listing is, therefore, an effective increase in the plate voltage rating since it implies, on all listed tubes, that the plate voltage may increase to an absolute maximum 7 per cent higher than the value listed without rendering the performance and serviceability unsatisfactory.

Those of you who are in neighborhoods where high line voltages, in the vicinity of 125 volts, are frequently encountered should take heed of the new RMA ratings for rectifier tubes. If they pop too often for comfort in sets which you service, bring the voltage down to the design maximum, based on a line voltage of 117. You can do this quite simply by inserting a resistor in series with the power transformer center tap and ground. Make sure that the resistor wattage rating is sufficient. Usually a value of the order of 500 to 1000 ohms will do the trick on most sets, with a wattage rating for the resistor of 20 or more, depending upon the receiver B-power consumption.

The maximum a.c. voltage per plate for the 5Z4, at 117 volts line supply, is now 350 volts, just 50 volts lower than the previous absolute maximum, with condenser input. This same rating applies likewise to the 5Y3, 5Y4, and 5W4, formerly rated at 400 volts. The d.c. output current rating for the 5Z4 remains at 125 ma, as does the 5Y3, while the 5Y4 and 5W4 have been boosted from 110 to 125 ma. The choke input design maximum a.c. voltage for the 5T4 plates remains unchanged at 550 volts, but the d.c. output current rating takes a 10 per cent drop. For the 5U4G, both plate and d.c. output current ratings are reduced 10 per cent from their previous ratings of 500 volts, 250 ma to 450 volts, 225 ma.

The design maximum for the output plate voltage has been increased from 250 to 300, for the 6A8G, while the screen rating is maintained at 100 volts. However, the anode grid voltage design maximum has been brought down to 200 volts from its former 250-volt maximum. The same situation exists with regard to the 6D8G.

All ratings on the 6K8G have been substantially increased. The hexode plate and screen voltages are now 300 volts each, instead of 250, while the triode has been raised from 100 volts to a plate voltage of 125. For the 6L7, the previous absolute maximums for the plate and screen of 250 and 100 volts respectively have been increased to 300 and 150 volts for the corresponding elements.

¶ From Bell Laboratories Record
February, 1940

The Exponential Transmission Line

By CHARLES R. BURROWS

IN RADIO operation it is sometimes desirable to connect two antennas in parallel to a transmission line. If the impedance of each antenna alone matches that of the line, when both antennas are connected they will present an impedance of only half that of the line. Such a mismatch results in reflection and standing waves on the line, with greater line losses and less radiation. The match may be restored by inserting a transformer, or a section of line along which the impedance changes exponentially with length.

Experiments recently carried out by the Bell Laboratories show that practical lines of the exponential type can be constructed. In the experimental setup it consists of a pair of conductors whose distance apart decreases progressively from the high to the low impedance end. At the high impedance end the conductors are no. 6 wire. These are changed successively to tubes 1/4″ and 3/8″ in diameter toward the low impedance end where the current is greater and tends to increase heating. Increasing the size of the conductor also increases the spacing and decreases the possibility of voltage breakdown.

The input impedance of an experimental 600 to 300-ohm exponential line terminated with a 300-ohm resistance is shown in figure 1. Solid circles represent measurements made on a line nine meters long and open circles those on one three meters long. The curve gives the calculated value of the input impedance. The lower abscissa scale is the ratio of the frequency to that for which the line is one wave-length long and the upper scale gives the ratio of the frequency to that at the cutoff. At the higher frequencies the input impedance approaches the desired value of 600 ohms but at the lower frequencies the line merely serves as a connection between the input and the load. The agreement of these experimental results with the theoretical formulas was considered a sufficient check to justify

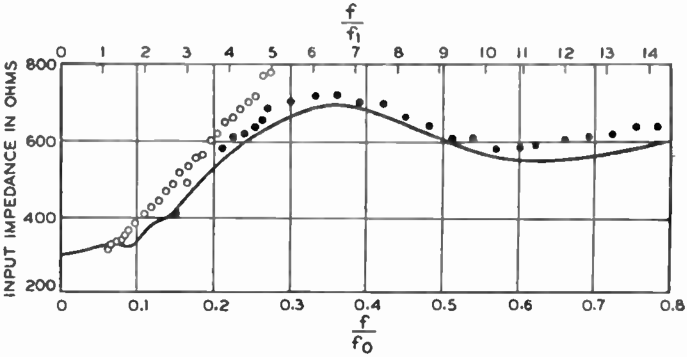


Figure 1. Impedance characteristics of an experimental 600 to 300-ohm exponential transmission line. The lower abscissa scale is the ratio of the frequency to that for which the length of the line is one wavelength and the upper scale gives the ratio of the frequency to the cutoff frequency.

constructing a full scale model for study on the commercial trans-oceanic frequencies.

Preliminary tests on a full-size model gave large deviations from the expected results,the major cause of which was found to be the inherent stray capacity of the mechanical support at the terminals. An auxiliary experiment on a uniform line showed that it was possible to reduce the effect of this stray capacity by adding the correct amount of inductance in series with the resistance load. When thus terminated the input impedance of the 600 to 300-ohm exponential line was that shown in figure 2. The displacement between the theoretical and experimental curves at the higher frequencies is due to the deviation of the comparison resistance from its direct current value. Deviations of the input impedance from the desired 600-ohm value are not serious compared with those commonly found on uniform transmission lines in the transoceanic frequency range.

The locations of these maxima and minima are the same as would be found with a uniform line terminated in approximately its characteristic impedance but with a small reactive component. This occurs because the characteristic impedance of the exponential line is not a constant resistance equal to the characteristic impedance of the corresponding uniform line except at infinite frequency. As the frequency decreases the characteristic impedance has an increasing reactive component and becomes a pure reactance at and below the cut-off frequency. To reduce reflection from the terminal and variations in the input impedance, the line can be terminated by a condenser in series with the resistance load.

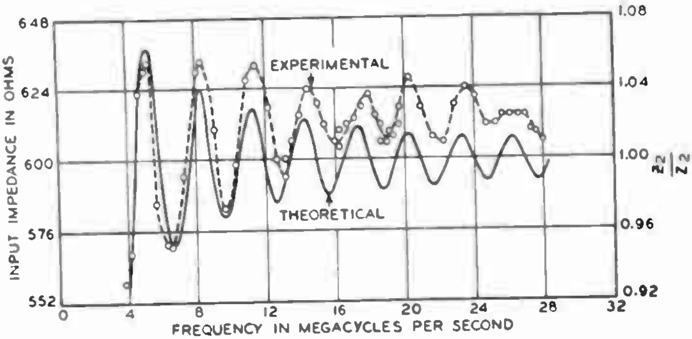


Figure 2. Input impedance of an exponential line with series inductance to compensate for stray capacity at the terminals. The difference between the theoretical and experimental curves is due to deviation at high frequencies of the comparison resistance from its direct current values.

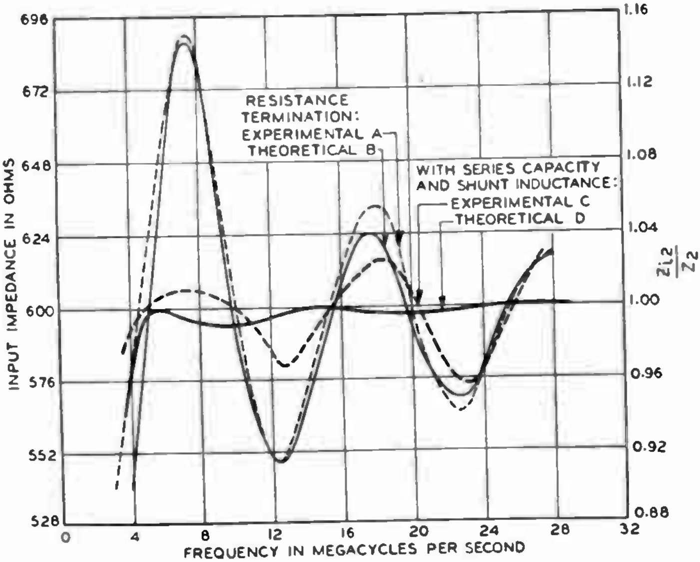


Figure 3. Input impedance of a 600 to 300-ohm exponential line fifteen meters long with a resistance termination; also with a series capacity at the high impedance end and an inductance shunted across the resistance at the low impedance end.

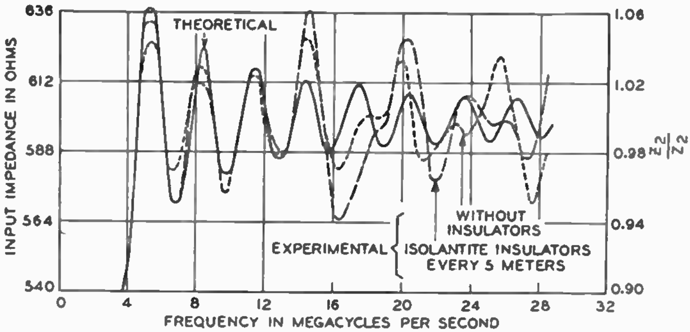


Figure 4. Impedance of the experimental exponential line.

In figure 3 curves A and B show respectively the measured and the calculated values of input impedance of a 600 to 300-ohm exponential line fifteen meters long with a resistance termination. Curves C and D give the input impedance when a series capacity was added at the high impedance end and an inductance was shunted across the resistance at the low impedance end. At the lower frequencies where the improvement is needed most the experimental curve C approaches the theoretical curve D, but at the higher frequencies it approaches the theoretical curve B for a resistance termination. This is because in the calculations for curve D, the distributed capacity of the inductance was ignored. That capacity, however, is sufficient to make its reactance anti-resonant with that of the inductance at the high-frequency end, thereby making the termination more nearly approach a pure resistance.

Results of measurements made on the exponential line are given in figure 4. The solid curve was calculated from theory and the two broken curves show the experimental values with and without insulators. Insulators change the input impedance but do not materially increase the amount of its variation.

Theory indicates that the exponential line may be used as an impedance transformer over a wide frequency range and experiment shows that the difficulties of constructing a line having these properties can be overcome.

¶ From Electronics
November, 1939

40-CM. WAVES

In Aviation

Tests at M.I.T. reveal practical apparatus for generating a 40-cm. "hillside" of signal for blind landing of airplanes. Horn radiators and a receiver having 15-microvolt sensitivity show practicability of 700-Mc communication.

RECENT progress in the field of the ultra-ultra high frequencies, above 500 Mc., has consisted principally in the development of more efficient generators, more sensitive detectors. Behind the scenes, however, several organizations have been working toward the application of the very short waves to the problems of aerial navigation and guidance. One of the outstanding examples of this work is the collaboration between the Civil Aeronautics Authority and the Massachusetts Institute of Technology on a system of instrument landing which employs 40 centimeter waves[1] and which makes use of nearly all of the modern developments in the field of microwave research. The system is the solution of a problem proposed by a C.A.A. engineer, Irving Metcalf, and developed in practical form by the electrical engineering department staff of M. I. T. under Professor E. L. Bowles. The apparatus was recently demonstrated in experimental form to C.A.A. officials at the East Boston Airport.

- Beams from Horn Radiators

The transmitting equipment operates on a frequency of approximately 700 Mc. At such high frequencies, beams may be formed by radiating the energy from horn structures of convenient dimensions. Two such horns were used in the demonstration, each fed by a separate transmitter. The horns are wooden structures, about 26 feet deep, and 10 by 2½ feet at the mouth. They are lined with copper sheeting. At the end of each horn is a rectangular box which closes

[1] A preliminary report of this work was carried in the January, 1939, issue of *Electronics*, pages 12-14. The demonstration was reported from the aeronautical point of view in the November, 1939, issue of *Aviation*.

the throat. Inside the box is a quarter-wave antenna which protrudes into the box directly from a coaxial transmission line. The length of the antenna is about 10 cms, (roughly 4 inches). The 700-Mc. energy radiated from the antenna is conveyed down the horn to its mouth, and there it spreads out in a flat fan-like pattern, whose width is at right angles to the long dimension of the mouth of the horn and parallel to the ground. (This relationship obeys the rule for diffraction effects, namely that the diffraction pattern spreads widest at right angles to the long dimension of the slit). Consequently the horn generates a flat nearly horizontal beam of signal, inclined at a slight angle to the airport surface. Two horns are used, each fed with signals of the same frequency, one modulated at 150 cps, the other at 90 cps. The horns are set up so that the central axis of one makes an angle of 5 degrees to the earth's surface, the other an angle of 10 degrees. The fan-like beams from the two horns overlap in a region which extends from about 3 degrees to 7 degrees. The overlap region constitutes a "hillside" of signal down which the plane glides to the airport surface. In the plane, the receiver tells the pilot when both signals (90 cps and 150 cps modulations) are received. When both are received at equal strength the glide angle is 7.5 degrees, which is somewhat steep for most aircraft, hence the receiver is set to indicate the proper position when the upper beam is received somewhat stronger than the lower, producing a normal glide angle of from 3 to 4 degrees.

The arrangement just described gives so-called "vertical guidance", that is, it guides the plane in the up-down direction. Similar guidance in the horizontal or left-right direction is also necessary. In the demonstration the horizontal guidance was provided by a conventional long-wave runway localizer transmitter, designed and operated by engineers of the Washington Institute of Technology. When the C.A.A.-M.I.T. system is completed the horizontal guidance may be set-up by 40-cm. waves in the same fashion as the vertical guidance.

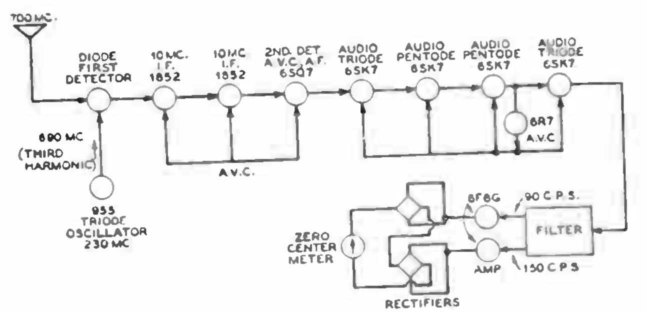
• The 700-Mc. Generators

The horn structures just described are highly directional (in the plane of the fan pattern) and hence conserve the energy fed to them from the transmitter proper. For this reason, very small amounts of transmitter power will suffice, so long as the receiver in the plane has adequate sensitivity. Two possibilities arise: a transmitter of several hundred watts power may be used with an insensitive receiver, or a few watts of transmitter power may be used with an elaborate receiver. The low-power arrangement was used at the demonstration, although the high-power method has been tested with success.

The generation of hundreds of watts of power at 700 Mc. has been possible only since the advent of the beam-type of cathode-ray generator. One of the "klystron" generators originated at Stanford University was available for the purpose, and was set up in operating condition on the airport, mounted in a truck complete with high voltage power supply and a continuous vacuum-pumping system. With less than 100 watts output, in previous tests, adequate signal strength was received in the plane at a distance of more than 25 miles, which constitutes a record for microwave transmissions. In the demonstration, however, it was more convenient to use lower power, and to rely on the high sensitivity of the receiver. Accordingly, two conventional triode oscillators were used, one for each horn radiator. The oscillators employed the Western Electric type 316A door-knob tubes in coaxial-line tuned circuits, and were fed with about 25 watts of power, one modulated at 90 cps, the other at 150 cps. The output of the oscillators was in the neighborhood of one watt at 700 Mc. (43 cms), but even this small power was adequate to produce a strong signal at distances greater than five miles. Since the glide path to the airport surface is usually less than five miles long, the performance was satisfactory, despite the very low power of the transmitters.

- The 15-Microvolt Microwave Receiver

From the standpoint of radio engineering, the most significant development in the project (save possibly the use of horn radiators) is the 40-cm receiver. This receiver displays the phenomenal sensitivity of 15 microvolts input for full output (off-scale swing on the indicating meter). The tube lineup is

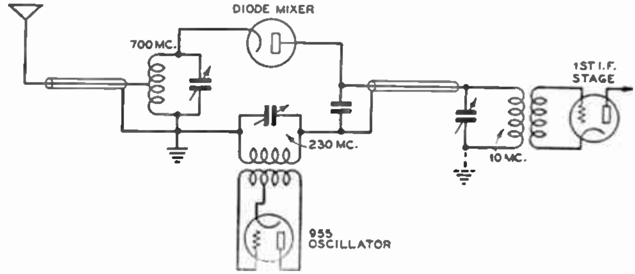


Tube line-up of the receiver. Two 700-Mc signals, modulated at 90 and 150 cps respectively, are amplified several hundred thousand times before being separated in a filter and applied to the indicating meter.

shown in the accompanying figure. The antenna is of the coaxial variety developed by the Bell Labs. It is fixed to one of the wing struts. The coaxial lead-in connects to the input circuit. The first detector is a diode tube, a W. E. development type. This tube serves two functions. In the first place it develops the third harmonic of the oscillator output, and in the second place it mixes this third harmonic with the input signal, producing a 10-Mc. intermediate frequency. The dual aspect of the diode action is illustrated in the accompanying diagram. Three tuned circuits are connected in series with the diode, as shown. The first is tuned to 700 Mc., the input frequency. The second is tuned to 230 Mc., the oscillator frequency, and the third is tuned to 10 Mc., the intermediate frequency. At other than these resonant frequencies, the tuned circuits are essentially short circuits, so it is possible to consider the action of each circuit as though it were the only element in the series with the diode. Hence the diode produces a 690 Mc. frequency as the third harmonic of the oscillator voltage, mixes it with the 700 Mc. input, and derives the 10 Mc. i.f. voltage, simultaneously.

The oscillator proper, which employs a 955 acorn triode, is a specially-designed coaxial tuned circuit similar to those developed by Peterson. The tuned circuit is in the form of a high-Q resonator, which encloses the tube, and which is so proportioned as to produce a highly stabilized output.

The i.f. output of the first detector is amplified in two 1852 i.f. stages, which pass a band several hundred kilocycles wide, but which develop a gain of several thousand times overall. The second detector is a diode element in a 6SQ7 diode-triode tube. Then follows the triode section of the same tube as an a.f. amplifier. A.v.c. voltage is



The diode first-detector circuit in the superheterodyne receiver. Circuits tuned to the signal frequency, the oscillator frequency and the intermediate frequency are connected in series with the diode, which develops the third harmonic of the oscillator output and mixes it with the signal, simultaneously.

developed and applied to the 1852 tubes. The audio output of the 6SQ7 is then fed to an elaborate a.v.c. controlled audio amplifier employing four 6SK7 tubes, the first and last triodes, the others as pentodes.

The output of the third 6SK7 feeds a 6R7 which acts as an a.v.c. diode and amplifier. A.v.c. voltage is applied to all four 6SK7's, with the result that the output is substantially constant (within about 20 per cent) with audio frequency inputs ranging from one millivolt to three volts. The gain in this amplifier is very great, of the order of 100,000 times. The problem of motor-boating and noise has been solved by the use of resistance-capacitance band-pass couplings between stages, which pass components from 50 to 400 cycles, thus including the 90-cps and 150-cps modulations which are of importance, but discriminating against noise, and inhibiting low-frequency oscillations.

The output of the final 6SK7 amplifier leads to a filter which separates the 90-cps signal from the 150 cps. Each of these components is amplified individually in the sections of a 6F8G double triode, and applied to two copper oxide bridge-type rectifiers. The connection between opposed outputs of the two bridges is made to a zero-center microammeter which thereby is made to indicate the relative strength of the 90- and 150-cps components. The gain of the 90 cps channel may be varied in the 6F8G stage relative to that in the 150 cps channel. This allows a zero-center indication to be obtained with varying ratios of 90 cps to 150 cps modulation, which in turn corresponds to positions in the upper and lower portions of the overlap region between the two fan patterns. By adjusting the relative gain of the two channels, the glide angle may be adjusted to suit the landing characteristics of different types of planes.

• Observations During Test Flights

In the test flights, the pilot flew about five miles from the airport, and picked up the glide path at an altitude of about 900 feet. By keeping the two cross pointers on the indicating instrument (one for the vertical guidance, the other for the horizontal), he guided the plane to the airport surface, but did not land because of a high crosswind which would have made landing difficult. Throughout the descent, the rate of climb meter and the airspeed indicator remained fixed in position, indicating that the plane was following a straight line to the ground. The straight-line aspect of the system is an important distinction from that of the conventional longer-wave instrument-landing systems, which follow a more or less curved contour of constant signal strength. The straight line path of the new system makes a definite point of contact with the ground, so that the plane reached its lowest altitude over a region no more than 50 feet in diameter.

The indications of the system were also made to appear on a cathode-ray tube, on whose face three spots appeared. The spots were formed by a commutating system, and were so controlled that they indicated not only the position of the plane relative to the glide path but also the tilt of the planes wings, and its azimuthal position. The latter indications were derived electrically from the gyro compass and artificial horizon instruments in the plane, in the manner described in the reference previously cited. The three luminescent spots have the appearance of fixed spots on the ground, and hence allow the pilot to judge almost instinctively his position relative to the airport at all times during the descent.

Since the horns determine the shape of the pattern, the glide path is not changed by variations on the airport surface, such as would be caused by a snowfall. The signal regions extend a considerable distance to the left and right of the horn openings, hence it is quite feasible to place the horns to one side of the glide path, and thus remove them from the airport surface.

New Permanent Magnet

A NEW permanent magnet assembly, roughly three times as strong as any previously known, was disclosed recently by the General Electric Research Laboratory. It permits a tiny piece of sintered alnico to lift and hold 4,450 times its own weight.

The previous record mounting, developed in the laboratory last year, allowed a piece of the same material to lift 1500 times its own weight. Sintered alnico is an alloy of aluminum, nickel, iron and cobalt made by pressing together the powdered metals and heating almost to the melting point. By itself, without the special assembly, an alnico magnet has a normal lifting power of 500 times its own weight.

A new mounting of brass and iron in which the magnetic flux passes through many air gaps, instead of the usual two, in bridging from pole to pole, is responsible for the greatly increased power. The new assembly is not a commercial development and the largest turned out in the laboratory to date contains but three cubic centimeters of alnico.

Though smaller than a thimble and weighing three-fourths of an ounce, this magnet in its mounting has supported as much as 200 pounds in tests. One a cubic centimeter in size, supported 67 pounds of small weights added one at a time.

¶ From Communications
October, 1939

Automatic TIME and WEATHER

By LEWIS WINNER

IT IS strikingly strange that so important a factor in our daily program as *Time,* and its close ally *Weather,* have received such feeble attention, until comparatively recently. That probably appears to be paradoxical, realizing the importance of these two veteran friends. But only with advent of progressive communication and electrical engineering and modern advertising, have *Time* and *Weather* publicly become such amazing attention holders. Today you can look at a sign, turn in on the radio, or better yet, call upon the telephone and receive accurate information, any time of the 24-hour day. Of course, it is true that this unique telephone service is not available everywhere, but *Time* will march on, and it won't be long, as they say.

In telling time, two methods are used. One, of course, is the simple direct microphone method, where the operator or announcer simply looks at a special synchronous clock, and reads off the time into a transmitter. The other is the intriguing automatic method, providing time of day service through the facilities of recorded film operated by any one of several ingenious devices.

Oddly enough, this uncanny automatic system was first conceived in that famous city, Stockholm, in Sweden, where there are more telephones per person than anywhere else in the world. The date, early in 1934; and the place, the engineering laboratory of the L. M. Ericsson company.

The Ericsson system employs a photo-electrically prepared film disc mounted between two glass plates, rotated slowly by a controlled motor; an optical system with its photoelectric cells and beam of light, actuated by eccentric cams, and operated by gears through the same motor that rotates the film discs. Lifting up the receiver automatically actuates a relay device that opens the time announcement circuit, and feeds the recorded message to the line into the receiver. This announcement is broken up into hours, minutes and even seconds.

The intervening years have seen a host of remarkable engineering strides in this device, and today it is even more uncanny in its reliability, accuracy and quality of reproduction. So popular has it become that close to 20,000 people call every day to ask for the time. Remembering that there are only 125,000 subscribers in this city of Stockholm, it is quite apparent that the percentage of interest is quite high.

One of the unusual features of this device is the film disc, using concentric bands. It is possible with this concentric method to provide a comparatively long series of messages on this disc which is only some 6″ in diameter. To operate or to transcribe these messages, the optical system moves from the outer edge in and back again for the repeats. The time device uses five of these discs, but of course this can be extended to include many more for additional time messages or special data that may be of interest to the listener, such as advertising, about which more will be said later.

As many as 150 patrons may call in at one time, with an equal level of volume available for every one. This is made possible by the use of a low impedance output operating out of a high gain resistance coupled audio amplifier connected to a parallel operated telephone circuit. Like a direct controlled device, it is not possible to break into a section of an announcement after you have dialed your number. Instead you hear the beginning and end of the message several times, just as you do when you call the direct operator. A time disconnect relay that disconnects the amplifier during the moment that the dialing is being completed, affords this service.

As stated previously, it is possible to extend the number of film discs to afford additional messages. This has been done with the machine that provides *Weather* service. In this instance, of course, no clock is used, but the same timing principle is used. Six discs, with their special weather reports recorded thereon, are used. The specific messages desired are available by turning large drum dials, that appear through the front of the cabinet. On these drum dials are numbers, each of which corresponds to a specific weather condition. When the drum is turned, that portion of the film with the specific weather report desired, appears before the optical system, and when you call for your report, it is this message that you hear.

A typical weather report would entail the turning of dial A, for the day of week and part of the day, viz, Monday morning. Then the next would be adjusted for the direction of wind, viz., N NE. This is followed by the dial that affords us the strength of the wind. Then we have the type of weather, that is, if it will rain or snow. On the next drum we are able to turn to miscellaneous phrasing as, "Later on," or

"Next Day." And finally we have the forecast, as "Clearing Skies" or "Increasing Cloudiness." There are 180 different classifications of data available, thus affording a multitude of combinations.

So popular has this service been that as many as 23,000 calls a day have been recorded. And during specific seasons when certain sports are in vogue, this increases many times. And speaking of certain sports, this machine has also been equipped with discs that provide information on conditions at mountain tops for skiing, one of the most popular sports in Sweden and other countries in this region. In addition information on the temperature of bathing pools, direction of wind, waves, tides, is also available in many cities. For fishermen, other data are also supplied. Thus it is quite evident that these devices have proven themselves most effective servants of Mr. and Mrs. Public, and have correspondingly served to amplify the prominence of *Time* and *Weather*.

• Polish Time and Weather Systems

A few years after the introduction of the Swedish systems for *Time* and *Weather*, T. Korn, a brilliant young engineer of Warsaw, Poland, conceived another method permitting the automatic transmission of *Time* and *Weather* reports. He chose to use a rotating cylinder, on the surface of which was carried a recorded film, with its hours and minutes, or weather forecasts. This film is lighted by a thin beam of light, which is reflected by the mirrored surface of the drum. This, in turn, is modulated by the sound recorded on the film, and then on to the photo cell, the output of which is fed into a regular telephone amplifier, and finally into the trunk line. This mirrored drum is encased in a metal housing, and driven slowly by a synchronous motor. The photo cells and optical system peering through transparent shield openings on the rotating drum are shifted by eccentric cams, controlled by gear to the synchronous motor.

On one side is the hour shifting device, and on the other side is the minute section, split into two divisions. A resistance coupled audio amplifier is also employed, in a rather high gain circuit.

Utilizing the same pattern of design is the *Weather* machine, except that here six cells are used in conjunction with different portions of the complete weather forecast. The changes in forecast are controlled by a push button system.

• American Systems

A short time after the introduction of the Ericsson system, J. L. Franklin, of Atlanta, Georgia, announced his method of telling *Time* by an automatic device. And here again we have the reflected light principle used. In this instance, the bottoms of grooves, on a metallic cylinder, carrying strips of transparent film record, are chromium plated, offering a very highly reflected surface. When non-metallic cylinders are used, then ribbons of chromium plated metal may be used. The optical system used here is mounted on top of the film casing. The beam of light thrown is reflected into the photo cells.

Two cylinders are used. One is the hour cylinder, with twelve spiral groves, resembling a twelve-thread screw. The minute cylinder with sixty grooves carries the recorded film in each of its sixty slots. These cylinders are actuated by eccentric cams controlled by a synchronous motor.

The time device is mounted in an attractive metal casing, beneath which is housed the amplifying system. Beneath this unit is the mercury switch compartment.

In view of the grooved design of the film cylinders an unusual degree of film-change flexibility is afforded. Thus it is entirely possible to change sections of the drum quite rapidly, which is excellent in those instances where special messages are to be included and interchanged.

And speaking of special messages, we come to an interesting use to which this American device has been put by many advertising firms. For instance, the First National Bank in St. Louis installed one at the beginning of the year and within a period of two weeks nearly 605,000 calls were put through for time alone, which is certainly an inspiring percentage of interest in *Time*. It must be remembered that there are only 125,000 subscribers in St. Louis. Another installation in Montclair, New Jersey, has also proven the popularity of *Time* with everyone. To promote the interest in the service this device affords, extensive advertising campaign has been instituted in newspapers, billboards, car cards and direct mail.

Since, of course, this private installation must serve the community twenty-four hours a day, it naturally must be checked frequently. To this end, special service engineers have been selected to keep a steady eye on their operation. In some instances, the installations have been made in radio and electrical stores, and in radio stations, as in the case of station WEEI in New Haven. The servicing of these instruments is within the scope of the alert radio service man, with his kit of modern testing and mechanical equipment. And incidentally here is a new industry for the service man to study seriously, for with increased interest being shown everywhere in the automatic devices of this nature by the public and sponsors, it will not be long before there will be an enthusiastic demand for him. What should he know? The fundamental principles of sound coupled with a thorough knowledge of amplifiers, synchronous motors, and essentials of mechanics.

It must be remembered, too, that although these systems are now being used for wired circuits, they can eventually be transformed for use in radio systems, public-address work, and many other forms of wire and radio communications requiring a series of duplicated messages.

• Semi-Automatic Systems

In addition to these automatic

methods of telling *Time* and *Weather,* there are the semi-automatic methods, requiring constant "personal" transmission, and personal recording several times a day.

The constant "personal" transmissions used for *Time* are in effect semi-automatic in view of the automatic time indicators required, and specially developed for this work. For instance, at the New York Telephone Exchange there is a time announcement turret, which is actually a dual unit with two clock units, driven by alternating current of regulated frequency. On the face of each of the clock units is a time indicator. This records time in fifteen-second steps. In addition to this clock are three lights, white, green and red.

At a predetermined interval, before each quarter minute change in the time indicator, a green signal on the turret lights and the operator receives an audible tone in her head receiver to warn her to begin her announcement. "When you hear the signal, the time will be two-five and three-quarters." This is followed, exactly at the time announced by a time signal. The green signal lights and the announcement tone is heard in the operator's head receiver only when one or more subscribers are connected to the time bureau. This connection is indicated by a white light, so that the white light, the green light and the audible signal, the announcement and finally, the time signal follow each other. Thus the operators or announcers, of which there are seventy and specially trained, serve to complete the cycle of automatic service. Included on the turret are volume indicators, that enable the operator to check her voice level constantly.

I mentioned a moment ago that the frequency of the current fed to the time indicators was regulated. This is performed by a frequency-standard method, established by a "crystal clock" at the Bell Labs. This "crystal" is our old friend quartz. We know that thin wafers that may be cut from quartz will have a natural state of vibration, depending on their size; and when inserted in a suitable circuit, they will control the rate of electric vibrations to an accuracy of one part in a million. Four such crystals, confined in a time vault at the Bell Labs., have been independently operated and checking each other continuously for more than ten years. Even though the frequency of the current driving the clocks at the Time Bureau is regulated by this time standard, the clocks are also checked by special radio apparatus at the Bureau with the familiar and reliable time signals from the Naval Observatory at Washington.

While we are at the New York Telephone Company, let us drop in to see how they forecast the *Weather* reports. Here again we have a semi-automatic method, calling for the services of an announcer, only several times a day, however. And they use, our veteran standby of automatic recording, a steel tape. I say "veteran," for truly it represents one of our first methods of successful recording for commercial purposes, although there is hardly a comparison in the results obtained today as against yesterday.

It will be remembered that the Dane, Poulsen, introduced magnetic steel wire recording as far back as 1900, at this time for copying high speed arc system signals. Since suitable amplifiers were not available then, the quality was bad; but nevertheless there was proof that here was method of recording that was to be considered. In 1924, Dr. Stille, a German engineer, began a thorough study and search of the possibilities of this form of recording, and soon he found that steel tape offered better recording possibilities than wire. He developed an electromagnetic system, resulting in a reduction of wave form distortion. Years brought on other developments, until the steel tape became suitable for broadcasting purposes, the first evidences of which came to light in 1932 when the British Broadcasting System transmitted the Christmas Day speech of his late Majesty King George V by this method. Today, it is successfully used in a number of recording methods, one of which is the public information service by telephone companies and others engaged in the dissemination of duplicated data.

In the New York Telephone system, a moving belt of steel tape, about 30 feet long, passes across the poles of an electro-magnet, at a rate of about a foot a second. Speech currents produce a varying magnetism on the tape.

The quality and uniformity of the tape guide the results of the system. Tungsten magnet steel is ofttimes the choice of most, providing a minimum of magnetic aging. It is possible with this tape to "erase" a message at will. This, of course, is most important at such an installation as that at New York Telephone studios, where as one weather report is recorded on one tape, it is "wiped" off the next tape, and made ready for the next recording. This "erasing" is done with the same machine that records. In other words, the tape rides through the recording magnet and "erasing" magnet. To "erase," it is only necessary to increase the magnetic field, that neutralizes the original magnetic recording applied to the tape.

The messages impressed on the tape vary from 25 to 38 words, with a level of 33 words as an average. The messages must not take over 25 seconds, and operators are trained to talk at this rate. If more than 25 seconds are consumed during the recording, the message must be erased. To enable the operator to watch this speed, she watches a clock with a second hand, and two signal lights which flash a warning if the volume of her voice is too high or too low.

At the present writing three of these talking tape machines are in use. Thus far the calls for this information have been varying from 30,000 to 50,000 a day, certainly a strong indication as to the popularity of this service. The service inaugurated on April 8 of last year in the New York area is now also being tried out in Hightstown, New Jersey, to supply information to the farmers on crops and market conditions. The messages take about three minutes and are varied as many times a day as the situation warrants.

• Film Tape Recording

Still another form of tape recording exists. This is the film tape, not the photographic film tape, but the mechanographic film tape, as developed by James A. Miller in cooperation with the Philips Company of Eindhoven, Holland. Used in this system is a special film, 7 millimeters in width, with a coating of clear material on the base, over which is an extremely thin layer of opaque material, approximately 2 microns thick. A specially prepared sapphire cutting tool is employed. The edges of this tool form an oblique angle with the surface of the film, cutting a hill and dale sound track. Being done mechanically, the cut is clean, with the points of demarcation between the opaque and transparent portions being very sharply defined. The opaque portions have a very high density while the transparency of the clear portion is most uniform. With this special cutting device, it is possible to record up to 10,000 c.p.s., with a power consumption of only two watts.

Unique about this system is that, first, more than one track can be recorded on the same piece of film. Cutting and re-recording can be done from the original. It is not necessary to enter a dark-room to load the film magazines, since this is not a photographic process, and therefore light does not affect the film.

The film is wound on a metallic hub, and at a swift glance it has the appearance of several wax records piled up.

To play back, the film is fed through an optical system, at a speed of 60 feet a second, with the resultant impulses being fed into a quality amplifier.

The high fidelity characteristics of this system are most unusual. In playback tests, it was difficult to distinguish the recorded version from the live transmissions, by either the ear or meter test.

One popular radio station in the East is now using this system in an automatic announcing method. . . for station letters and location. Other similar projects are in the planning. With the many properties this film tape system offers, it is easy to see how effective a tool it will be for public service as *Weather* forecasting.

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¶ From Radio,
February, 1940

Parallel CATHODE MODULATION

An Alternative System of Cathode Modulation for Medium-Powered Equipment

By RAY L. DAWLEY

CATHODE modulation, as has been discussed in previous issues of RADIO, consists of the simultaneous plate and grid modulation of an r.f. amplifier in the proper relative amounts by the injection of the audio energy into the cathode circuit of the amplifier. This audio energy may be impressed into the cathode circuit by means of a transformer, [1, 2] a dynamically variable series resistor,[3] or by means of a common choke in the cathode circuits of the amplifier and the modulator. It is this latter system which will be described in this article.

Experience with many types of cathode modulated amplifiers has shown that the value of driving impedance to be inserted into the cathode circuit should be of the order of 500 ohms. The correct impedance value seldom varies over a ratio of more than two to one from this mean. [1, 2] Degenerative feedback experience and theory has also shown that when the audio energy from a single-ended amplifier stage is taken from the cathode circuit, the output impedance of the audio amplifier is also effectively reduced to this same order of magnitude.

Obviously, then, an audio amplifier tube with the audio energy taken from its cathode circuit and with the plate by-passed to its plate supply is ideally suited to use as a cathode modulator for an r.f. amplifier with nothing more than a common choke for the coupling medium. Figure 1 illustrates the meth-

[1] "Cathode Modulation," Jones, RADIO, October 1939, p. 14.
[2] "Cathode Modulation Operating Data," RADIO Staff, RADIO, December 1939, p. 16.
[3] "Series Cathode Modulation," Dawley, RADIO, December 1939, p. 24.

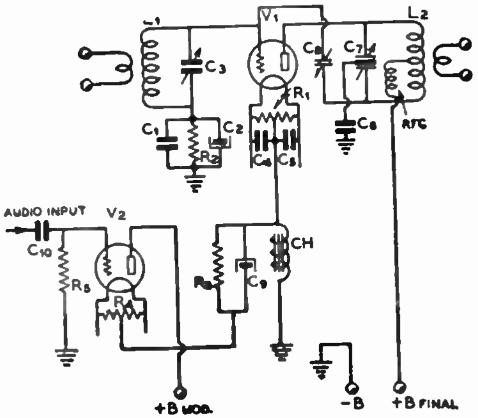

Figure 1. Wiring diagram of a single-ended r.f. amplifier being modulated by a triode parallel cathode modulator. R_3, by-passed by C_9, plus the drop across the choke CH furnishes the bias for the modulator tube V_2.

- C_1—.005-µfd. mica
- C_2—8-µfd. 450-volt elect
- C_3—Conventional for band of operation
- C_4, C_5—.001-µfd. mica
- C_6—.002-µfd. 5000-volt mica
- C_7—Conventional for band of operation
- C_8—Neut. condenser for V_1
- C_9—10-µfd. 100-volt elect.
- C_{10}—.05-µfd. 400-volt tubular
- R_1—C.t. resistor or tap on fil. trans.
- R_2—10,000 to 25,000 ohms, 10 watts
- R_3—500 ohms, 10 watts
- R_4—C.t. res. or tap on fil. trans.
- R_5—100,000 ohms, 1 watt
- L_1, L_2—Coils for band operated
- RFC—Conventional for band operated
- CH—3-to-10 hy. 150-ma. filter choke
- V_1—809, T-20, or similar
- V_2—2A3 or pair 45's in parallel

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od of connection by illustrating how a tube such as the 2A3 might be used to modulate an 809 or similar tube with 50 or 60 watts input.

• Advantages of Parallel Cathode Modulation

Cathode modulation has certain advantages over other systems of amplitude modulation, and a thorough inspection of the diagram of figure 1 will show that parallel cathode modulation has two main advantages over other cathode modulation systems for use with medium-powered equipment. These are: First, since the cathode impedance of the modulator tube is very closely the same as that of the cathode circuit of the tube to be modulated, no matching transformer is needed as a coupling impedance between them; it is only necessary to insert a common choke in the common cathode circuit of the two tubes. Second, the tubes in the parallel cathode modulator are operating with 100 per cent degenerative feedback; the plate is returned to the h.v. power supply and all the audio voltage output of the stage is impressed upon the grid of the tube 180° out of phase with the incoming voltage.

• Degenerative Feedback

It is this inherent degenerative feedback which lowers the effective plate impedance (or cathode impedance, if you want to call it that) to such a great extent. Although the percentage of feedback will be the same in all cases (100 per cent), the value of feedback expressed in decibels will be a function of the amplification factor of the tube. The amount by which the plate impedance is lowered, however, is dependent upon the amount of feedback expressed in decibels. Thus a 2A3 operating under rated conditions will put out 133 peak volts into a 2500-ohm load with a 45-volt grid swing. With 100 per cent degenerative feedback it will put out the same peak voltage but will require a driving voltage of 133 plus 45 or 178 volts. From these values we determine that the feedback around the stage is slightly less than 12 db. This value of feedback will lower the effective plate impedance of the 2A3 to a value in the vicinity of 300 ohms. This value will operate very well into the cathode circuit of the amplifier.

On the other hand a 6L6 operating into its rated load and at the rated plate and screen voltages will put out slightly over 300 peak volts with a 17.5-volt peak grid swing. With 100 per cent degenerative feedback the new grid swing that will be required is about 320 peak volts, thus giving about 25 db of degenerative feedback. This much feedback will lower the plate impedance of the 6L6 to an effective value in the vicinity of 500 ohms.

• Modulator Tubes

From the preceding paragraph we see that as long as high transconductance tubes are used the plate impedance will be lowered to a value that will be satisfactory for use as a parallel cathode modulator. A single 2A3 can be figured to give an output of about 5 watts; a single 6L6, about 12 watts; and a pair of 6L6's, about 25 watts. Suggested modulator and r.f. amplifier combinations are: a single 2A3 operating at 300 volts and 55 volts bias to modulate an 809 or T-20 with 750 volts at 75 plate ma.; a single 6L6 at 375 volts plate, 250 screen, and —17.5 grid to modulate an 811, T-40, HK-24, or 35T at 1250 volts and 75 to 100 plate ma.; a pair of 6L6's in parallel at the above conditions to modulate a pair of the amplifier tubes either in parallel or push-pull at the same plate voltage (1250 volts) and at twice the plate current.

At inputs greater than about 250 watts (the highest of the above conditions) other systems of cathode modulation are more desirable. At lower inputs than the above other tube combinations will suggest themselves; there are a number of tube combinations that would be suitable for battery operated and portable equipment. Since all high transconductance tubes will have an effective plate (cathode) impedance of the order of 500 ohms with 100 per cent degenerative feedback it is only necessary to determine the power output of the modulator tube from the tube characteristic tables and multiply this by a factor of 8 or 10 to determine the input to the r.f. stage which may be satisfactorily modulated.

Due to the fact that there is such a large amount of degenerative feedback around the modulator

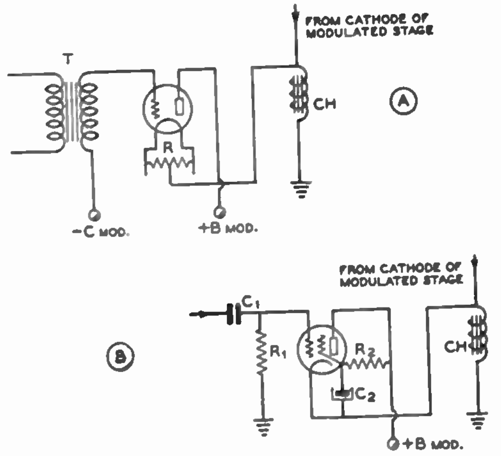


Figure 2. (A) Using external bias with triode modulator tube and transformer in grid circuit. CH—See figure 1 and text. T—2-to-1 or 3-to-1 audio trans. (B) Connection of beam tetrode modulator tube with drop across choke as modulator bias. R_2—50,000 ohms, 3 watts; and C_2—8μfd. 450-volt electrolytic, act to furnish proper screen voltage to the beam tetrode and to keep the screen at cathode potential with respect to audio. C_1 and R_1 can be as indicated in figure 1 or a step-up transformer as in figure 2A may be used.

tube, distortion within this tube will be greatly minimized. Single-ended beam tubes operated in the conventional manner have a rather large percentage of harmonic distortion: 8 to 15 per cent is not uncommon. However, with the audio energy being taken from the cathode of the tube, not only is the plate impedance lowered but the harmonic distortion is lowered by a comparable amount.

Another thing that will be noticed by reference to the paragraph under *Degenerative Feedback* is that the voltage swing required on the grid of the modulator tube is quite high, and that it is determined almost primarily by the power output of the tube rather than by the amplification factor as it would be in a conventional amplifier stage. This again is a result of the degenerative feedback, and would be obvious from the fact that the cathode impedances of all high transconductance tubes are approximately the same. Thus the 2A3 will require about 200 peak volts of grid swing and the 6L6 will require about 325 volts. The last stage of the speech amplifier should be designed with this thought in mind; it can best be a 6C5 or similar tube operating into a 2- or 3-to-1 (step-up) audio transformer with about 300 volts on the plate of the 6C5. No driving power is required of the stage but plenty of voltage output is needed.

• Biasing the Modulator

Alternative methods of connecting the parallel cathode modulator into the circuit are illustrated in figure 2. Figure 2A shows the method to be used with triodes such as the 2A3 (or larger tubes such as the 242-A, 211, 845, or similar should they be available and should it be desired to use them). Bias for the grid can be obtained from batteries or from the bias pack of the transmitter. The full amount required by the tube will not have to be supplied in this position since the drop across the choke due to the plate current of the modulated amplifier and the modulator will be added to the external bias. The amount which will be contributed by the choke can be calculated by adding the modulator and amplifier plate current together (expressed as amperes) and multiplying this current by the d.c. resistance of the choke. A semi-fixed resistor in series with the choke can be used to supply the additional bias if the extra voltage drop can be tolerated. With a large, low μ tube such as an 845, this drop would be appreciable.

Since the drop across the choke will normally be between 10 and 30 volts, the circuit shown in figure 2B can be used with 6L6 tubes as modulators. These tubes require only this amount of bias so that the total grid bias for the tubes can be taken from the voltage drop across the choke. Notice also that when using 6L6 tubes (or other beam tubes) as modulators, the screen is by-passed to the *cathode* and not to ground as it would be in a conventional amplifier with the cathode grounded. If the screen were by-passed to ground and not to the cathode in this mode of operation, the tube would be operating as a high μ triode instead of as a beam tetrode and the transconductance would be greatly decreased. Cathode-resistor biasing of the parallel cathode modulated tube is shown in figure 1. A separate filament transformer should be used to supply the 6L6 modulator tubes. The heater of the tube may be connected to the cathode or not, as desired.

Another thing to remember when using this system of modulation is that the modulator stage must always be operated single ended. If more than one tube is to be used in the *modulator* the tubes must be operated in parallel. They cannot be operated in push-pull since there is (theoretically) no fundamental frequency component in the cathode circuit of matched push-pull tubes.

• The Choke

The only item of coupling between the modulator and the modulated amplifier is a conventional choke. It is only necessary that this choke have reasonably low resistance (less than 150 ohms) and that it be capable of carrying the combined plate currents of the modulator and of the modulated amplifier stage. It need not have very high inductance (3 to 10 henries is ample) since the impedance in the common cathode circuit of the two amplifiers is quite low. An additional inexpensive filter choke of the type that would be used in the power supply to the modulated amplifier will be ample for use in this position.

• Operation

The other conditions for operation of this system were covered in the December, 1939 issue of RADIO.

¶ From Radio News, February, 1940

Fundamentals of RECORDING

By OLIVER READ
Technical Editor

THE art of home recording has moved at a fast pace ever since so-called "electrical cut records" made their appearance several years ago. At that time, the record companies began to consider the *quality* of the record rather than how much *noise* could be reproduced. The broadcasters began to make use of recordings on their programs, chiefly as an economy measure and the recording companies threw up their hands in disgust. All their labors had been done in vain, they thought, and a decided drop in record sales was immediately forecast.

Were they right in their predictions? Definitely not! Today more records are sold every week than even the most optimistic sales manager ever dreamed could be. And what improvement has been made in all types of records to bring this about, was it the adoption of better recording procedure, the use of electrical instead of mechanical recordings or the unforeseen ability of the broadcaster actually to create the demand for new discs?

We think it was a combination of all. At any rate, increasing interest has been shown in recent years in home recordings as well as the purchasing of commercial records and today the home recordist has at his fingertips a means of transcribing his favorite program, artist, commentator, skit, or what have you, right in his own home.

The first recorders were somewhat of a novelty, and these made records of the "Jones Family" that actually sounded more like "Amos 'n' Andy" when played-back to the spell-bound listener. These were very crude in comparison to the methods used today.

Semi-professionel recording is nothing more or less than an intelligent application of certain fundamental rules of sound and motion. The manufacturers have given the public recorders which are capable of producing records of a high degree of perfection, *providing* the operator uses his equipment in the manner for which it was designed.

We may delve into the art of recording in two ways to make records in a hit-or-miss fashion, or really to study the proper procedure and then apply our findings to the making of true high-fidelity discs. It is the purpose of this article to bring out some of the points we have encountered in this new and fascinating hobby and to pass it along.

• Equipment Needed

First of all, we must decide on whether or not we are to record high fidelity programs or use our equipment solely as a means for voice study or on average types of music or entertainment. This is important and requires an analysis of various recorders before we may decide on any one in particular. Recorders may be divided into three groups—the home portable, the semi-professional (portable or stationary), and the professional studio type. The latter is used only by the better recording studios and will not be discussed in this article.

The home recorder is either permanently mounted within a radio cabinet as part of a combination radio, or is of the type which may be carried about without too much effort and set up at any location where power for its operation is available. It records at a speed of 78 rpm, although some include that speed with an alternate choice of 33⅓ rpm. Most recorders cut from the outside of the disc to the inside, while a few give a choice of either outside-in or inside-out.

Home recorders include a suitable amplifier, pickup, volume level indicator, and playback facilities. A twelve inch turntable is used in nearly all models and record blanks up to twelve inches in diameter are available. The prices range from $75.00 to $185.00 for these units and they are entirely satisfactory for *general* recording where the recordist is satisfied with all but highest quality records. These are comparable to many of the commercial records sold on the open market and possess a surface noise level even lower than duplicate pressings sold.

The second classification deals with the semi-professional type of recorder. These are used in much the same manner as the home portables but are capable of much better fidelity and accuracy. The units include more costly cutting heads and playback pickup, a heavier motor and drive mechanism, and have the amplifier equipment separate from the table assembly in most cases. The price of this type of unit is considerably higher than the portable home type, and is based on the fact that the parts used and the care in manufacture needed for mechanical perfection is greater.

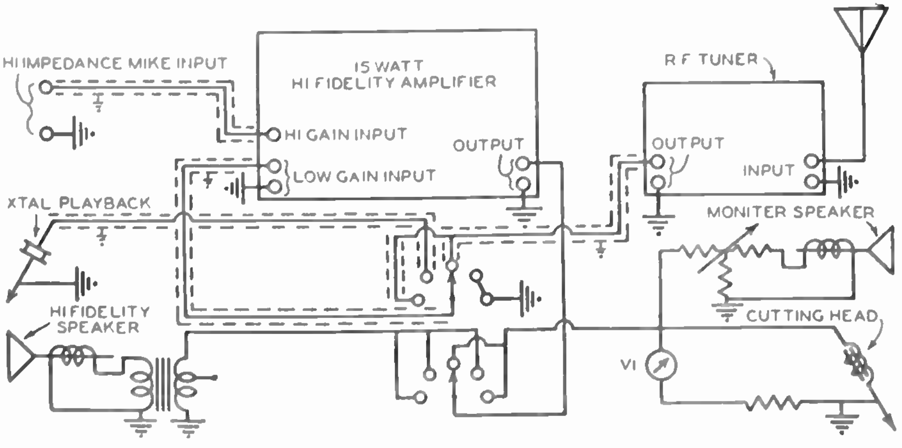
The third type is used only in the professional recording studio. This recording turntable and cutting head is mounted on a concrete block foundation to prevent any vibration transfer to the table. It looks like a combination lathe and turntable. The table itself weighs some 120 pounds. This is driven by a pulley-belt combination for smooth drive. The professional type is used largely for the making of so-called "electrical transcriptions." These records are 16" in diameter and are able to give 15 minutes of recorded material. The professional recorder was fully discussed in the September 1938 issue of *Radio News*.

We shall confine our discussion to the second, or semi-professional type, inasmuch as all of the important points apply to the portables as well.

Suppose that we wish to use our equipment in as much a versatile manner as possible for *all* types of recording: music off the air, or direct microphone pickup (either at a permanent location or in portable service). We must then be able to record all sizes of blanks up to 16" so that, when the occasion presents itself, we can record for a quarter hour on one side. Next, we should choose between the two methods of cutting—outside-in, or, inside-out. The latter method is most satisfactory for all types of discs as the "scrap" winds itself automatically around the hub and clears away from the needle. If, on the other hand, the scrap material were to entangle around the needle, there would be a good chance of the needle jumping a groove and ruining the record.

The above precaution should be observed on acetate discs in particular, as the cut material leaves the disc immediately after cutting.

Diagram of a full recording set-up.



On the plastic discs, the static electricity charge generated by the friction holds this material in place in the groove as it is cut and the record can be cut from the outside-in with no danger of the scrap fouling the needle.

Both the portable and semi-professional types are available with two distinct methods of cutting drive arrangement. One is the overhead screw type. This consists of the hub assembly and worm gear, a special threaded drive rod, and a rigid carriage for the support of the cutting mechanism. The threaded rod must be accurately machined to provide an even number of lines per inch, free from backlash or play, burrs or imperfections, and positioned in a horizontal plane with respect to the turntable surface.

The second type makes use of a cam arrangement that is located under the table board. Most of these are designed to cut from the outside-in. In appearance, they represent a conventional playback pickup. This type of recording mechanism is widely used on portable units and is entirely satisfactory where a high degree of fine cutting is not required.

- High-Fidelity Recording at Home

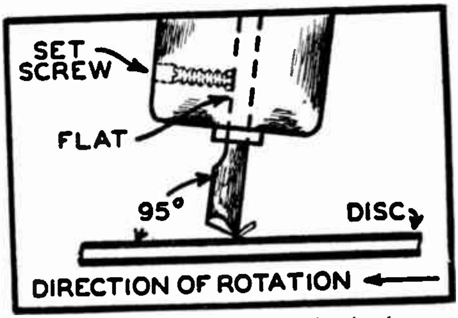
Part of the author's permanent recording setup is shown on pages 52 and 53. This equipment has been chosen after making several hundred records from radio broadcasts and from studio pickup; and been designed around a portable transcription table of conventional professional variety. The recordist can use any similar table of comparable quality to obtain the results had on this unit. The turntable itself is of sufficient weight to be rim-driven with maximum steadiness and torque and this assures freedom from "wows" caused by any variation in speed as the recording is done or when it is played back.

The motor is synchronous, and operates from a 110-120 volt, 60 cycle source. It is heavy enough to allow sufficient reserve so that when a heavy bass passage is encountered in recording, the increased drag on the motor will not affect the running speed. The motor requires oiling and cleaning the assembly at least once a year to remove all excessive grease and oil which has accumulated dust.

The turntable is of aluminum, and turned to perfect balance on a lathe. The "table" must run absolutely smoothly and be carefully tested for balance before it meets the requirements of a good recording "table." It is of sufficient weight to be used for high-fidelity work. Rubber drive wheels are used to transmit power to the rim as well as to afford vibration freedom from the motor.

Cutting is done from the inside-out, either at 33⅓ or 78 rpm. A thin rubber mat should be used under the record to prevent scratching of the disc and to offer a slight amount of shockproofing. Guide screws are provided so that the cutting drive will not slip at the hub assembly.

• The Cutting Head



Position of the cutting head.

Of greatest importance is the selection of a cutting head which will fulfill all of the requirements of high-fidelity recording. On the "Head" rests the ability to transit *all audio frequencies* onto the disc *without* audio peaks and it should do this most efficiently and precisely. Such is the *Universal* Full-Frequency Cutting Head shown and used on this equipment. Built and adjusted to the precision of a fine watch, this cutter will respond to all frequencies from 30 to 10,000 cycles and over with excellent fidelity. The earlier types of magnetic heads made use of rubber dampers. These rotted after two or three years and the balance of the armature was upset and distortion resulted. The only remedy was to install new ones and this required expert adjustment. The head shown has *no* such rubber dampers, and the initial adjustment will hold for many years. The impedance of the cutting head coil is 15 ohms and this is accurately matched to the amplifier by means of a line-to-voice-coil transformer.

Inasmuch as a standard level indicator is used "calibrated for a 500 ohm line," this method was adopted as the most satisfactory. An average recording level of plus 14 db. (0-db. equal to 6 milliwatts across 500 ohms) was found to be the best for all types of discs and the head will handle considerably more power on peaks without any distortion.

Cutting heads are available in many varieties. Most of them are of the magnetic type, and operate in much the same manner as a magnetic pickup. The crystal type has now found its way to the market. These are rather expensive and the range capability is about the same as a high grade magnetic type. Greater care is required in the use of these, and, like all crystal devices, are subject to changes in temperature. They should not be used in direct sunlight or exposed to any high temperatures or the adjustments will suffer and a possible cracking of the crystal take place.

One thing is certain, for true high-fidelity we cannot be satisfied with any cutting head which is incapable of reproducing all frequencies of a large symphony orchestra and its abundance of overtones and rich harmonics. Cutting heads range in price from $15.00 for the speech-frequency type, to as high as $400.00 for the best grade of precision equipment used by the large recording companies. High-fidelity heads may be had for a cost of approximately $90.00.

• "Giving It the Needle"

The best cutting head in the world cannot do its job if the recording needle is in any way responsible for inaccurate cutting of the material on the disc. Two general types of needles are used in recording—the steel and the sapphire pointed. The first type are of high-grade steel, ground and polished to a razor-edged chisel point. Any imperfection on the cutting edge of the needle will be transmitted to the disc in the form of surface noise and must be avoided. If a burr is present, the needle will actually dig-in to the surface and ruin the record.

Steel needles are suitable for recording on soft surfaces such as acetate or any of the soft plastic kinds now widely used for recording. They are good for up to 15 twelve inch records before they require re-sharpening. Their quality may be tested by cutting on a blank (without audio) and then playing the record back to observe whether or not any noise is present on the disc, which will be very evident if all is not well at the needle.

For the best results, we recommend the use of the *sapphire* needle. This type is more enduring and possesses a harder material that may be used for some 15 hours of recording before it is necessary to return them to the manufacturer for re-sharpening. These are rather costly to purchase but are well worth the investment when it is realized that the recordist has a needle which is not likely to chip during a recording of some particular selection.

Sapphire needles are fragile to shock, and should be protected when not in use. Our own is covered with a small cork slipped over the needle so that in case the carriage accidentally drops to the record, or if struck, the point will be protected. Care must be used in placing the needle in position on the record.

• Choice of Disc

Many excellent makes of blank discs are now on the market to choose from. The portables which cut from the outside-in may use the new plastic blanks to good advantage. For best all-around recording, the acetate type is recommended. These are also widely used (16") for transcriptions and for broadcast purposes. The acetate type of disc has an aluminum base which is covered with a coating of cellulose acetate (some authorities claim it similar to the duco we have on our cars). This material is soft in texture and is flowed or sprayed onto the aluminum in an even coat.

The thickness of this coating usually determines the cost of the record. The BC stations generally use a heavy disc, supplied with more than the usual amount of coating. The depth of cut is important and the scrap should be approximately the thickness of a human hair. Too deep a cut will result in cutting through the coating and on to the aluminum base and is to be avoided. Chances are that the needle would be ruined as well as the recording.

Aluminum blanks are sometimes used. These have a much higher surface noise than the acetates or plastic types. A diamond cuttting needle is required when the grooves are not precut. This needle actually drags along the record in application.

- Choice of Amplifier

Here again, we must be careful to choose an amplifier which has the ability to pass *all* frequencies that are to be fed into the cutting head. This amplifier must be versatile in its discriminator channel so that full advantage of tone correction may be used. Such an amplifier is the Radio News Full-Range Amplifier described in detail in the December, January, February issues just past.

This unit has a power output of 10 watts undistorted or 15 watts peak and this is more than sufficient for full modulation of the cutting head. The amplifier is mounted in a relay rack directly under a cathode ray oscilloscope, which may be used for observing audio waveforms. Reference to the articles on the amplifier will show that provision has been made for both high and low-gain inputs. The output transformer specified will match any standard line or voice-coil combination.

Complete tone compensation is provided. Both the highs and the lows may be either *attenuated* or *accentuated* at will. This is exactly what we want when recording music at a recording speed of 33⅓ rpm. as will be explained later. We also can add further to the effect of played back recordings by including volume expansion for *both* the high and low frequencies. This applies mostly to commercial records which are sold on the open market. These are recorded within definite volume-range-limits, and do not represent a true picture to the listener as far as hi-fidelity is concerned.

A symphony orchestra has an overall range of about 52 db. This range is compressed in the studio to much narrower limits to prevent overcutting of the wax groove. The home recordist, on the other hand, does not have to be concerned about this condition as long as precautions are taken "not to overdo it," and to watch the depth of cut intelligently. So we can see from the explanation that in the home, a wider range is permissible and then the record may be played back without *any* expansion and be an original transcription in this respect.

The amplifier must possess a frequency range of from 30 to 10,000 cycles, both in fairness to the cutting head and to the sound source, such as a symphony orchestra. The amplifier must also be capable of rather flat characteristics in order to be capable of high-fidelity. The hum level must be extremely low so that no trace will appear on the record. This model of the Radio News amplifier has its power supply mounted on the lowest panel in the rack.

Two plate current meters are provided instead of one on this model so that individual tube currents may be observed simultaneously. This is important and high-fidelity recording just will not permit any distortion in the amplifier. Shielding is most complete, from the input circuits all the way through to the output.

- Playback Pickup

A much easier unit to choose is the pickup. This must be of good grade and fully capable of reproducing all frequencies from the record. Many excellent makes are now sold which are able to accomplish this. First, we must consider the weight of the needle as it rests on the disc. This should not exceed two ounces. Next comes the type of pickup we will purchase. There are magnetic units, dynamic units, and crystal types to choose from. The fidelity will be in proportion to the cost of the pickup, in general. The magnetic units are the most durable and are less subject to temperature changes than the crystals. Either may be used for playback with about equal results.

The pickup should be free in its motion, both vertical as well as horizontal, so that the amount of wear on the record be kept to a low degree. The needle should always be tight in the armature when in use or the playback will lack true reproduction, particularly of the high notes. One of the latest types of pickups makes use of a miniature dynamic unit. These are now being used in many broadcast studios for transcription work. They possess a high degree of ruggedness found only in some of the best magnetic types.

- Volume Indicators

Several types of indicators are used on recorders but the purpose of each is the same. Some of the low priced units make use of an a.c. voltmeter across the output line to the cutting head. The better portables use a copper-oxide type of rectified instrument known as the DB meter. If high-fidelity recordings are to be made on acetate discs, we can highly recommend the instrument shown. This meter, a Simpson model 47 has an especially designed solid bar magnet and is known as a "slow speed" meter.

There are many sound passages which contain an abundance of instantaneous peaks that show on a fast reading meter in such a manner as to mislead the operator. We have found that it is far more satisfactory to have an accurate *average level* reading for best results and this instrument was chosen in preference to the high-speed types. The meter needle rises rapidly on peaks, but has a slow return downward across the scale. This gives enough time to observe the level which is not the case in some of the more commonly used methods of volume indicators. Suitable multipliers are provided to increase the range of the instrument to a maximum of plus 18 db. The meter comes in the standard range.

- Radio Tuner

We must have a suitable tuner

if we are to record programs from "off-the-air." The main requirement in the selection of this unit is to be sure that the full modulated carrier of the broadcast transmitter can be received. This is needed, of course, for maximum results. Most super-het receivers on the market today possess a high degree of selectivity and are unsuited for high-fidelity as the side-bands of the carrier usually suffer unless the receiver is peaked to have flat-top characteristics.

It is better to design a tuner for any given recording setup and this will permit us to take full advantage of the full range of audio. Present regulations permit the broadcast station to transmit on a channel that is 10 kc. in width. In other words, frequencies as high as 5000 cycles appear on each side of the carrier frequency of the transmitter. When frequency modulation is adopted we may hear a much more complete audio range than is now possible from a conventional transmitter.

To meet present conditions we are using the tuner shown in the February issue of Radio News. This has been stripped to the bare essentials of an oscillator, first detector, and a second detector. The combination allows complete coverage of local stations with maximum fidelity. The selectivity is good enough to permit only one station at a time to be heard, and this without any side-band splatter from adjacent channels. The receiving antenna should be just long enough for all local stations to be heard at good volume through the amplifier.

Another type of tuner may follow design of the tuned radio-frequency type. At any rate, the one point to consider is that we must have "all of the station" appear at the amplifier or we cannot expect good results. The detector should operate as a rectifier on the best possible portion of the plate curve for linear detection so that no distortion will be caused by the tuner itself. Coupling is done to the low-gain input of the amplifier in conventional manner. It is best to establish a volume level at the tuner, and once set, not changed. Volume may be controlled at the amplifier with more accurate results.

• Choice of Microphones

Here again, we find plenty of good microphones to choose from. What type is best suited to recording? The answer to that question will depend on what applications are to be covered most. For home recording of the family voices, the crystal, capacity, carbon, velocity, dynamic, or inductor may be used. If the microphone is to be passed around to various members of the family, we may choose one of the hand units. Probably the best will be the crystal. This unit is rugged and will operate in any position. If price is an obstacle, we may use a carbon mike with suitable handle, as shown on page 52.

If the recorder is one of the portables, we suggest one of the following: crystal, dynamic, or capacity (Velotron). A suitable collapsible floor stand may be carried about with the equipment and set up wherever the occasion presents itself.

For the professional or where the requirements are more exact, we have found that not one, but two or three microphones may be used to good advantage. Such types as a dynamic, a directional crystal, and a velocity all find application for good recording. The dynamic type shown, *Electro-Voice 620C* is of high impedance type, performs well both inside as well as out-of-doors, and is not affected by wind, moisture, or temperature. This is ideal where sound-effect records are to be made. In the studio, the dynamic possesses characteristics which make it ideal for both voice and all types of music. By tilting the head to a vertical position, it responds to all directions with equal effectiveness. In a solo positon, it permits either distant or close pick-up with excellent quality.

The directional crystal type of microphone, *Shure Brothers Uniplex,* shown, is ideal where recordings are made in a hall or ballroom that has a PA system in operation at the same time as a record is being made. This mike is highly sensitive in the direction to which it is aimed and permits pickup in difficult situations that many types are not able to handle.

We have always had a soft spot in our heart for the velocity mike for pickup of a soloist. It seems to possess all of the qualities for this application in the studio. This microphone is particularly suited to a *permanent* setup in a room or studio. It features pickup from both front and rear with equal sensitivity, and is, therefore an ideal type to use for recording two or more people at one time, such as when reading script in a presentation of a play. It is not as well suited to outdoor pickup as the other types, as noisy operation will result when wind passes through the screen and moves the ribbon.

Many makes of microphones are available, and if one chooses with care, he may be assured of excellent response in connection with the high-fidelity amplifier used.

• Recording Technique

Now that we know just what equipment we will need, we may go into the finer points of recording. We shall use the setup as shown as being representative of nearly all types, whether permanently located or set up at a portable location. There are definite steps that should be taken when using the equipment for the first time. First, the moving parts should be inspected for proper lubrication and cleanliness. Second, the recorder should be assembled (if necessary) following the manufacturer's specifications which accompany the recorder.

Third, the table must be absolutely flat. This may be adjusted with the aid of a small carpenter's level placed on top of the table. Undue wear on the record will result if this precaution is neglected. Fourth, the cutting needle should be inserted into the head in such a position that when it rests on the record, the angle should be 85 degrees. In other words—the needle should follow the record at an angle of 5 degrees from vertical.

If too great an angle is used—chattering and echo will result in recording. The needle must be tightened securely before making a record. Some heads are provided with a conventional means of needle screw, while the *Universal* head is furnished with a small screwdriver and the needle is held firmly in place by tightening the set-screw. This method offsets possible chance of damaging the adjustment from accidental shock or impact, and also reduces the weight of the armature.

A flat is provided on one side of the needle shank and this side must face the front of the head and is on the opposite side of cutting edge. Turning of the needle is thus avoided. Never drop the needle onto the record but lower it gently *after the table is turning*. Failure to observe this rule will result in a gouged disc and possibly a chipped needle.

A test record should be run to determine whether or not there are any defects in the needle. Run off a few grooves and then play back for observation. If any noise is present, it will be heard as a scratch or hissing. Later you will find that a good needle will cut quietly and this may be judged by the ear without playing back. The needle should not be heard in a quiet room as it is cutting.

The depth of cut is extremely important. This, as mentioned in earlier paragraphs, should be adjusted so that the scrap is of the same consistency as *one* human hair. This adjustment is made with the spring tension on the right hand side. The cutting may also be observed by microscopic inspection. The microscope is a handy attachment to have when recording orchestra music or the like.

The scrap is highly inflammable and should be disposed of in a metal can with tight fitting lid. This scrap should be continuous thread if properly cut and should be shiny in appearance. If the scrap appears as a dull grey, it indicates that the cut is not great enough and the tension spring must be slightly loosened for deeper cut.

Some recorders cut at 98 lines, or grooves, to the inch, others at 102 and 110 grooves per inch. In the first case, the error of over-cutting is far easier to prevent than in the other two, but in any case, the operator has to observe the precautions earlier set forth.

The first record should be made with microphone on voice from some member of the family in order to check the recording against the normal speaking voice of the subject. This recording should be a faithful reproduction and it is easy to compare the two for accuracy. The position of the subject with respect to the microphone is important for best results. By having the subject speak at different distances from the mike, the operator will soon find the best placement and this should be noted for any particular mike.

After the recordist has become entirely familiar with the fundamentals in this type of procedure he may attempt the more difficult types of microphone pickup. It is best to progress in small steps as blank discs are expensive and are not to be wasted. Set up the microphone in the living room at home. This room is usually provided with enough carpets, rugs, and drapes to relieve any bad reverberation effects. If some member of the family plays, and a piano is available a test record may be run and then studied for comparison.

The manufacturer specifies how much volume is required for correct operation of the head. An average level of 14 db. is usually sufficient for nearly all magnetic heads. Too high level will result in distortion, overcutting, and unsatisfactory overall performance. Too low a level will result in improper modulation of the recording head and the surface noise will be near the lower passage levels.

After each record has been made, the selector switch should be turned to the "playback" position and the recording studied for response, level, surface noise and any irregularities. Correction may then be made before attempting another run. Only by careful study can we expect to achieve good results. Make notes whenever possible on the label—such as the level used, microphone placement, etc. Then when an unusually fine recording turns out, we can tell at a glance just what conditons were used at the time.

• Recording Broadcast Programs

The serious minded recordist will wish to record certain programs "off-the-air." Our own particular fancy in this respect is to record the *Sunday Evening Hour*. It so happens that this program enjoys a beauty of microphone pickup that is hard to beat.

When the selector switch is placed in the "record-tuner" position, all connections of the various units are automatically made and we are ready to proceed with the recording. Volume is adjusted at the amplifier so that a level of 14 db. reads on the mëter. It is very important that the tuner be precisely tuned to the station or distortion will result. If the tuner has a tendency to drift in frequency, we must allow sufficient time for it to reach operating temperature before recording.

A form of aural monitor must be used in order to follow the program. The regular speaker provided in some recorders may be used to good advantage for this purpose, although this does not apply when microphone pickup is used. To do this, would result in feed-back from speaker to mike and the disc would be ruined. Headphones should be used for the latter.

Excellent recordings are made with good equipment, of orchestras which contain a wider range of frequency than do the commercial records or pressings in most cases. The surface noise is so low that one cannot detect needle noise unless the room is absolutely quiet. It is best not to "ride gain" when recording unless the music is of such a type that extremely low passages predominate. In such cases, the volume may be increased for the duration of this passage, and later returned to normal.

After a few records have been run, the operator will know just how much maximum and minimum range may be tolerated with his particular equipment.

• Recording at Slow Speed

Many recorders are designed for both 78 and 33⅓ rpm. In no case should the user attempt to record music at 33⅓ until he is entirely satisfied with results on 78 rpm. This type of recording requires more elaborate treatment than does the standard speed and certain precautions must be taken in order that all frequencies will cut with equal amplitude on the disc. The actual speed of the traveling disc near the inside is very slow and the high notes will suffer greatly if some correction is not made.

This requires that the high notes be boosted at the amplifier to overcome the losses. Trial will determine how much boost is needed. As the speed increases, these high notes will take-hold in normal fashion and the amount of boost may be reduced.

A good investment for the recordist is in the purchase of a *Universal* test frequency record. By using it as a standard of comparison, this record will be valuable and we can learn much about the characteristics of our equipment. This record may be played on an extra phono turntable and fed into the amplifier in the recording position. The test is then run and a recording made during the process. When played back, one may observe what changes have taken place from the original and studied for correction of the tone compensators.

The 16″ transcription discs require even greater care in recording as the inside-to-out ratio of speed is greater than that encountered with the 10 or 12″ sizes. These are most suitable for music when recordings are made at the higher speed and this is recommended where a 15-minute playing time is not wanted.

• Frequency Response Recording

A cathode ray oscilloscope is a valuable addition to the recording setup. With it we may check the response of the amplifier in terms of voltage to frequency, study the harmonic content of the recording amplifier, and observe waveform under various conditions. The response of the cutting head may be determined by feeding the output of a beat-frequency audio oscillator into the amplifier and then on to the cutting head. The oscilloscope may be used as a no-current voltmeter so that the input voltage be kept constant at all frequencies. This is important, as we want to determine just what is taking place in the amplifier and cutting head.

If we know that the response of the amplifier is flat we may be reasonably sure that the head will be modulated at the same response as actually comes from the oscillator-amplifier combination. After the recording has been made, the disc is substituted for the audio oscillator and we may proceed in making a curve on the response of the head at various frequencies.

The decibel meter is used as an output indicator across the line. The volume at the amplifier is set to read 0 db. at the meter. The record is started and the first frequency, say 30 cycles from the record is read for level (frequency should be jotted down on the disc at each setting of the audio oscillator) prior to the test. This reading may be —10 db. The next reading, say at 50 cycles may read as —8 db. These are noted on a piece of logarithmic graph paper.

When we hit 200 cycles, the reading may change to 0 db. and so on up the frequency range. Each frequency is marked on the graph and later, when complete, will give a true picture of the ability of the cutting head to respond to various frequencies. The gain at the amplifier *must not be changed* after the run is started.

- Conclusion

We have attempted to give the reader a complete story on home recording without going into highly technical explanations regarding recording technique as it is known in the large commercial studios. Wax recording, etc., requires a treatise that, although similar to instantaneous recording, involves closer adherence to fundamentals and details and we feel this field is limited to only a very few and will not be discussed in this manuscript

The reader may be assured of excellent results if he will but observe the fundamentals set forth. Purchase equipment with care, don't be too hasty to turn out the first records, study the individual parts of the recorder and the accessories, place microphones intelligently, watch the db. meter when recording, don't use excessive audio to the head, balance the audio at the amplifier to give pleasing proportion to the type of recording being played, keep new and finished blanks in a metal container to preserve their surface and to prevent undue hardening of the material, use only the best needles—both for cutting as well as for play-back.

By following these simple rules, you will produce the best recordings.

(See pages 52, 53 for photographs.)

Pictorial Section

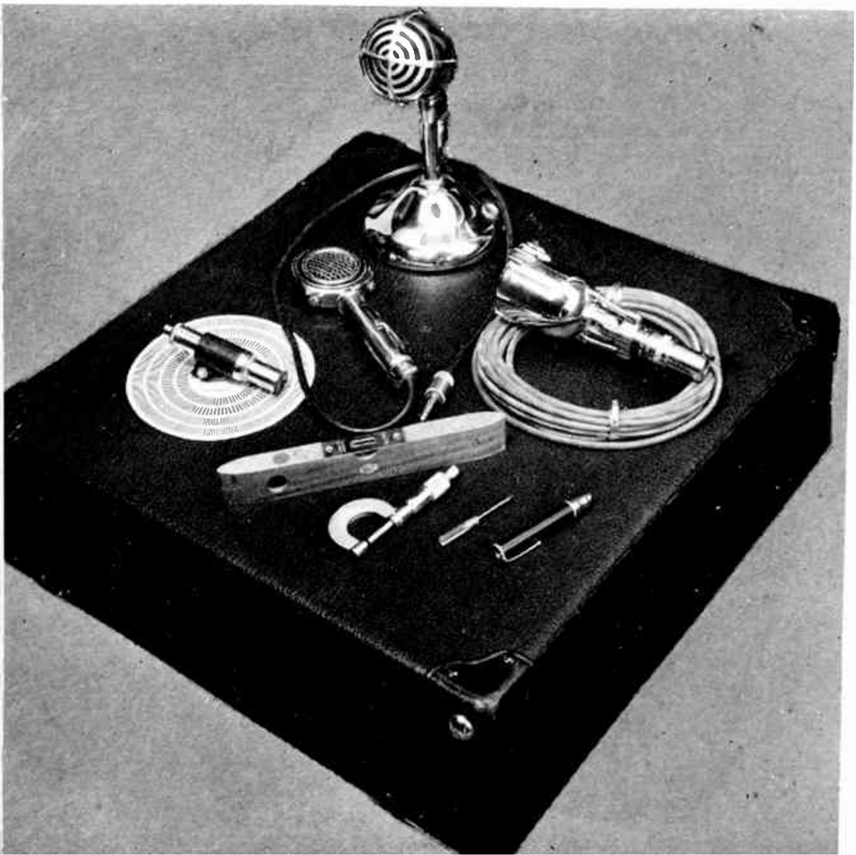
● A section of an ultra-high-frequency oscillator for laboratory use.
(Illustration courtesy Bell Laboratories Record)

Fundamentals of
RECORDING

(Discussed on pages 37-50)

(Illustrations courtesy Radio News)

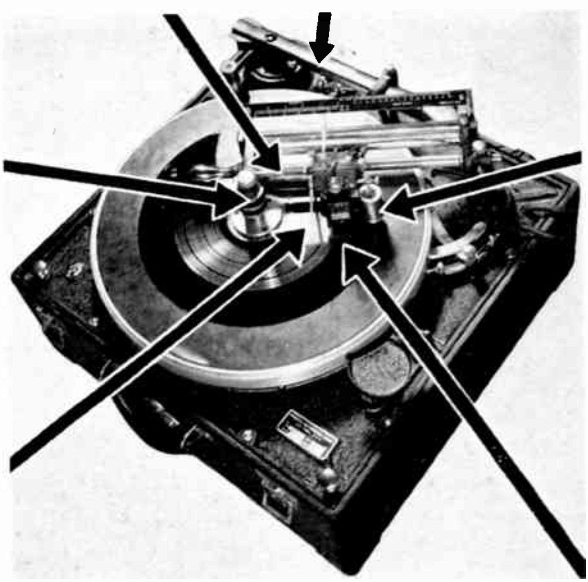
● Aside from the recorder and amplifier, these are the various accessories which are needed to get the most out of your new hobby.



". . . . . . increasing interest has been shown in recent years in home recording as well as the purchasing of commercial records and today the home recordist has at his fingertips a means of transcribing his favorite program, artist, commentator, skit, or what have you, right in his own home.

"The first recorders were somewhat of a novelty, and these made records of the 'Jones Family' that actually sounded more like 'Amos 'n' Andy' when played back to the spell-bound listener. These were crude in comparison to the methods used today."

—*The Author*

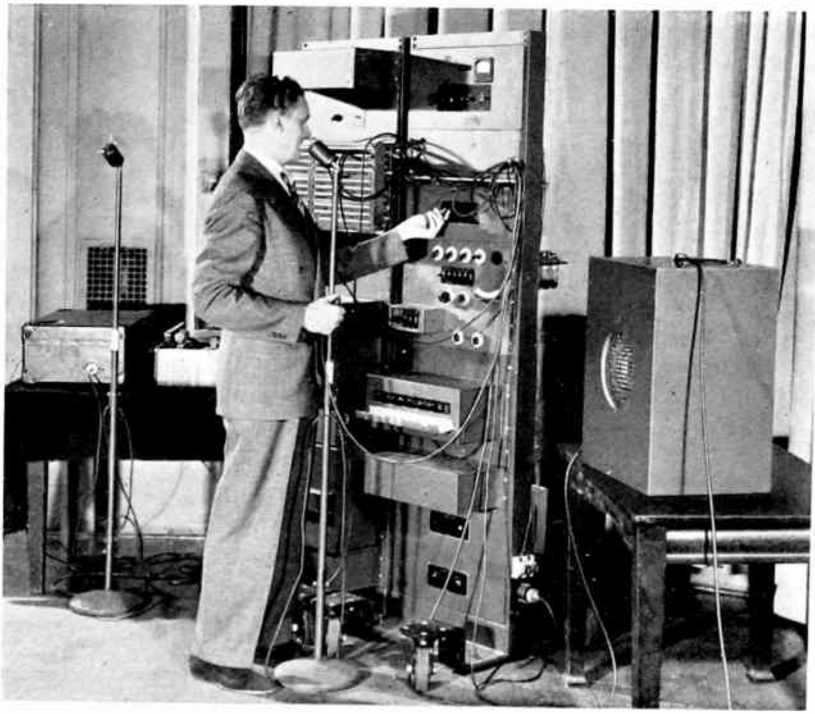


Important parts of the recorder discussed by the author.

THE VOCODER

• The Bell System Vocoder, a speech coding and reproducing device, is described in detail on page 55. In brief, it consists of a system of analysers which convert the pitch component and the amplitudes of the frequencies within bands of 300 cycles up to 2950 cycles into varying d.c. "code" voltages. These "code" voltages are then fed into a reproducing system which can reconstruct the original speech or music, or the system can alter the original sound in almost any desired manner.

(Illustration courtesy Bell Laboratories Record)



From Bell Laboratories Record
December, 1939

THE VOCODER

By HOMER DUDLEY

AT THE World's Fairs in New York and San Francisco great interest was shown in the speech synthesizer in the Bell System exhibits. Known as the Voder, this device creates spoken sounds and combines them into connected speech. Its raw materials are two complex tones, a hiss and a buzz; selection of one or the other and its intensity and tone quality are controlled by an operator through a keyboard.[1]

The Voder is an offshoot of a more extensive system, first demonstrated in its experimental stage some three years ago. That system analyzed spoken sounds, and then used the information to control the synthesizing circuit. At the time World's Fair displays were under consideration, so it was naturally perceived that the synthesizer, manually controlled, could be made into a dramatic demonstration. Development was for a while concentrated in that field; as a successful Voder became assured, attention was shifted back to the broader and parent system. Shortly thereafter the system was given the name "Vocoder" because it operates on the principle of deriving voice codes to re-create the speech which it analyzes.

Figure 1 shows the over-all circuit for remaking speech; the analyzer is at the left and the synthesizer at the right. Electrical speech waves from a microphone are analyzed for pitch by the top channel and for spectrum by a group of channels at the bottom.

In the pitch analysis the fundamental frequency, which for simplicity will be called the pitch, is measured by a circuit containing a frequency - discriminating network for obtaining this frequency in reasonably pure form; a frequency meter for counting, by more or less uniform pulses, the current reversals therein; and a filter for eliminating the actual speech frequencies but retaining a slowly changing current that is a direct measure of the pitch. (Unvoiced

[1] Pedro the Voder, Bell Laboratories Record, Feb., 1939, p. 170; RADIO TECHNICAL DIGEST, May-June, 1939, p. 22.

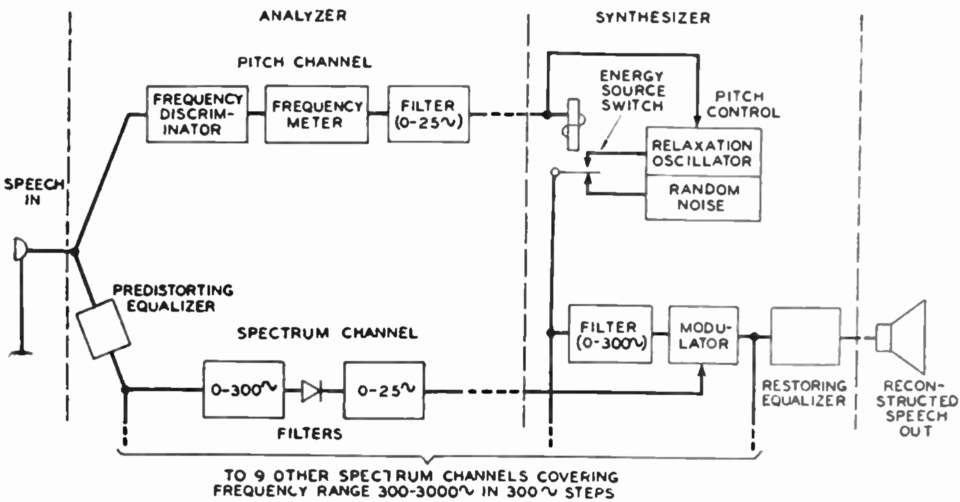
sounds, whether in whispering or the unvoiced sounds of normal speech, have insufficient power to operate the frequency meter.) The output current of the pitch channel is then a pitch-defining signal with its current approximately proportional to the pitch of the voiced sound and equal to zero for the unvoiced sounds.

There are ten spectrum-analyzing channels,[2] the first handling the frequency range 0-250 cycles and the other nine, the bands, 300 cycles wide, extending from 250 cycles to 2950 cycles, a top frequency which is representative of commercial telephone circuits. Each spectrum-analyzing channel contains the proper band filter followed by a rectifier for measuring the power therein and a 25-cycle low-pass filter for retaining the current indicative of this power but eliminating any of the original speech frequencies.

The operation of the analyzer is illustrated in figure 2 (page 57) by a group of oscillograms taken in analyzing the sentence "She saw Mary." To insure that the same speech was analyzed in obtaining the various oscillograms, the sentence was recorded on a high-quality magnetic-tape recorder and reproductions therefrom supplied current to the analyzer. The speech-wave input to the analyzer is shown in the line next to the bottom while the output is shown in the other oscillogram traces; the

[2]A 30-channel vocoder covering the wide range of speech frequencies required for high quality has also been built and is being used as a tool in laboratory investigations.

Figure 1. Simplified schematic of the Vocoder.

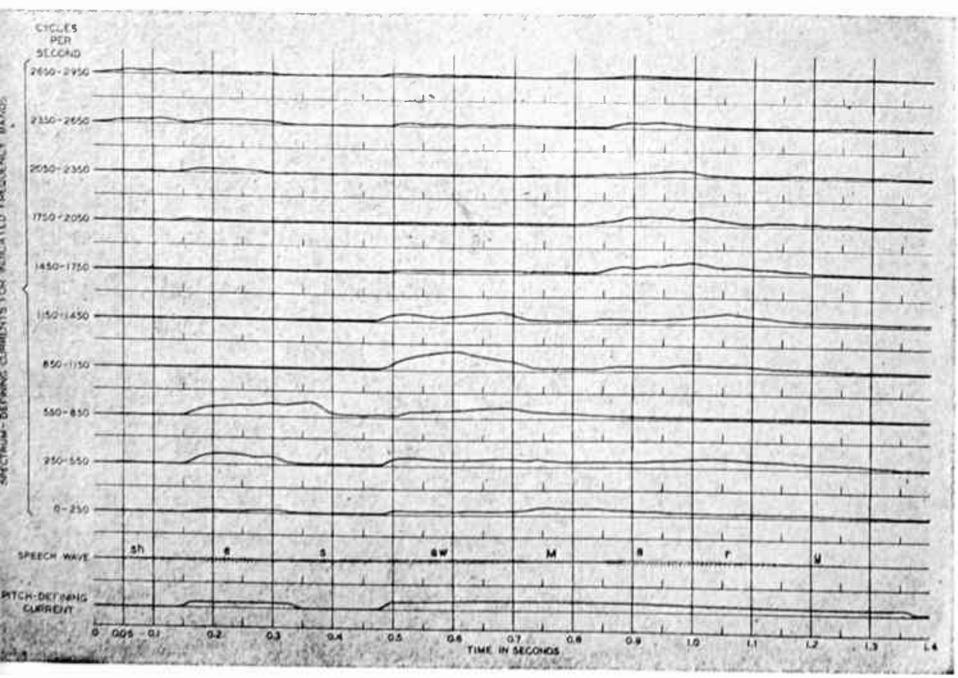


pitch-defining signal is at the bottom in the figure and the ten spectrum-defining signals in numerical order at the top. For convenient reference the oscillograms are lined up together whereas in the actual circuit the speech-defining signals lag about 17 milli-seconds behind the speech-input wave. The inaudible speech-defining output signals contain all the essential speech information as to the input wave, but it is to be noted that they are slow-changing and in this way correspond to lip or tongue motions, as contrasted with the higher audible vibration rates of the rapid-changing speech wave itself. The dropping of the pitch to zero for the unvoiced sounds "sh" and "s" is also readily seen.

Figure 2 gives an idea also as to the synthesizing process. In the analyzer the speech wave is the input and the eleven speech-defining signals are the output; in the synthesizer the eleven speech-defining signals are the input and the speech wave the output.

The steps in speech synthesis are indicated at the right of figure I. The relaxation oscillator is the source of the buzz; and the random noise circuit the source of the hiss. The hiss is connected in circuit for unvoiced sounds and for quiet intervals. (In the latter case no sound output from the synthesizer results

Figure 2. The original speech wave and an analysis of its components, expressed as the variation of several direct currents.



because there are no currents in the spectrum channels.) When a voiced sound is analyzed a pitch current other than zero is received with the result that the buzz is set for the current pitch by the "pitch control" on the relaxation oscillator; also, the relay marked "energy source switch" operates, switching from the hiss source to the buzz source.

The outputs from the spectrum-analyzing channels are fed to the proper synthesizing spectrum controls with the band filters lined up to correspond. The power derived from the energy sources of the synthesizer in these various bands is then passed through modulators under the control of the spectrum-defining currents. The result is that the power output from the synthesizer is sensibly proportional in each filtered band to that measured by the analyzer in the original speech. From the loudspeaker comes, then, speech approximately the same in pitch and in spectrum as the original. This synthetic speech lags the original speech by about 17 milliseconds due to the inherent delay in electrical circuits of the types used.

In the present models of the Vocoder, control switches have been introduced which permit modifications in the operation of the synthesizer. Through the manipulation of these controls interesting effects are produced. Some of the possibilities of the Vocoder were recently demonstrated by the author and his associate, C. W. Vadersen, before the Acoustical Society of America and before the New York Electrical Society. In those presentations Mr. Vadersen supplied by his own voice the incoming speech which was picked up by a microphone as shown in the headpiece; and at the same time he manipulated the controls to produce desired effects. A remote-control switch was also provided through which, for the purposes of comparison, the author could switch the microphone directly to the loudspeaker and so let the audience hear how the speech would sound if it had not been modified by the Vocoder.

In these demonstrations comparison is first made between direct speech and the best re-creation that the apparatus could make. Then by manipulation of dials and switches, speech is modified in various ways. Normal speech becomes a throaty whisper when the hiss is substituted for the buzz. Although the hiss is relatively faint, it is shown to be essential for discrimination as between "church" and "shirts."

Ordinarily the re-created pitch moves up and down with that of the original. If variation is prevented, the re-created speech is a monotone, like a chant. When the relative variation is cut in half, the voice seems flat and dragging; when the swings are twice normal, the voice seems more brilliant; when four times normal it sounds febrile, unnatural. The controls can be reversed so that high becomes low: the tune of a song is then unrecognizable, and speech has some of the lilting characteristics of Scandinavian tongues. Another control fixes the basic value of the re-created pitch; if this is "fluttered" by hand, the voice becomes that of an old person. By appropriate setting of the basic pitch, the voice may be anything from a low bass to a high soprano, and several amusing tricks can be performed. In one of these, the basic pitch is set to maintain a constant ratio of 5 to 4 to the original. This is a "major third" higher and harmonizes with the original. In two-part harmony, the demonstrator then sings a duet with himself. Connecting a spare synthesizer set for a 3 to 4 ratio he then sings one part in a trio, the others being taken by his electrical doubles. Finally, with the basic pitch-control of the apparatus, he becomes a father reprimanding his daughter; then the girl herself, and then becomes the grandfather interceding for the youngster.

For the vocal-cord tones of the original, the Vocoder substitutes the output of a relaxation oscillator. But any sound rich in harmonics can be used: an automobile horn, an airplane roar, an organ. In some demonstrations, the sound, taken from a phonograph record, replaces the buzz input from the oscillator. Keeping careful time with the puffs of a locomotive, the demonstrator can make the locomotive puff intelligibly "We're - start - ing - slow - ly - faster, faster, faster" as the puffs come closer together. Or a church bell may say "Stop - stop - stop - don't - do - that." A particularly striking effect is that of singing with an organ to supply the tones. Although the words may be spoken, the demonstrator usually sings them to hold the rhythm. It makes no difference whether his voice is melodious or not; the tonal quality comes only from the musical source.

These tricks and others have suggested uses for the Vocoder in radio and sound pictures. It appears to have possibilities as a tool in the investigation of speech, since by its numerous controls important variables in speech can be isolated for study. The engineering possibilities which may grow out of the application of the principles employed in this device are hard to predict at the present time. The speech-defining currents, however, do have features of simplicity and inaudibility which may open the way to new types of privacy systems or to a reduction in the range required for the transmission of intelligible telephonic speech.

(See page 54 for illustration)

¶ From The T. & R. Bulletin, September 1939.

CRYSTAL FILTERS

PART II*

By E. L. GARDINER, B.Sc., (G6GR)

A DESCRIPTION OF WORK DUE TO DR. JAMES ROBINSON, INVENTOR OF THE "STENODE" CRYSTAL FILTER, WRITTEN BY HIS ASSISTANT.

- The Double-Crystal Band-pass

SUPPOSE two exactly similar crystals are available, but differing in frequency by about the width of bandpass required. Let them be connected in parallel in the usual circuit of figure 3, and the phasing condenser adjusted to compensate for the total parallel capacity of the two crystals and their holders. The circuit will now behave as two complete crystal gates in parallel, and will give a response curve having two sharp peaks, somewhat as sketched in figure 9. Each curve will have the phase relationships described when considering figure 5, and in the region between the two crystal frequencies it is clear that the voltages through one of

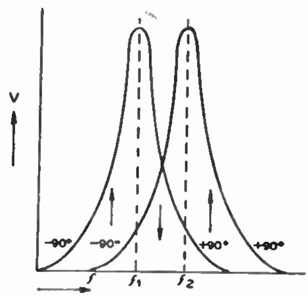


Figure 9. Response curve obtained by the use of two crystals of slightly different frequencies connected in parallel in the bridge circuit of figure 3.

them will be in opposite phase to those through the other. At the output point D they will therefore be in opposition, and their combined effect will be very low.

This is unfortunately not of much practical use as a bandpass arrangement, but might become so if the phase of one crystal response curve could be completely reversed,

* Part I, *T&R Bulletin*, August, 1939, appeared in the January-February, 1940, issue of *Radio Technical Digest*. Figure references are continued from Part I.

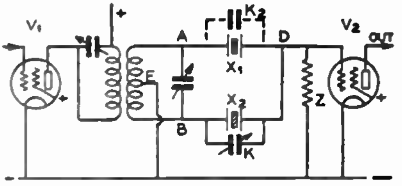


Figure 10. Placing a second crystal X_2 in the opposite arm of the bridge as shown above will produce a band-pass characteristic.

so that the phases in the middle region became additive. Fortunately an extremely simple way of doing this exists, and it is surprising that so many years elapsed before the practical advantages of the arrangement were realized. The second crystal is merely moved to the opposite arm of the bridge, being joined in parallel with the condenser K. It now receives input from the opposite end of the coil AB, which is in opposite phase to that applied to the original crystal, and so delivers an output in reversed phase at D. At first sight it would seem necessary to provide the second crystal, X_2, with its own balancing condenser K_2 in the other arm of the bridge, as shown dotted in figure 10 but since the action of these condensers is purely differential, the effect of K_2 would be to reduce the balance setting of K. It can therefore be omitted, K being set to a value that is lower than its original setting by the capacity of K_2. Practically, the two balancing condensers necessary with two similar crystals would tend to be equal, and so K might be omitted; but as small differences in capacity between the two arms of the bridge are generally present, K will be joined across whichever arm has in fact the lowest residual capacity. A good arrangement is to join a fixed condenser of a few micro-micro-farads capacity across one crystal, and a variable condenser of somewhat larger maximum capacity across the other. By varying this condenser it is then an easy matter to introduce a predominance of capacity into either arm as required. We can still talk of the balance condition, just as when only one crystal is used, for in this condition the response curves of both crystals will be symmetrical.

The phase conditions are now different from figure 9, since those of one curve have been reversed. Let it be the right-hand curve. Then in the region between f_1 and f_2 both crystals will be contributing voltages in the phase $+ 90°$, which will assist each other over most of that region, resulting in a larger output at D than from either crystal alone. At the peaks, each crystal is approximately 90° out of phase with the response due to the other at that frequency, which is in any case comparatively small. There is thus little interaction, the peak voltages being perhaps reduced by a few per cent., and similar conditions occur for the limited region just around each peak frequency, where rapid phase changes are occurring. The resultant curve is of the bandpass form as shown in figure 11, and has an effective width slightly greater than the frequency difference between the two crystals.

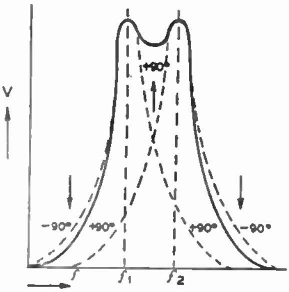


Figure 11. The effect upon the response curve of moving the second crystal into the opposite arm of the bridge, as shown in figure 10.

Response is high over the band f_1 to f_2, but is very low outside this region, where the phases due to each crystal remain in opposition. Before considering just how low the response is we must treat separately the two cases when the difference $f_2—f_1$ is large or small.

- Filters for C.W.

It will be simplest to consider first the case when the two crystals are quite near together in frequency, say 300 cycles (0.3 kc.) at an i.f. of about 465 kc. The response curve of figure 11 will now be very high and narrow as in figure 13, and at the mid-frequency half-way between f_1 and f_2 there will be considerable response from both crystals, in approximately additive phase. Thus the central dip between the crystal frequencies will be slight, and no special measures need be taken to eliminate it. We can now afford to operate each crystal at high effective selectivity, and as was explained when discussing variable selectivity from a single crystal, the load impedance Z of figures 3 and 6 can be low in value. In practice a resistance of between 5,000 and 50,000 ohms is suitable, and the simplest possible circuit can be used (figure 10) with a resistance in the position Z.

It is important to realize that the slope of the curve outside the crystal frequencies, namely the cut-off slope of the filter, will be greater than that of a single crystal used alone. At any outside point, say near the skirts of the curve on the left hand side, there will be the response of the crystal X_1, just as there would be in an ordinary crystal gate. There is, however quite an appreciable response at that point also, from the crystal X_2, which is only a few hundred cycles different in frequency, and this response is in phase opposition to that through X_1. The resulting response must therefore be less than that through either crystal alone. If the crystals were infinitely near together in frequency, then the slope of the curve would approximate to the square of that for a single crystal. Practically, however, it is intermediate between this and the slope given by a single crystal, becoming less as the spacing between the crystals becomes greater, but being always better than the latter. If selectivity be defined as the ratio between the wanted signal and a signal sufficiently different in frequency to be outside the band-pass, then it will be true to say that the double crystal arrangement will always be more selective than a similar crystal used alone.

• Balancing the Band-pass Filter

What now will happen if the balancing condenser K of figure 10 is varied from the setting which gives the symmetrical curve of figure 11? In the single crystal gate we have seen that if the balancing or phasing condenser be increased, a "zero" point occurs on the high frequency side of the crystal frequency, as explained when discussing figure 7. Now K is connected to act as a balancing condenser for the crystal X_2 in the band-pass circuit, so if it be increased in capacity, a zero point is to be expected on the high-frequency side of X_2, as shown at P_2 in figure 12. The position of this point can be moved about by the operator to dodge interference just as if he were using a single crystal gate.

But in increasing K something else has occurred. The capacity in the arm of the bridge containing X_1 has been increased, which exactly corresponds to a *reduction* in value of the imaginary balancing capacity K_2 which completes the bridge circuit for that crystal. This introduces a zero point P_1 on the *low-frequency* side of X_1 (because the conditions are the exact reverse of those pertaining at X_2) and therefore falling outside the pass-band on low frequency side. Two symmetrical zero points thus occur simultaneously, giving the condition shown in figure 12. The position of each point will vary with the balancing condenser. Thus it becomes possible to reduce interference on both sides simultaneously. This produces a very real improvement over the single crystal arrangement in which a zero on one side is necessarily accompanied by an increased response on the other, probably bringing in interference from signals on that side of resonance.

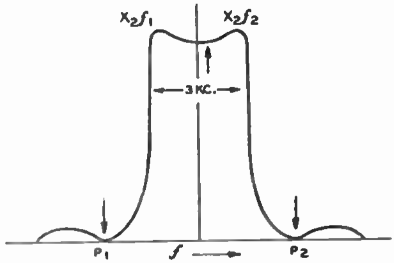


Figure 12. The effect of increasing the balancing capacity is to introduce two "zero" points at P_1 and P_2, at the same time raising the central region.

• Advantages

We can now understand the reasons why a narrow band-pass obtained from a pair of crystals is much more useful to the practical amateur than the older form of crystal gate. The latter has been found very valuable for a number of years, but it has a few defects which often prevent its full use, and which are overcome by the band-pass.

First there is the question of ease in handling, coupled with tuning drift. The single crystal has a very sharply peaked response, and signals must be tuned in "on the nose"

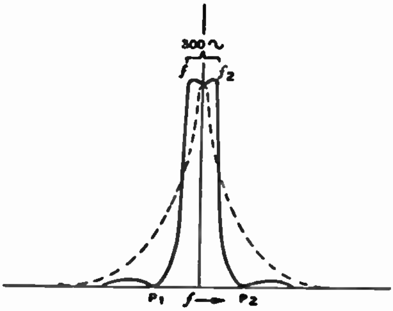


Figure 13. A comparison between the response of a narrow bandpass filter, and that of a single similar crystal used alone.

of this curve in order to gain the full benefit from the filter. If it is highly selective, the proportion of detuning permissible is very slight indeed. This means that with the majority of receivers it is a distinctly tricky matter to tune in a signal accurately through the crystal, and in the stress of a dx competition, for example, valuable time is often lost. Once the signal has been tuned, however, quite a small trace of oscillator drift in the receiver will lose it again, and this or any other slight disturbance may demand fresh searching at each changeover during a QSO. Admittedly these difficulties have been reduced by careful design in the more perfect commercial receivers, but they are seldom entirely absent, particularly in amateur built equipment.

A second group of difficulties arise at the transmitter. A perfectly stable c.c. transmission may be received through a crystal satisfactorily, but unfortunately there seems little prospect of all signals coming under this category. Not infrequently a transmission will drift, through gradual heating of the transmitting crystal, and it may become difficult to hold at the receiver without constant retuning. Then there are self-excited transmissions, signals possessing a violent chirp, and the numerous rough or modulated notes to be heard on any crowded band. These will often belong to the most sought-after dx stations, who may perhaps be working under very unfavorable conditions. Such signals can seldom be received at all through a normal crystal gate, or if selectivity can be broadened to an extent which will deal with them, a considerable residue of interference will also be heard.

The use of a double-crystal bandpass having an effective width of perhaps half a kilocycle completely overcomes all but the worst of the difficulties mentioned. The receiver need now only be tuned so that the signal falls *between* the frequencies of the two crystals, and there is a certain amount of latitude in adjustment which makes searching comparatively simple. Drift in either receiver or transmitter is unimportant provided that it does not exceed the width of the pass-band, while a chirping or modulated signal will be well received if it does not vary materially by more than the band-width. The increased strength of modulated or unsteady signals in comparison with the single crystal is very striking. As has been explained, the actual rejection of outside interference from whatever cause, is greater with the band-pass system, except in the infrequent case where an interfering signal falls within a few hundred cycles of the wanted transmission. In such a case there will seldom be two such transmissions equally close on each side of the one required, consequently, it will be possible to clear the interference by tuning the wanted carrier near to one edge of the pass-band. This is probably the only penalty to be paid for the improved utility of the band-pass filter, all the advantages of which have not yet been mentioned.

Careful measurements have indicated that in the vital matter of signal-to-noise ratio the band-pass filter shows an improvement of about 20 db over a typical single crystal filter. The reason for this is indicated in figure 13, where the dotted curve represents the type of response to be expected from the latter. The curves are of course drawn on a somewhat wide scale, for if represented in the more usual proportions, they would be so steep and narrow as to be contained with difficulty in the sketch. It is well known that the response of a receiver to untuned noises, such as atmospherics, or ignition interference, will be reduced in proportion as selectivity is increased. The degree is said to be proportional to the square root of the band-width, and the area within the response curve of the receiver provides a measure of its susceptibility to noise from outside sources. Now it will be seen that whereas the single crystal curve is very narrow at the peak, it widens more rapidly than the corresponding band-pass curve, while towards the skirts it is considerably wider. The total area beneath it will be somewhat greater. Hence, while the improvement in signal-to-noise ratio on switching in a single crystal filter may be about 40 db in a typical case, the improvement effected by a band-pass filter some 300 cycles wide has been estimated at 60 db, showing a 20 db advantage in favor of the latter. It must, of course, be realized that the above figures are relative, and will not apply exactly to all cases. For example when the band-width of a double crystal filter is increased, a point will be reached at which its noise-rejecting properties become equal to a single crystal filter adjusted to its maximum selectivity, whilst a band-pass of sufficient width for telephonic use will be still less effective against noise. It is, however, likely to remain superior to an ordinary crystal gate which has been widened out to give telephony of comparable quality.

In the reception of c.w. by means of a crystal filter adjusted to maximum selectivity, criticism is often levelled against the unpleasant ringing effect imparted to the signals. This effect is inherent in the single crystal arrangement, and is a manifestation of the exceedingly low damping of the crystal. The same effect can also be obtained from other circuits in which damping is very low, such as a reacting detector adjusted critically just below the oscillation threshold. Unfortunately the better a crystal-gate is working, and the higher its response to the wanted carrier above all others, the lower will be the effective damping of the crystal, and the more noticeable will be the ring. The crystal is thrown into oscillation by a signal impulse, and remains in vibration for an appreciable time after this impulse has ceased. Code signals tend to run into each other, forming nearly a continuous sound, and at the worst, high speed sending becomes almost, or even quite, unreadable. Atmospheric noise or interference also acquires a ringing tone of the same pitch as the signals, which become in consequence very difficult to copy.

Here again the band-pass filter provides a solution to the problem, for it is found that when a pair of crystals are used, ringing is almost absent. The probable explanation of this improvement lies in the fact that whereas in the case of a single crystal the carrier wave is carefully adjusted to resonance with the crystal (and is thus ideally placed to excite ringing) in the band-pass arrangement the carrier will normally lie about midway in frequency between the two crystals used. Being a hundred cycles or more away from the resonant frequency of either, it is not able to excite such violent oscillation in them. Energy is being applied to the filter at a substantially different frequency from that of either crystal, whilst in the previous case it is applied at the exact crystal frequency. It is incorrect to say that there is no ringing with the double crystal filter, but the effect is so slight that it is hardly noticeable in normal use, and the writer has never known a case where signals have become unreadable from that cause. As would be expected, increasing band-width by the choice of crystals more widely separated in frequency, still further reduces the effect, until at bandwidths of several kilocycles ringing cannot be detected.

To sum up the reasons why a pair of crystals should be used in preference to a single crystal when receiving telegraphic signals, we may place first, higher effective selectivity accompanied by a greater reduction of noise, followed by considerably improved ease of tuning, elimination of the effects of drift in both receiver and transmitter (unless this is initially very bad), ability to read chirpy, modulated or unsteady signals, and the absence of any unpleasant degree of ringing. To obtain these advantages the cost of an additional crystal and slight changes in circuit wiring are all that is required, and it will be shown in Part III, which describes the practical side of the subject, that neither of these need be very serious.

PART III

The T. & R. Bulletin, October, 1939

• Filters for Telephony

Broadly speaking the use of a single crystal gate has been confined to telegraphic reception. It is true that in recent years receivers have been fitted with variable selectivity adjustments whereby the crystal filter can be broadened out to an extent which will render telephony intelligible, but since this is done by lifting the skirts of the response curve, it is liable to bring in additional interference. The fact that many amateurs do in practice use the crystal filter to lift difficult telephony signals out of the interference, in spite of the serious reduction in the higher modulation tones which results, and that speech is rendered on the whole more readable by doing so, is a tribute to the usefulness of crystal filters in general. It does not, however, mean that the single crystal type is suited to this purpose, for which it was admittedly not primarily intended.

By the use of two crystals, however, a band-pass can be obtained which is much simpler to use and more perfect than can be arrived at practically through the use of many i.f. circuits in cascade. If a width of about 3 kilocycles be chosen, and the receiver adjusted so that the incoming carrier falls near to one edge of the band, then single sideband reception will result, giving reproduction of modulation tones up to about 3,000 cycles. This is sufficient for very clear-cut and intelligible speech. Moreover, since the band-pass response is somewhat concave, as shown in figure 11, conditions are very favorable to crisp reproduction. The carrier, falling near one peak of the curve, will be amplified rather more than the average modulation. Thus the percentage modulation at the following detector is somewhat reduced, and will not reach 100 percent even when the original signal was 100 percent modulated. It is well known that single-sideband reception is fairly free from distortion if the modulation depth does not exceed some 70 percent, but that detection introduces considerable distortion when this percentage is exceeded. The latter condition is automatically avoided by the use of double crystal band-pass as described above.

Similarly, sidebands corresponding to tones of about 1,500 cycles will fall near the middle of the curve, and will be somewhat reduced, whilst higher frequencies up to 3,000 cycles will fall near to the second peak of the curve, and will be increased relatively. Thus the reproduction of higher frequencies in the region most desirable for good intelligibility, is lifted somewhat. The goal of the sound amplification engineer, namely a response curve which is level over the medium frequency range, but which rises at both the upper and lower limits, has thus been reached.

Single sideband reception giving reproduction up to about 3,000 cycles is probably the best theoretical compromise known for the reception of telephony through interference. It will permit three equally powerful stations to operate within a channel 10 kilocycles wide with a minimum of sideband splash, and no direct interference. Under congested amateur conditions it will enable a signal to be clearly received provided there is no other of similar strength within 3 kilocycles on one side or the other. While this separation may still leave something to be desired, it is doubtful whether any known system can separate telephony signals successfully at still closer spacing except by the sacrifice of so much quality that speech becomes almost unreadable. A band-width of 3 kilocycles has been assumed in this argument, but it is of course equally easy to select any narrower band if the user is prepared to tolerate poorer quality of reproduction. The beauty of double crystal working is brought home here, because in the case of tuned circuits it becomes increasingly difficult to obtain a good band-pass as the width is reduced, and still more difficult to maintain the several circuits in line; in the case of crystals the design becomes simpler and the cut-off more sharp as band-width is reduced.

It has been estimated that a sharp 3 kilocycle band-pass will roughly double the number of telephony signals than can comfortably be read during congested periods on the 7 Mc. band, in comparison to a typical modern communication receiver which is not fitted with such a filter. The response of modern receivers is nearly always of the single-peaked variety, being obtained from perhaps four or six i.f. circuits in line. While the width may be effectively a few kilocycles only on weak signals, it will be at least 6 or 7 kilocycles when signals are strong, because the response falls gradually and there are appreciable skirts to the curve which enable very strong interfering signals to break through. Probably an attenuation of 1,000:1 can be taken as about the figure necessary completely to reduce the strongest interference usually encountered, although even this value will not cope with a 100 watt station only a mile or two away! A typical i.f. amplifier employing six circuits at 465 kc. will give this ratio at about 6 kilocycles from resonance, or in a very good receiver, possibly 4 kilocycles, implying an effective bandwidth in the presence of strong interference of from 8 to 12 kilocycles. The crystal filter will attenuate 1,000 times at 1.5 kilocycles from either edge of the pass band. Thus, its maximum effective width is 6 kilocycles for 3 kilocycles crystal separation. If the crystals were chosen at 2.5 kilocycles separation, and the balancing condenser used to steepen the cut-off slope, an effective width of as little as 4 kilocycles could be reached.

An example of the practical advantages of this reduction can best be found in broadcast reception. Consider the separation of Deutschlandsender from Droitwich on the long-wave band. A modern receiver employing six i.f. circuits will separate the German station moderately, but with a considerable residue of sideband splash. At an intermediate point between the two, a mixture of jumbled programs will be heard. Comparing now the performance of a receiver containing only one i.f. stage but incorporating a crystal band-pass filter of 4 kilocycles effective width, used in the single sideband condition: The

German program will be found to suffer from perhaps one third as much splash as in the former case, while at a point half way between the two transmitters no direct program interference will be heard from either. There will be a silent spot, containing nothing but an occasional trace of splash as the sidebands of the two stations heterodyne each other. Were we dealing with amateur conditions, there would be room for another transmission at that frequency.

• Impedance Matching

To obtain a 3 kilocycle band-pass it is only necessary to modify the telegraphic filter by selecting a pair of crystals differing in frequency by 3 kilocycles instead of a few hundred cycles. Switching from one band-width to another is thus quite easily arranged when desired. If, however, the circuit of figure 10 be retained, there will be one serious defect. The central dip between f_1 and f_2 (figure 11 or 12) will be excessive, being perhaps 10 or 20 times down in voltage. Fortunately, several simple expedients will overcome this difficulty, the most convenient from the amateur point of view being based on the effects of impedance matching, which were explained in Part I when discussing the single crystal filter so that they could be referred to at this point without further explanation. It was there shown that the effective selectivity of a crystal depends upon the input and output load values, and that if these are made high, the response curve is considerably broadened. By taking this step, the response of each crystal at the mid-point of figure 11 can be increased until it approaches half the peak response, when the central region becomes level. In practice a slight central dip has been shown to be useful, partly to improve the conditions for single sideband reproduction, and partly because the effect of other i.f. and pre-selecting circuits lined up to the mid-frequency will be to lift the center. If, therefore, the curve were initially flat, it would become convex in shape through the action of these additional circuits, which must be present in any practical receiver. Impedance matching must not therefore be carried too far. It has also been pointed out that if the balancing condenser be adjusted to bring in "zero points" near to the sides of the band-pass, as in figure 12, the center will at the same time be raised. The condenser can in fact be regarded as a means for transferring energy from outside to inside the pass-band. Thus unless the initial response is left somewhat concave, the center will be raised excessively, if the balancing condenser be used to reject interference.

Practically the only alteration necessary to level the response sufficiently, is the substitution of the load resistance shown in figure 10 by a tuned circuit, as depicted in figure 14. The following valve (tube) may with advantage be tapped at a point about one third the turns up this coil from the grounded end, as shown, in order to prevent it damping the circuit exces-

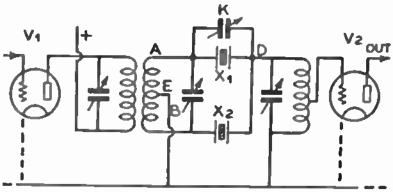


Figure 14. By substituting a tuned circuit for the load resistance, the above filter circuit suited to communication telephony reception is obtained.

sively. This tapping is only essential, however, when the filter is followed by a diode or other detector, having a comparatively low impedance. To obtain the best results it is of course necessary that the input and output circuits shall possess high dynamic resistance, since it is upon this factor that the filling-up of the central dip depends. Thus they should be coils of high Q. In practice it is preferable to employ rather high values of inductance tuned by low values of capacity, 2,000 micro-henries being a good figure for an i.f. of about 465 kc.

A sense of proportion will, however, be helpful in selecting the best values of impedance. Naturally the task of levelling the band-pass will be much easier when a width of only 2 or 3 kilocycles is wanted (as in most amateur applications) than in the case of a broadcast receiver in which widths from 4 to 10 kilocycles may be chosen. In the latter case it becomes necessary to choose coils of really excellent Q, say from 200 to 300, and to couple them critically to the respective primary or secondary windings. Both input and output couplings then become loosely coupled transformers, having both primary and secondary tuned to the mid-band frequency. It then becomes possible to attain a pass-band at least 8 kilocycles wide and level to within 2 db. For amateur telephony reception, however, it will be sufficient to use an output coil having a Q of about 150, directly tapped to the following valve (tube), while the input circuit can be a normal center-tapped i.f. transformer, preferably with critical coupling.

IN THE interests of public service and radio station convenience, the FCC agreed recently that station announcements of the use of mechanical records can be made at 30-minute intervals instead of the 15-minute requirements as heretofore. This is to avoid interrupting the entertainment continuity of a recorded series of records, or of the long records now quite generally used, particularly of recorded programs relayed by wire facilities. The change was made effective from January 4, 1940.

¶ From RCA Review, January, 1940.

TELEVISION RECEPTION

• In An Airplane

By R. S. HOLMES

ON THE occasion of the twentieth anniversary, October 17, 1939, of the formation of the Radio Corporation of America, a demonsration of television reception in an airplane was given for the press in cooperation with United Airlines. The principal feature of the demonstration was the reception of television images in the plane while flying at about 21,000 feet over Washington, D. C., an airline distance of about 200 miles from the transmitter on top of the Empire State Building in New York City.

As part of this demonstration a two-way conversation was carried on between the television studio and the airplane. Mr. David Sarnoff, President of the Radio Corporation of America, and Mr. W. A. Patterson, President of the United Airlines, conversed with several members of the group in the plane, who were watching them on the television receiver. This conversation was broadcast over the Blue Network of the National Broadcasting Company and both the studio picture and the conversation were broadcast over television station W2XBS.

A further interesting feature of the demonstration occurred when a landing of the plane at North Beach Airport was televised by the NBC Telemobile Units, relayed to Empire State, and observed on the screen of the receiver inside the plane. Thus the people in the plane saw themselves land as viewed from the ground.

The receiver used for this demonstration was a standard television broadcast receiver which was equipped with a 12-inch kinescope. It was operated on a 50-cycle power supply provided by a rotary converter driven by storage batteries. Close speed regulation of the rotary converter was not necessary, since the normal variations in power supply frequency with respect to the vertical scanning frequency had no effect upon the operation of the receiver. A radio-frequency amplifier was added to the receiver to increase its sensitivity.

The receiving antenna was a half-wave dipole mounted cross-wise under the belly of the ship as shown in figure 1. A transmission line about 15 feet long connected it to the receiver, which was mounted in the forward end of the passenger compartment as shown in figure 2.

The airplane was a Douglas DC3 21-passenger United "Mainliner." Two seats were removed to make room for the receiver and power equipment.

During the test flights preparatory to the demonstration and during the demonstration itself several observations of a technical nature were made. Flights were made on four different days. The first flight, on October 2, was a short hop around New York. As to be expected in an airplane, reflections from ground and buildings produced multiple images that were observed when the plane was close to the transmitter. There were innumerable multiple images, both positive and negative, spread almost completely across the picture, some moving rapidly and others nearly stationary. All of these multiple images decreased in intensity as distance increased from the transmitter and they disappeared completely, leaving a clean picture, at about 25 miles from the transmitter. For the most part the multiple images were much lower in intensity than the main signal, but at infrequent intervals they would rise in amplitude to equal, or even exceed, that of the main image.

On the other test flights the plane was flown from New York to Washington and back. In general the picture was very good so long as the plane was within line of sight from the top of the Empire State Building.

During the second flight, on October 4, there was a heavy overcast about 300 or 400 feet thick at 4500 feet. Below the overcast it was hazy, and above, it was entirely clear. On this day no signal was received directly over Washington at 17,500 feet, which is approximately line of sight for this 200-mile path. The signal was picked up about 20 miles northeast of Washington at this elevation, and was satisfactory most of the way back to New York.

On the third test flight, October 16, the weather was clear, with no clouds at all. The signal was received all the way to Washington so long as the plane was in line of sight. In fact the signal was reasonably good at 16,000 feet over Washington and improved with elevation up to 21,600 feet, the highest altitude attained.

On the day of the demonstration, October 17, there were scattered clouds. The signal on this day appeared to be maximum over Washington at about 18,000 feet, was somewhat less at 21,000 feet, and disappeared at 15,000 or 16,000 feet.

Sufficient data were not obtained to determine why the signal distribution varied with elevation on the different days. Exact field strength measurements were not made. Information on the weather has been included to indicate a difference in conditions during the several days of tests. Some interference in the picture was experienced from electrical equipment and motor ignition systems in the airplane. This was corrected by adjustment of the ground and shield connections. Other interference, also created in the airplane and probably due to intermittent bonding connections or vibrating control wires actuated by motor vibration, was not entirely eliminated. Severe diathermy interference was experienced at times. No difficulty was experienced with the receiving equipment from vibration of the plane or from operation at high elevations. The plane carried oxygen equipment for use of the passengers and crew at the unusual elevations where most of the tests were made.

Short-Wave Broadcasts Promote Foreign Trade

FOREIGN listeners to KGEI, General Electric's short-wave broadcasting station at San Francisco, like American merchandise.

This is shown in many of the hundreds of letters received by KGEI which reveal that the international broadcasters not only are building good will for the United States but also are directly promoting American foreign trade.

A letter just received from C. R. Halle, Pietermaritzburg, Natal, South Africa, says in part:

"I suppose you consider this place a part of darkest Africa belonging to Britain and leave it at that. Well, in reality it is darn near an American Colony. Just think this over:

"I have just come home in an American car, after seeing to the electricity supply from American transformers to American stoves and refrigerators. I listen on my American radio set to your American station KGEI and tonight I shall see a lot of American films in a cinema outside which about 20,000 pounds worth of American cars will be parked. And so it goes on . . . not to mention the wife's American stockings, etc."

¶ From Electronics and Television
& Short-Wave World,
February, 1940

THE SKIATRON

By A. H. ROSENTHAL

IT IS generally recognized that the future of television, its cultural and commercial importance, its value for entertainment anu propaganda, depend to a great extent upon the development of a television system which is able to provide pictures of any desired size and brightness in a way as simple and efficient as realized in the technique of the cinema. What is the common characteristic feature in cinematography which makes it possible to build small home projectors for a picture size of a few feet, as well as the bigest theatre projectors, providing pictures large and bright enough to be viewed by thousands of people? It is the principle of the optical projection of successive pictures of varying transparency, whereby each picture is retained for a certain time and projected as a whole by a standard light source on to the viewing screen. Translated into the language of television technique: It is the principle of light control combined with optical storage.

The production of pictures by light control methods means the use of a standard light source, i.e., an incandescent—or an arc lamp, to illuminate the viewing screen, and the modulation of the light intensity values of the various picture elements, simultaneously by the varying transparency values of the film picture in the case of cinematography, or successively by a light modulator actuated by the received signal in the case of television. In both cases the total light flux available, and therewith the possible size and brightness of the picture depend mainly upon the brightness of the light source used and upon the apertures of the projecting optics.

The chief advantage—from the point of view of the optical efficiency—of a film projector over a television projector is essentially the advantage of simultaneous over successive projection of the picture elements. The link between these two methods of projection is provided by the principle of optical

The technical stage reached in the development of television receivers may be summed up somewhat as follows: The direct viewing cathode-ray tube—a tube where the picture is built up on the fluorescent screen at its end—is giving satisfactory pictures of good definition and adequate brightness for pictures up to approximately 10-12 inches or so. There is no doubt whatsoever that with the growth of television the demand for much larger pictures, pictures which can compare in size, quality and appearance with home cinema pictures, will be more apparent. Home pictures projected from small-size cathode-ray tubes through an optical system have been demonstrated, but results so far have not been too satisfactory, such projected cathode-ray tube pictures leaving a lot to be desired, both in brightness and in picture appearance. Apart from cinema screen television, Scophony have produced by means of their mechanical optical scanning methods projected pictures in three sizes for the home, namely 18 in. by 14 in., 24 in. by 20 in., and 4 ft. by 3 ft., which were demonstrated just before the outbreak of the war. In their search for large projected pictures, Scophony have actually effected an important development in television reception by the invention of the Supersonic Light Control, which was the first practical means of "storing" picture signals and of projecting a series of picture elements simultaneously. This is an advantage which is absent in receivers using cathode-ray tubes.

Scophony felt that the future of television reception lies in the expansion of the principle of storage. The next development described in this article by its inventor, Dr. Rosenthal, of the Scophony Laboratories, makes use of storage over the whole of the picture. Theoretically, it represents the ultimate ideal.

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storage, by which a number of the successively arriving picture signals corresponding to the individual picture elements are stored in the form of variations of some optical property side by side on a carrier, in which form they can be simultaneously—and lasting for a certain time interval—projected.

The well known successes of the Scophony television system based on mechanical-optical principles, to provide pictures of cinema standard, were obtained by the optical storage of several hundred picture elements on a carrier of supersonic waves in the Scophony light control.

The most direct attempt to employ the advantage of the full optical storage of cinematographic technique to television has been the intermediate-film method. Here the television signals are photographically recorded as small film pictures on a cinema film as a carrier which can be projected by a standard cinema projector. But apart from a considerable and objectionable time lag between recording and projection of the images, caused by the necessary processing of the film, the system is very uneconomical by reason of the large amounts of film consumed.

A promising variation of this method, consisting of the use of an endless film, from which the pictures can be removed after having been projected and which can then be recoated with emulsion, is so complicated that no practical results could be obtained. Yet, if the received television signals could be recorded in a directly visible, i.e., projectable form on a carrier, and, more than that, if these recorded pictures could be retained on this carrier just for the duration of the picture repetition—or frame period during which they can be projected, and then, after having served their purpose, could be removed and replaced by a record of the following picture, all the drawbacks of the intermediate-film method would have been overcome, and an ideal system of television projection would result.

- Optical Variation

What means does physical science offer towards the attainment of such an ideal solution of large screen television?

It is obvious that the received signals, in order to be recorded on the picture carrier screen, have to be distributed spacially on this screen, which can best be done by scanning the screen by a cathode-ray beam modulated by the signals in the manner usual in cathode-ray tubes. But the screen itself must be influenced by the cathode-ray beam in such a way that a temporary point-to-point variation of its optical qualities results, i.e., a recorded picture which can be projected on to a large screen similar to a film picture.

It has already been proposed to use in a television receiver an image screen, the opacity or the reflecting power of which changes from point to point according to the intensity values of the received picture signals, so that such a screen if viewed directly or imaged by the light from a separate source on to another screen gives a representation of the picture. For such screens it has been proposed to use mechanical shutters, electro-optical or dichroic media and to utilize the orientation effects in colloids and like substances.

But no satisfactory results could be obtained from these proposals.

The most direct and ideal approach towards a solution of our problem would be a screen made of a material the transparency or opacity of which could be varied by suitable radiations, as for instance, cathode-rays, and which would retain its varied opacity for a desired period.

Are there materials of such ideal qualities known?

As it frequently happens in the history of applied science, some effect or other has been known as a laboratory curiosity for many years until dragged to the limelight of technical application and usefulness because some technical problem arose for which it seemed to offer just the right solution. To answer the above question: There have been discovered already in the early days of cathode ray research in 1894 by E. Goldstein, and have been known since, such materials which, normally transparent to visible light, are coloured, i.e., rendered more or less opaque, when they are struck by cathode-rays. Various scientists investigated later the properties of these materials in all details and found many interesting quantitative relations to other branches of science, for instance to photography, phosphorescence and electron conduction.

- Ionic Crystals

Examples of such materials are crystals of the alkali and alkaline earth halides, such as the chlorides, bromides and iodides of sodium and potassium, lithium bromide, calcium fluoride, and strontium fluoride and chloride. All these crystals belong to the class of the so-called "ionic crystals," in which there are electrically positive and negative components, and the forces that hold these components together are of an electric nature, at least in part.

If these crystals, which are normally transparent to visible light, are struck by a beam of cathode rays, X-rays, radium rays or by light of a suitable wavelength, a deposit of opaque material, which is constituted by the so-called "Farbzentren" or colour centres, is created in these crystals, the degree of opacity depending on the intensity of the incident radiation.

In the case of alkali halide crystals, research has indicated that the colour centres probably consist of neutral alkali atoms which are loosely bound in the interior of the crystals in some manner or other, and which are somewhat similar to the deposit of metallic silver in a latent photographic image. The deposit of metal in the crystal lattice can also be created by heating an alkali halide crystal in an atmosphere of the vapour of its alkali metal, which diffuses into the crystal.

Once formed, the opaque deposit can also be destroyed by the above-mentioned rays, the amount of destruction in a given time interval depending upon the intensity of the rays and on the density of the deposit already formed. Thus the gross effect of any given intensity of the incident radiation, being the result of an equilibrium between the formation and destruction of the deposit, may be an increase of the deposit for low intensities and a decrease for the high intensities, in a manner similar to the well-known "solarisation" of the latent photographic image. Thus, over a range of low intensities of the incident radiation, increase in intensity will result in an increase of the deposit, while over a range of high intensities an increase in intensity will result in a decrease of the deposit.

The materials exhibiting this property may be defined as ionic crystals in which the injections of electrons into the crystal lattice can produce an opaque deposit, and we may denote this property as electron-opacity.

The material may be in the form of a single flat crystal, a mosaic of small crystals, or a micro-crystalline structure. A composite crystal or a mixture of two or more of such crystalline materials may be used.

In most cases, and particularly when the material is in the form of a single crystal, a disappearance of the opaque deposit can be produced by maintaining the crystal in an electric field and at a suitable temperature in which case the deposit is drawn through the crystal towards the positive pole producing the electric field. When it reaches the positive pole it disappears, leaving the crystal substantially transparent. The speed of movement of the deposit depends upon the strength of the field and upon the temperature, and can be varied within wide limits by varying either magnitude. For a given field strength this speed of movement increases with the temperature of the crystal.

- **Utilizing the Effects**

There are different possible ways to utilize these most interesting physical effects for the purpose of a television projection apparatus, depending on which of the various forms and modifications mentioned above it, which these effects manifest themselves, we intend to use. Quite generally such a television system comprises scanning an image screen including a material of the type described with a beam of radiant energy modulated in intensity in accordance with the received picture signals.

This scanning produces periodically at frame scanning frequency in each elemental area of the screen a density of opaque deposit which differs from a fixed datum level of density by an amount depending upon the instantaneous value of the intensity of the beam striking the area. The density of the produced deposit is caused to return to the fixed datum level, whereby the frequency of the return for the successive deposits in said elemental area is equal to the frame scanning frequency.

The datum level of density may be zero, in which case the scanning beam produces directly an opaque deposit in each elemental area of the image screen proportional in density to the instantaneous intensity of the beam when it strikes the area, and this deposit is caused to disappear periodically at the frame scanning frequency.

Alternatively the datum level of density may correspond to picture black, in which case the scanning beam is adapted to remove the deposit from each elemental area to an extent depending upon the instantaneous intensity of the beam when it strikes the area, and the density of the deposit in each elemental area is caused to return to a maximum value corresponding to picture black periodically at frame scanning frequency.

All the various forms and operation which are fully described in the British Patents Nos. 513,776,

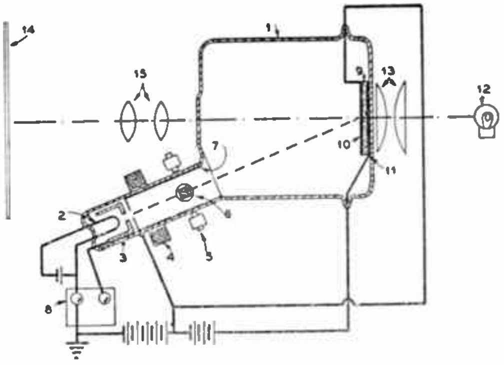

Figure 1. Sectional diagram of the Skiatron. Operation of the device is discussed in the text.

514,155 and 514,776 and further applications, need not be dealt with here. Following are some examples which reveal most clearly the principle of the device or on which most experimental evidence has been collected.

Referring to figure 1 a cathode-ray tube 1 is provided with a cathode 2, a control grid 3, a beam focusing coil 4, deflecting coils 5, 6 and an accelerating anode 7. Picture signals from the receiver 8 are applied between the cathode and control grid in such a way that the positive potential of the grid decreases with increase in signal strength, so that a modulated beam is produced and is swept over the image screen in the usual manner.

The image screen consists of a flat crystal 9 of an alkali halide such as potassium chloride, provided on each side with an electrode 10, 11 designed to permit the passage of light. These electrodes are shown in the form of thin transparent sputtered metallic layers, but they can also be in the form of fine meshes or the like. The potential of the electrode 11 is maintained positive with respect to that of the electrode 10 to provide an electric field in the crystal. The crystal 9 is traversed by light from the incandescent lamp 12 which is concentrated on the projection lens 15 by the optical condenser 13, and an image of the crystal is formed on the projection screen 14 by means of the projection lens 15.

• How the System Functions

The apparatus operates as follows:

On striking a given elemental area of the crystal 9, the modulated cathode-ray beam produces therein an opaque deposit of a density proportional to the instantaneous intensity of the beam. After the beam leaves this area the deposit persists and moves through the crystal in the direction of its thickness towards the more positive electrode 11, where it disappears.

This phenomenon can be explained by assuming that the incident cathode-ray beam injects into the elemental area of the crystal a number of electrons corresponding to the instantaneous intensity of the beam when it strikes the area. These tend to travel as free electrons towards the positive electrode between the crystal lattice, which is composed of alternate positive alkali ions and negative halogen ions. During this travel certain electrons will be captured by the alkali ions, which have a great electron affinity.

An alkali ion and an electron together form an electrically neutral metallic alkali atom which constitutes the above-mentioned colour centre, and thus the position of each captured electron is made visible as a colour centre.

The impinging electrons of the cathode-ray beam may release secondary electrons in greater numbers on their impact. These secondary electrons also tend to travel inside the crystal lattice, thus increasing the effect. Some time later, by the heat movement of the lattice (the crystal being held at the necessary temperature) the metallic alkali atom is again split up into an ion and an electron, and the freed electron continues its path through the lattice towards the positive electrode until it is again captured by another alkali ion, forming a visible colour centre nearer to the positive electrode.

Thus the stream of electrons shot into the crystal by the beam and moving towards the positive electrode appears in the form of an opaque deposit constituted by the colour centres and moving through the crystal towards the positive electrode and disappearing there.

The velocity of this opaque deposit is proportional to the electric field strength in the crystal and increases also with an increase in temperature of the crystal.

By a suitable choice of these magnitudes in relation to the thickness of the crystal, it can be arranged that the deposit of a given elemental area traverses the thickness of the crystal in substantially the picture frame scanning period, i.e., during the time interval between two consecutive scannings of the elemental area by the beam. In other words, the frequency of the disappearance of the successive deposits is caused to be equal to the frame scanning frequency. The opacity of a given elemental area, which corresponds to the intensity of the beam when it strikes the area will thus remain constant until the beam strikes the area at the next scan, when it will immediately adjust itself to the new value.

Although the deposits produced in a given elemental area must be caused to disappear periodically at substantially frame scanning frequency, the disappearance of one deposit need not coincide exactly with the formation of a new deposit in that area but can occur at slightly later time. This can be achieved by regulating the velocity of the opaque deposit produced in an elemental area by one scan in such a way that it has not quite reached the positive electrode when the succeeding scan reaches the area. Thus any desired slight overlapping may be obtained.

• Picture Frequency

From the foregoing it is obvious that the picture repetition frequency can be much lower than is usual with normal reception methods since the intensity is held constant during the whole frame period and no flickering occurs. The minimum repetition frequency is now determined only by the demands of the eye in perceiving continuous movement and can be about 17-20 frames per second. This enables a considerable reduction in the necessary frequency band width of the transmitted signals to be achieved, or allows with the same band width a higher definition to be obtained, or permits of the use of the free part of the band for other purposes. It would further allow a considerable simplification on the transmission side since there would be no need for interlacing and a straight scanning system could be used. This latter fact is particularly advantageous for film transmitters, which can be made simpler for straight than for interlaced scanning.

It is not essential to have two electrodes as shown for setting up the electric field. The electrode 10 can usually be dispensed with since the cathode-ray beam striking the surface of the crystal 9 will cause an emission of secondary electrons, thereby setting up an equilibrium potential of a certain fixed value. The electrode 11 is then maintained positive with respect to this equilibrium potential.

In certain cases the electrode 11 can also be dispensed with. For example, if the ratio of secondary electrons ejected from the crystal to primary electrons incident on the crystal is less than 1, the equilibrium potential will approach that of the cathode 2, in which case the potential of the opposite surface of the crystal will be more positive to an extent depending on the leakage resistance between the anode 7 and the end wall of the tube 1. This leakage resistance may be predetermined by giving to the inner surface of the tube a certain conductivity, for instance, by coating it with a semi-transparent film of rhodium or platinum or a suitable metal oxide.

Since the velocity of the deposit on its way through the crystal depends on the temperature of the crystal, it is desirable to provide some means of temperature control. In many cases the heat produced by the incident cathode-ray beam, or by the heat rays emitted by the incandescent lamp 12, or by both, will be found sufficient to maintain the crystal at the desired temperature. Where higher temperatures, or a more exact temperature control is required, special means may be provided.

(Further information regarding the Skiatron is tentatively scheduled to appear in an early issue of the Radio Technical Digest.—The Editors.)

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¶ From QST,*
January, 1940

Q MEASUREMENTS

The home measurement of coil merit factor

By C. B. STAFFORD

Q MEASUREMENTS of coils have a definite place in every radio engineering laboratory, and many of us have enough equipment to make comparable measurements in our own labs. Sometimes an apparently good coil will show no gain when placed in a receiver. By Q measurements, we may determine whether the coil is at fault. The merit of winding a coil on different form materials is of interest. Other applications will suggest themselves to those who become familiar with Q measurements.

Accurate Q measurements usually require a good deal of expensive equipment. However, most of us have enough equipment in our junk boxes to make comparative measurements. If all of the measurements are made on the same pieces of equipment, the relative values of the several coils measured will be determined. In experimental construction, this is as valuable as the absolute Q.

- Definition

The figure of merit of a coil, commonly denoted by the symbol Q, is defined as being equal to the inductive reactance divided by the resistance, or

$$Q = \frac{X_L}{R} = \frac{2\pi fL}{R} \qquad (1)$$

In this definition, as in many others in electrical engineering, R represents not only the direct current resistance of the circuit, but also the lumped losses represented by the core and dielectric losses. Q is in a general way a measure of the efficiency of a coil. It is proportional to the ratio of the inductance—that part which is desired—to the losses. In a transmitter it partially determines the power output of the plate circuit. In a receiver, it is a vital factor in determining the selectivity, image ratio, and signal-to-noise ratio. It influences the voltage which will develop across the tank condenser in an amplifier. And last, although the list is far from complete, it determines the lowest voltage at

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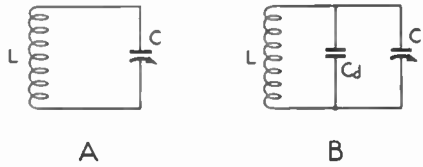


Figure 1. A simple resonant circuit is shown at A, while B shows the distributed capacity represented as a separate condenser.

which the oscillator of a superheterodyne will function.

If Q is determined by the use of the defining equation, the result is of little value due to the inaccuracies inherent in the simpler determinations of L and R. In order more clearly to understand the problem, this type of Q measurement will be illustrated. The first discussion will be followed by simpler and more accurate methods.

As an example of the direct application of the defining formula, let $f = 60$ cycles per second, $L = 2$ henries, and $R = 100$ ohms. Then (App. 1) Q will be 7.54. In an air core coil for audio frequencies, in which R is approximately equal to the direct current resistance, the above method might be used to determine Q. Although beyond the scope of this article, there are better and more accurate ways of measuring the Q of audio frequency coils than the one above.

Suppose now that we wanted to use this same method to measure the Q of a radio-frequency coil. We would be unable to determine easily the correct value to use for R, and other errors would appear when we measured the inductance by the most obvious method. Because this matter of inductance measurement will be useful in a method of Q measurement taken up later, it will be discussed rather completely.

Perhaps the most common method of finding the inductance, which is required for the computation of Q by the direct method, is to connect the unknown inductance in parallel with a known capacity and determine the resonant frequency of the combination. This requires either a known frequency and a calibrated condenser, or a calibrated variable frequency source and a known fixed condenser. Since

$f = \dfrac{1}{2\pi\sqrt{LC}}$, we may solve for L and write

$$L = \frac{1}{4\pi^2 f^2 C} \qquad (2)$$

This equation applies when the units are henries, cycles per second, and farads. Using the more common units of microhenries ($L = \mu h.$), kilocycles ($f =$ kc.), and micromicrofarads ($C = \mu\mu fd.$),

$$L = \left(\frac{159{,}160}{f}\right)^2 \frac{1}{C} \qquad (3)$$

Using this formula, and knowing the capacity and the frequency, we may solve directly for the induc-

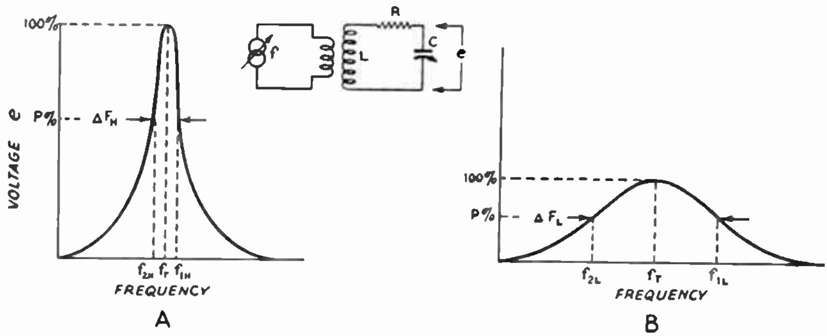


Figure 2. Resonant curves of a high-Q circuit (A) and a low-Q circuit (B).

tance in microhenries. The numerous graphs and slide-rules for the determination of L, C, or f, when the other two are known, are based upon this equation. As an example of this method of solution, let us suppose that a certain coil tunes to 600 kc. with an external capacity of 410 $\mu\mu$fd.

Substituting these values into (3), we find $L = 171.6$ μh. (App. 2). We shall say that the inductance thus found is that indicated by the *single frequency* method at 600 kc., and we shall label this value $L_{600} = 171.6$ μh.

If this equation is true, we should be able to employ the same method at some other frequency and obtain the same answer. Doing this, we find that this coil requires 80 $\mu\mu$fd. to tune it to 1200 kc. This sounds, and is, reasonable, as it takes less capacity to tune a coil to a higher frequency. Substituting these new values into (3), we find $L_{1200} = 219.9$ μh. (App. 3). Most embarrassingly, this value for L at 1200 kc. is not the same as the one obtained at 600. Not only are we stumped in not yet having determined the value for R, but it looks as if our determination of L is also questionable. Our discrepancy of 48.3 μh. is really serious. Assuming the lower inductance to be correct, there is an error of 28.1%. In these days of accuracy of one part in millions, such an error is inexcusable.

A reasonable assumption is that we have not included all of the elements of the circuit. We started with two known values, the external tuning capacity and the resonant frequency. With broadcast stations all around us, there is little reason for frequency error, so we must have erred in our capacity measurement. As a starting point, let us assume that there is some unknown fixed capacity shunting our standard condenser. Let us replace all stray capacities by one fixed capacity. The circuit assumed in the two examples given is shown in figure

1-A. Figure 1-B shows the circuit which we shall assume to exist in the following derivation.

Applying (2) to the circuit of figure 1-B, we find $L = \frac{1}{4\pi^2 f^2 (C_d + C_x)}$. This is true since the total capacity C is equal to the sum of the component capacities C_d and C_x. This applies to the general case. If we now take the two special cases of two different frequencies, indicated by f_1 and f_2, tuned to resonance by their respective capacities, C_1 and C_2, plus the common fixed capacity C_d, the following equations are obtained:

$$L = \frac{1}{4\pi^2 f_1^2 (C_d + C_1)} \quad (4a)$$

TABLE I
Symbols and Abbreviations
C — Capacity
C_d — Distributed capacity
E — Voltage—fixed for any one measurement
e — Voltage — varied with adjustment during measurement
f — Frequency
P — % voltage, when $R = X$, is of resonant voltage
Q — Figure of merit
R — Resistance representing losses in the circuit
X_L — Inductive reactance
X_C — Capacitive reactance
Z — Impedance
Δ — Small change or difference in the factor indicated.

$$L = \frac{1}{4\pi^2 f_2^2 (C_d + C_2)} \quad (4b)$$

All of the values but L and C_d are known in these two simultaneous equations, and we may therefore effect a solution. Setting (4a) equal to (4b), and solving for C_d, we find (App. 4)

$$C_d = \frac{f_2^2 C_2 - f_1^2 C_1}{f_1^2 - f_2^2} \quad (5)$$

Now we have obtained a formula for determining any fixed shunting capacity associated with the coil being measured. This in itself is a useful formula for it permits us accurately to measure the distributed capacity of a coil. The adjacent and/or overlapping component lengths of the turns of a coil form condensers. Their total capacities are generally considered constant for any given winding. If the two frequencies used above differ by a ratio of two to one, as in the examples given, the resulting error is negligible.

Since we know C_d in terms of f and C, we may simplify either (4a) or (4b) and solve for L (App. 5). Using the common units (App. 6), we find

$$L_{\mu h} = \frac{(f_1^2 - f_2^2) \times 10^{12}}{4\pi^2 f_2^2 f_1^2} \times \frac{1}{C_2 - C_1} \quad (6)$$

If one uses the same two frequencies for the majority of the meas-

TABLE II

$$K = \frac{(f_1^2 - f_2^2) \times 10^{12}}{4\pi^2 f_1^2 f_2^2} \qquad L = \frac{K}{C_2 - C_1}$$

f_1	f_2	K	
912	456	91,365	
1200	600	52,770	f = Kc.
2000	1000	18,998	L = μh.
4000	2000	4,749	C = $\mu\mu$fd.

urements, the factor multiplying

$$\frac{1}{C_2 - C_1}$$ can be once determined

and remembered or recorded as a constant. Table 2 shows a number of useful values. In (6) it makes no difference which subscript is used to denote the higher or lower frequency, so long as it is used the same way for both the capacity and frequency. If an error is made in this respect, the resulting value of L will be negative. It should be noted that although this equation is derived from (2), it is considerably different in appearance. (6) is the correct one to use when one does not know the total capacity which is tuning the coil. The error made in the examples was caused by the assumption that the external capacity was the only capacity present. Most coils would not have a distributed capacity as high as the coil used for an example.

Employing the values already given for 600 and 1200 kc., we find the inductance to be (App. 7) $L_{1200-600} = 159.9\ \mu h$. This is the true inductance of the coil. Table 3 gives the calculated inductance versus the method of calculation. From this the conclusion may be drawn that, for a given coil, the lower the frequency the more accurate will be the determination of the inductance by the single frequency method. This is reasonable to assume, since the lower the frequency the greater will be the capacity which is necessary to tune the coil to resonance. The distributed capacity is treated as a constant and, as the total capacity increases, the distributed capacity, and consequently the error, becomes a progressively smaller percentage of the total capacity. Therefore, at a sufficiently low frequency, C_d may reasonably be neglected.

If we could determine the effective total resistance, we would be able to calculate the Q of the coil. But it is even more difficult to determine the value of R at radio frequencies than it is in the audio range, so we are again stumped. So the problem must be approached from another angle.

• Band-Width Method

Perhaps the most accurate method of measuring Q is the band-width method. The shape of the resonance curve of a coil and condenser is partially determined

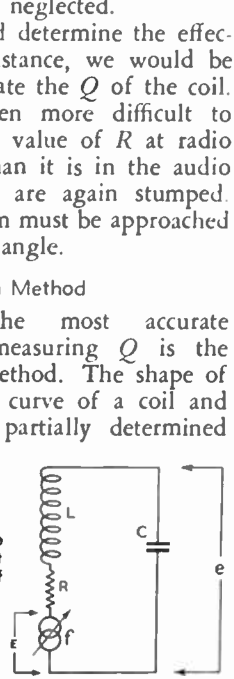
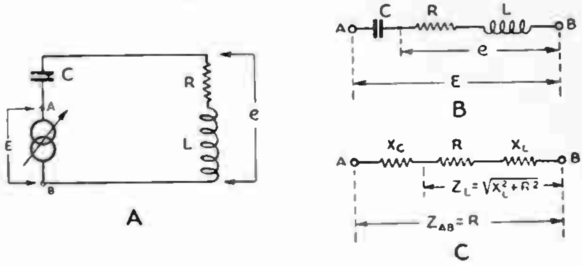


Figure 3. The equivalent circuit of the insert of figure 2.

Figure 4. The circuit used to show the relation between Q and voltage gain (A), redrawn for impedance analysis (B), and shown in terms of impedance (C).



by the Q of the circuit. Since the losses in the condenser are generally negligible, we may say that the shape of the resonance curve is governed by the Q of the coil. If the coil has a low Q, the curve will be wide and flat. If the coil's Q is high, the curve will be high and narrow. Figure 2 shows the curve of voltage developed across a coil and condenser plotted against the frequency impressed upon it. The insert shows the circuit used to determine the curve. A constant voltage of variable frequency is impressed on the coil by a loosely-coupled primary, and the voltage is measured across the resonant circuit. As the impressed frequency approaches, passes through, and exceeds the resonant frequency of the circuit, the voltage across the coil will rise to a peak and then fall. From inspection of the figure, it may be seen that ΔF is defined as the difference between the two frequencies at which the output voltage is $P\%$ of the peak voltage. The additional subscripts in figures 2-A, 2-B denote the high (H) or low (L) Q curve. It should be noted in figure 2-B that ΔF for a lower Q coil is much greater than for a high Q coil. This term ΔF is known as the band-width of the resonance curve. From inspection of the figures, it appears that, if a proper and convenient value is assigned to P, and since the Q of a circuit is apparently some function of the band-width, this characteristic might be used to determine Q.

Let us first assume that the reactance at the point where the voltage is $P\%$ of the peak value is equal to the resistance of $X = R$. Over the narrow range of frequencies employed in a single Q measurement, we may assume that the coupling, and therefore the voltage which develops across the coil, remains constant. With this in view, we may redraw the circuit shown in figure 2-A and place the generator in the secondary. This is shown in figure 3. From inspection we see that this is merely a series circuit composed of R, L, C, and a variable-frequency constant-potential generator. Since the impedance of the circuit is $Z = \sqrt{R^2 + X^2}$ at resonance, when the reactance X is zero, $Z_r = \sqrt{R^2} = R$. At $P\%$ down, when R is equal to X, $Z_1 = Z_2 = \sqrt{R^2 + R^2} = \sqrt{2}R$. Applying Ohm's Law for alternating current, $I = E/Z$,

$$I_r = \frac{E}{R} \text{ and } I_1 = I_2 = \frac{E}{\sqrt{2}R}$$

In view of the fact that the frequency is varied over such narrow limits, the reactance of the condenser in the circuit may be treated as a constant. If such is the case, the voltage e across the condenser is proportional only to the current flowing through the circuit. Using the values above to obtain the ratio of the voltage at $P\%$ down to the voltage at resonance

$$\frac{e_1}{e_r} = \frac{I_1}{I_r} = \frac{\frac{E}{\sqrt{2}R}}{\frac{E}{R}} = \frac{1}{\sqrt{2}} \quad (7)$$

$$e_1 = \frac{e_r}{\sqrt{2}} \text{ or } P = 70.7\%$$

This says that when the resistance and the reactance are equal, the voltage across the parallel circuit will be 70.7% of the voltage at resonance. Let us now apply this information to the evaluation of Q.

For fixed values of L, R, and C, as shown in figure 3, we may say that the capacitive and the inductive reactances change the amount between the limits of f_1 and f_2 as previously defined. A general proof of this is given in item 8 of the appendix. Since the total change in reactance as the frequency is varied slightly is equal to the sum of the changes in inductive and capacitive reactances, and since these two are equal, the total change is equal to twice the change of either of the components. The change in inductive reactance is $\Delta X_L = 2\pi\Delta fL$. The total change is, therefore,

$$\Delta X = 2\Delta X_L = (2)(2\pi\Delta fL) = 4\pi\Delta fL \quad (8)$$

The total change of frequency is $\Delta f = f_r - f_2 = f_1 - f_r$. We may now rewrite (8) as

$$\Delta X = 4\pi(f_r - f_2)L = 4\pi(f_1 - f_r)L \quad (9)$$

Since at resonance the reactance is zero, we may say that ΔX, which is the change in reactance (from zero) as we go to either f_1 or f_2, is equal to the total reactance at either of these frequencies. From this we may write

$$\begin{aligned} 4\pi(f_r - f_2)L &= \Delta X = X = R \\ 4\pi(f_1 - f_r)L &= \Delta X = X = R \end{aligned} \quad (10)$$

Adding the above two simultaneous equations (App. 9), we find

$$f_1 - f_2 = \frac{R}{2\pi L} = \Delta F \quad (11)$$

Dividing both sides of (11) by f_r

$$\frac{\Delta F}{f_r} = \frac{R}{2\pi f_r L} = \frac{1}{Q} \text{ or } Q = \frac{f_r}{\Delta F} = \frac{f_r}{f_1 - f_2} \quad (12)$$

This expression, (12), is actually used for measuring Q. From this we may say that Q is equal to the frequency divided by the bandwidth at 70.7% of the resonant voltage.

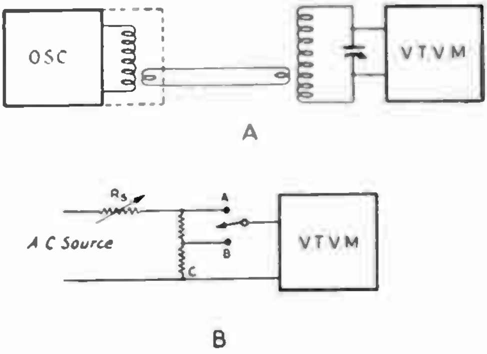


Figure 5. Circuit used with the band-width and capacity methods of Q measurement. The oscillator r.f. circuit need only be shielded in cases where the vacuum-tube voltmeter picks up signal from the oscillator by radiation. B shows the v.t.v.m. calibrating circuit (see text).

This same general method of attack may be used when only one frequency is available. In this case, a calibrated variable condenser is necessary. Referring to figure 3, suppose we keep the frequency constant and vary the capacity of the condenser both above and below the value at resonance. A curve similar to that of figure 2-A would result if capacity were plotted against the voltage e. From this it appears that the change of capacity necessary to drop the voltage to 0.707 maximum might be used as the change of frequency was used in the last derivation.

The reactance of figure 3 is equal to the difference between the inductive and the capacitive reactances, or, when e is equal to 70.7% of E,

$$2\pi fL - \frac{1}{2\pi fC_2} = \frac{1}{2\pi fC_1} - 2\pi fL = R = X$$

where C_1 and C_2 are the capacities necessary to drop the voltage as indicated. Adding these two equations and combining terms (App. 10)

$$2R = \frac{C_2 - C_1}{2\pi fC_1C_2} \qquad (13)$$

Since C_1 and C_2 are just slightly different from C_r (one higher and the other lower), it is almost exactly true that $C_1C_2 = C_r^2$. (13) may now be written

$$2R = \frac{C_2 - C_1}{2\pi fC_r^2} \text{ or } \frac{C_2 - C_1}{2C_r} = R(2\pi fC_r) \qquad (14)$$

Since at resonance, $2\pi fC = \dfrac{1}{2\pi fL}$, it is seen that

$$\frac{C_2 - C_1}{2C_r} = R\left(\frac{1}{2\pi fL}\right) = \frac{1}{Q} \text{ or } Q = \frac{2C_r}{C_2 - C_1} \qquad (15)$$

(15) is another one quite commonly used to determine Q.

Before leaving the theory for the practical means of applying these equations, we had better discuss one more method. This one has recently become one of the most common methods of measuring Q.

The circuit in figure 3 has been redrawn in figure 4-A. At resonance, the external circuit from A to B has an impedance $Z_{AB} = R$. The circuit represented by the inductance L and its losses R has an impedance $Z_L = \sqrt{X_L^2 + R^2}$. Figure 4-B shows another configuration of figure 4-A, and figure 4-C shows the same circuit in terms of impedances. At resonance, the voltage e across the coil is to the total voltage E as the ratio of the respective impedances, or

$$\frac{e}{E} = \frac{Z_L}{Z_{AB}} = \frac{\sqrt{X_L^2 + R^2}}{R}$$

This may also be written in the following forms:

$$\frac{e}{E} = \sqrt{\frac{X_L^2 + R^2}{R^2}} =$$

$$\sqrt{\frac{R^2}{R^2} + \frac{X_L^2}{R^2}} = \sqrt{1 + Q}$$

In the practical case, Q will rarely be less than 10, so that the *1* under the radical may be neglected without introducing too much objectionable error. Then,

$$Q = \frac{e}{E} \qquad (16)$$

- **Practical Applications of These Equations-
Band-Width Method**

From (12),

$$Q = \frac{f_r}{\Delta F} = \frac{f_r}{f_1 - f_2}$$

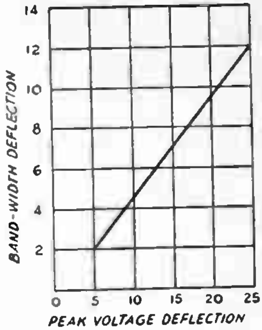
Equipment:

1. Frequency calibrated oscillator.
2. Voltmeter with band-width calibration.

Figure 5-A shows the circuit generally employed. A vacuum-tube voltmeter is used to measure the r.f. potential. In figure 5-B R_{BC} is 70.7% of R_{AC}. With the switch in the A position, R_s is adjusted to give a convenient deflection of the voltmeter. This will be referred to as the *peak voltage* deflection. This value is recorded and the switch turned to the B position. The deflection obtained will be called the *band width* deflection. By repeating this procedure for different settings of R_s, a series of peak versus band-width deflections will be obtained. These values should be plotted on graph paper, as shown in figure 6. The voltmeter deflection corresponding to 70.7% of the voltage necessary to produce any given deflection can then be read from the graph. If the frequency of the supply voltage is 60 cycles, the resistors need not be non-inductive. This frequency is readily available in most locations and is satisfactory for most Q-

Figure 6. Table and graph for finding deflection equivalent to 70.7% of the input voltage necessary to produce any given deflection.

VOLTMETER DEFLECTION	DEFLECTION AT 70.7% INPUT E
25	12
13	6
7	3
5	2



measurement voltmeter calibrations.

The procedure is as follows:

1. Couple the oscillator to the coil with a one-turn link.
2. Tune the coil to resonance (maximum deflection of the voltmeter) with the capacity.
3. Adjust the coupling so that when tuned exactly to resonance, the circuit will cause a nearly full-scale deflection of the voltmeter.
4. Measure the frequencies above and below resonance at which the voltmeter reads the band-width deflection corresponding to the peak deflection which occurred at resonance.
5. To determine Q, divide the resonant frequency by the difference between the two frequencies determined in step 4.

- Capacity Method

From (15)

$$Q = \frac{2C_r}{C_2 - C_1}$$

Equipment:

1. Single-frequency oscillator.
2. Calibrated variable condenser.
3. Voltmeter with band-width calibration.

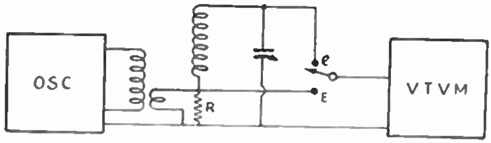
Fig. 5-A is also applicable to this method.

The procedure is:

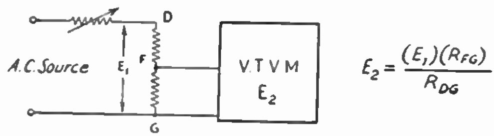
1-3 incl. Same as in previous method.

4. Measure the capacities above and below resonance at which the voltmeter reads the band-width deflection corresponding to the peak voltage deflection which occurred at resonance.
5. To determine Q, divide *twice* the capacity at resonance by the difference between the capacities determined in step 4.

The accuracy of this result depends upon the accuracy of the determination of the resonant capacity. If the coil has a high distributed capacity, the resulting error may be appreciable. It is therefore desirable to determine the distributed capacity by applying (5). This makes it necessary to use another frequency, but since this might well be chosen as twice the frequency used in (15), this represents no problem. In applying (15) always be careful that neither the



A



B

Figure 7. The circuit used in measuring Q by the voltage-gain method. The r.f. portions of the oscillator should be shielded if the v.t.v.m. picks up radiated energy. B shows the circuit used to calibrate the v.t.v.m.

distributed capacity of the coil nor the shunting capacity of the leads is high, or the determination of Q by this method will be badly in error.

- **Voltage Gain Method**

From (16)

$$Q = \frac{e}{E}$$

Equipment:

1. Single-frequency signal generator or oscillator.
2. Calibrated voltmeter.
3. Non-inductive low resistance.

Figure 7-A shows the circuit normally used. Figure 7-B shows one method which may be used to calibrate the voltmeter. To obtain the voltage across the vacuum-tube voltmeter, divide the voltage read on the a.c. input meter by the ratio of the total divider resistance to the resistance across the tap.

The voltage is introduced into the resonant circuit by applying it across the low resistance R. This resistance must be low enough so that it is an inappreciable part of the total resistance of the circuit. In practice, it is usually about 0.05 ohm.

The procedure is:

1. Tune the circuit to resonance.
2. Measure the voltage at E.
3. Retune with the voltmeter at e and measure.
4. To determine Q, divide e by E.

(Any of the above methods do not measure the Q of the coil alone but give the Q of the coil in combination with the condenser. Normally the Q of the condenser is so high that the figure obtained is

TABLE III

Method	*Frequency*	*Inductance*
Single-frequency	600 kc.	171.6 μh.
Single-frequency	1200 kc.	219.9
Two-frequency	1200-600 kc.	159.9 (correct)

practically that of the coil. However, when the condenser is used near minimum capacity, the ratio of the total capacity using air dielectric (low loss) to that using solid dielectric (higher loss) becomes lower and the Q of the condenser is lowered.[1] For this reason, a low-loss condenser set near maximum capacity should be used in Q measurements.—*Editor.*)

• Appendix

1. $$Q = \frac{2 \times 3.1416 \times 60 \times 2}{100} = 7.54$$

2. $$L_{600} = \left(\frac{159,160}{600}\right)^2 \times \frac{1}{410} = 171.6\ \mu h.$$

3. $$L_{1200} = \left(\frac{159,160}{1200}\right)^2 \times \frac{1}{80} = 219.9\ \mu h.$$

4. $$L = \frac{1}{4\pi^2 f_1^2 (C_A + C_1)} = \frac{1}{4\pi^2 f_2^2 (C_A + C_2)}$$
$$f_1^2 C_A + f_1^2 C_1 = f_2^2 C_A + f_2^2 C_2$$
$$C_A = \frac{f_2^2 C_2 - f_1^2 C_1}{f_1^2 - f_2^2}$$

5. $$L = \frac{1}{4\pi^2 f_1^2 (C_A + C_1)} = \frac{1}{4\pi^2 f_1^2 \left(\dfrac{f_2^2 C_2 - f_1^2 C_1}{f_1^2 - f_2^2} + C_1\right)}$$
$$= \frac{f_1^2 - f_2^2}{4\pi^2 f_1^2 (f_2^2 C_2 - f_1^2 C_1 + f_1^2 C_1 - f_2^2 C_1)}$$
$$= \frac{f_1^2 - f_2^2}{4\pi^2 f_1^2 f_2^2 (C_2 - C_1)}$$

6. $$L\mu h = \frac{(f_1^2 - f_2^2)(10^3)^2}{4\pi^2 f_1^2 (10^3)^2 (f_2^2)(10^3)^2} \times \frac{1}{(C_2 - C_1)(10^{-12})}$$
$$= \frac{(f_1^2 - f_2^2) \times 10^{12}}{4\pi^2 f_1^2 f_2^2} \times \frac{1}{C_2 - C_1}$$

7. $$L_{1200-600} = \frac{(1200^2 - 600^2) \times 10^{12}}{4\pi^2 (1200^2)(600^2)(410 - 80)}$$
$$= 159.9\ \mu h.$$

8. $$X_L = 2\pi f L \qquad X_c = \frac{-1}{2\pi f C}$$

When L is constant,
$$\frac{dX_L}{df} = 2\pi L \qquad \frac{dX_c}{df} = \frac{1}{2\pi f^2 C}$$
If these rates of change are equal,
$$2\pi L = \frac{1}{2\pi f^2 C} \quad \text{or,} \quad 2\pi f L = \frac{1}{2\pi f C}$$
We know, of course, that at resonance the latter is true.

9. $$\begin{cases} 4\pi (f_r - f_2) L = R \\ 4\pi (f_1 - f_r) L = R \end{cases}$$
$$\begin{cases} 4\pi f_r L - 4\pi f_2 L = R \\ 4\pi f_1 L - 4\pi f_r L = R \end{cases}$$
Adding,
$$4\pi f_r L - 4\pi f_r L + 4\pi f_1 L - 4\pi f_2 L = 2R$$
$$2R = 4\pi L (f_1 - f_2)$$
$$f_1 - f_2 = \frac{R}{2\pi L}$$

10. $$2\pi f L - \frac{1}{2\pi f C_2} = R$$
$$\frac{1}{2\pi f C_1} - 2\pi f L = R$$
Adding,
$$2\pi f L - 2\pi f L + \frac{1}{2\pi f C_1} - \frac{1}{2\pi f C_2} = 2R$$
$$\frac{C_2 - C_1}{2\pi f C_1 C_2} = 2R$$

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[1] Michel, "Factor-of-Merit of Short-Wave Coils," *G.E. Review*, Oct. 1937.

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THE TECHNICAL FIELD

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RADIO TECHNICAL DIGEST briefly summarizes for its readers the contents of leading radio articles in current technical publications, some of which may appear later in Radio Technical Digest.

COMMUNICATIONS

Bryan Davis Pub. Co., Inc.
19 E. 47 St., N.Y.C.
25c a copy—$2.00 yearly
JANUARY, 1940

A TRUE OMNIDIRECTIONAL RADIO BEACON, *by Edward Nelson Dingley, Jr.*—Mr. Dingley describes a radio beacon arrangement which radiates a signal simultaneously and continuously in all azimuthal directions in such a manner that the signal radiated in any one azimuth has a characteristic distinguishing it from that radiated in the other azimuths. The difference in character of the radiated signal in different azimuthal directions takes the form of an audio tone in an ordinary amplitude-modulation receiver. The difference of audio tone received in different directions is made possible by frequency modulating the transmitter and applying the output power simultaneously to three different antennas. The received signal will be a beat caused by the instantaneous frequency difference between the signals arriving from two of the transmitting antennas, the bearing being indicated by the frequency of the beat. An audio-frequency indicator then shows the bearing of the ground station in respect to the receiver.

EXPECTATIONS IN RADIO, *by Ray D. Rettenmyer*—A preview of 1940 based on general trends in the industry. Transmitters, transmitting equipment and receivers are among the subjects covered. The progress to be expected in the fields of facsimile, frequency modulation, television, police radio, recording, public address and aeronautical radio are also discussed.

APPLICATIONS OF THE VOLTAGE DOUBLER RECTIFIER, *by M. A. Honnell*—The double-diode voltage doubler has been fairly widely used in power supplies, but its application to other electronic arrangements has been rather limited. This article shows two voltage doubling circuits for the 6H6 which could be used to advantage in receivers and peak voltmeters.

DECEMBER, 1939

NEW U.H.F. TRANSMITTERS—A discussion of some of the features of the new General Electric television and frequency-modulated u.h.f. transmitters. Block diagrams of the transmitters are given, as well as photographs of the transmitters and a line drawing of a suggested form of antenna. An unusual feature of the f.m. transmitter is the use of a reactance tube as a frequency modulator. A means is provided whereby the output frequency may be held within 0.01 per cent through the use of a reference crystal oscillator and a discriminator.

FREQUENCY MODULATION, PART II, *by Charles H. Yocum*—Frequency modulation transmitter and receiver circuits are discussed. Both the Armstrong and the Shelby systems of obtaining phase modulation suitable for conversion to frequency modulation are explained. The operation of the receiver limiter and discriminator stages are described.

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electronics

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McGraw-Hill Pub. Co., Inc.
330 W. 42 St., N.Y.C.

JANUARY, 1940

FREQUENCY MODULATION—A REVOLUTION IN BROADCASTING?—A survey of facts, and matters requiring further investigation, gathered from engineers working with frequency modulation. The article is based on interviews made by the editors of *Electronics* with a F.C.C. representative and several engineers who are well informed on the subject.

TUNING FORK STABILIZATION, *by Ernst Norrman*—Tuning forks, which are an important source of accurate audio frequencies, are subject to variations in frequency with temperature and age. The author describes how the forks may be tempered to secure a zero temperature coefficient and describes an improved driving circuit which automatically stabilizes the amplitude of oscillation.

DIFFERENTIAL MODULATION METER, *by Verne V. Gunsolley*—One of the principal disadvantages to the customary form of modulation meter is that it is necessary to calibrate it with a definite carrier level and its calibration is correct only for the amount of carrier with which it was originally calibrated. Mr. Gunsolley describes a differential type meter in which a.v.c. is used and which is virtually unaffected by varying carrier strength, within limits.

R.F. POWER MEASUREMENT, *by P. M. Honnell*—A description of a simple and direct method of measuring r.f. power, independent of frequency. Both direct and load-back methods are covered, with suitable circuits being shown. The load-back method, in which the power output is rectified and applied in parallel or series with the r.f. stage d.c. input, is given a thorough treatment.

MULTI-WIRE DIPOLE ANTENNAS, *by John D. Kraus*—Describing a method of feeding high frequency antennas with moderately high impedance transmission lines, and without the use of matching transformers. The antennas consist of two or more close-spaced parallel elements so interconnected that the currents are in phase in all elements, thus raising the feed impedance.

AN AMPLIFIER FOR D.C. GALVANOMETERS, *by Arthur W. Sear*—Constructional data on a vacuum-tube amplifier which may be used to increase greatly the sensitivity of portable galvanometers. The sensitivity obtained when the three-stage amplifier is used compares favorably with that of a permanently mounted D'Arsonoval galvanometer, while the speed of measurement is considerably greater.

ELECTRONIC FLOW METER, *by Joseph M. Weinberger*—A device which records, by photoelectric means, the varying level of an opaque liquid in a transparent tube, and thus gives a continuous record of water flow. One leg of a U-tube containing mercury for measuring the flow is so arranged in a light-tight box that it acts as a valve between a light source and a photoelectric cell. The output of the cell is applied to a d.c. amplifier and caused to actuate a recording stylus.

DECEMBER, 1939

MODERN RADIO PLANT PRACTICE, *by Herbert Chase*—The success of a manufacturing concern depends as much upon efficient fabrication and assembly methods as it does upon engineering design. Mr. Chase describes the Stromberg Carlson radio plant, and shows how the plant floor has been arranged to facilitate speedy radio receiver construction.

A NEW IGNITRON FIRING CIRCUIT, *by Hans Klemperer*—One of the factors tending to discourage the wider use of ignitron is the fact that a thyratron is almost always needed in the starting circuit. A circuit is described which uses a saturable-core reactor in lieu of the thyratron. Both alternating and direct current are applied to the reactor in such a manner that voltage peaks suitable for controlling the firing circuit of the ignitron are produced.

DISC-CUTTING PROBLEMS, *by C. J. Lebel*—A discussion of some of the problems of instantaneous disc recording. Such subjects as stylus angle, grit in discs, overloaded cutters, disadvantages of outside-in cutting, output tubes and disc life are covered.

ROCHESTER FALL MEETING—A review of papers presented by I.R.E.-R.M.A. speakers at the Rochester Fall Meeting, the traditional meeting place of receiver engineers. Well over a dozen papers are reviewed. Such widely diversified subjects as phototubes and loop antennas are but two of those covered.

BRITISH VISION RECEIVERS, *by W. J. Brown*—The fact that commercial television in England is about two and one-half years older than in this country makes it interesting and profitable to study English television progress as a possible guide to future developments in the United States. The difference between present English receivers and those of several years past is discussed. A considerably lower cost and less complicated circuits are among the changes noticed in the newer receivers.

FEBRUARY, 1940

INSTANT BAND CHANGE WITH PUSH-BUTTON CONTROL, *by Leon Linn*—A transmitter allowing push-button band change to any of four amateur bands. The bandchange switches are mechanically ganged together by chain drives. A small electric motor is used to drive the bandswitch mechanism.

LOP-SIDED SPEECH AND MODULATION, *by George Grammer*—A discussion of extended positive peak modulation as applied to high - level modulated amateur transmitters. An attempt is made to show that full utilization of the system is not economically feasible, based on some rather questionable conclusions with regard to required modulator size for this type of operation.

COMPACT BATTERY RECEIVER FOR STATION OR PORTABLE USE, *by Don H. Mix*—Describing a simple battery-powered receiver using "miniature" tubes. A 1T4 semi-tuned r.f. stage is followed by another 1T4 as a regenerative detector and a 1S4 as an audio output stage.

A PRACTICAL 112-MC. F.M. TRANSMITTER, *by Byron Goodman*—A 5- to 6-watt 112-Mc. frequency-modulated transmitter. The circuit utilizes a pair of beam-power tubes as oscillator and frequency multiplier and a dual triode as a push-pull tripler output stage. Modulation is supplied by a reactance tube.

A REGENERATIVE PRESELECTOR WITH OUTPUT METERING BRIDGE, *by H. O. Talen*—A description of a regenerative preselector in which output is automatically kept at a nearly constant level and regeneration is stabilized through the use of an application of the output metering bridge circuit.

"WIRED WIRELESS" FOR REMOTE CONTROL, *by John Evans Williams*—Constructional details on carrier current transmitters and receivers for amateur remote control applications. Methods of coupling the control units into the 115-volt wiring are described and instructions for tuning up the units given.

BUILDING AND TUNING A THREE-ELEMENT BEAM, *by Harold Ulmer*—Detailed instructions for a three-element directive array. Both the mechanical and electrical details of the antenna are covered. The author stresses the necessity of adjusting the element lengths after the antenna has been erected.

ANOTHER APPROACH TO HIGH POWER, *by J. A. McCullough*—Describing a transmitter designed with the idea of allowing an increase in power without making it necessary to discard any equipment and substitute larger components. The one-kilowatt version of the transmitter uses four 75T tubes in push-pull-parallel in the final stage. For lower power output the same exciter is used, but the number of tubes in the final amplifier is reduced to either one or two.

JANUARY, 1940

WIDE-BAND FREQUENCY MODULATION IN AMATEUR COMMUNICATION, *by George Grammer and Byron Goodman*—The application and advantages of wide-band frequency modulation to amateur u.h.f. work. Various circuit arrangements suitable for use in the new service are described and suitable transmitting and receiving units employing the circuits are shown.

THE TRIANGLE ANTENNA, *by James Arnold*—Mr. Arnold's "triangle array" consists of three "J-fed" verticals, one at each corner of an equilateral triangle which is a half-wave on a side. Through the use of three knife switches to change the phasing of the elements six different bi-directional radiation patterns are made possible.

MORE ON THE COMBINED BEAT OSCILLATOR AND I.F. AMPLIFIER, *by R. A. McConnell*—An improved method of converting one of the receiver's i.f. stages so that it will act as a combined i.f. stage and b.f.o. The disadvantages of a previously described circuit are pointed out and a new circuit which does not have these disadvantages is shown.

REGENERATION IN THE PRESELECTOR, *by G. H. Browning*—A theoretical and practical investigation of the image rejection and gain characteristics of a single-stage regenerative preselector. It is shown that a tuned circuit Q of 1000 to 5000 may be realized without making the circuit unduly critical. A tabular record of the signal-to-noise ratios obtained with and without the preselector at various frequencies is given.

COMPACTNESS WITH ECONOMY, *by Allen Monderer*—Describing a 75-watt transmitter constructed on a 10½ by 3½ by 2¾ inch fruit-cake pan. A 6C5 Pierce oscillator is followed by a 6V6 buffer amplifier and an HK-24 output stage. The power supply is a separate unit.

IMPROVED PI-SECTION ANTENNA COUPLER, *by R. B. Jeffrey*—One of the principal disadvantages of the conventional pi-section antenna coupler is that with feed-line lengths which are integral multiples of a quarter wave the feeder sending-end impedance is such as to require impractically large or small coupler output condensers. This article shows a simple circuit wherein a loading coil is added in series with the antenna or feeders bring the impedance to a value which may be easily matched by the coupler.

A CODE-PRACTICE OSCILLATOR C.W. MONITOR, *by Vernon Chambers*—A description of an audio oscillator suitable for use as a code-practice oscillator or for transmitter keying monitoring service. As a code-practice oscillator the unit is operated from its self-contained batteries. For monitoring service the voltage for the oscillator is obtained from a resistor in the cathode of the transmitter final amplifier so that voltage is applied only when the final stage is drawing current.

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RADIO

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JANUARY, 1940

FREQUENCY MODULATION FUNDAMENTALS, *by C. H. Singer and C. W. Harrison*—A complete description of the basic theory of frequency modulation as applied to transmitters, receivers, and antenna systems. A discussion is given of the need and action of the pre-attenuator as used with phase-angle modulation as a means of obtaining frequency modulation. Reactance-tube frequency modulation is also covered as the other commonly used commercial f.m. system. The theoretical operation of the various units within the receiver is also covered.

75T's, CATHODE MODULATED FOR PHONE OR *C.W.*, *by Gene Turney, and F. Ralph Kenyon*—A description of the design and construction of a transmitter giving an output of over 150 watts with cathode modulation for phone, and about 400 watts on c.w. The transmitter is self-contained in a small relay rack. The speech amplifier-modulator using a pair of 6L6's in class AB, is also completely described.

U.H.F. AND THE WEATHER, *by M. S. Wilson*—By combining an understanding of the mechanics of refraction of ultra - high - frequency waves in the lower atmosphere with a knowledge of meteorology, one can determine in advance the probability of ground-wave or semi-dx. The accuracy of such predictions is a direct function of the completeness of available weather data providing all the vagaries of u.h.f. propagation are taken into consideration.

A 1623 TRANSMITTER-EXCITER, *by Jack Rothman*—A cleverly designed transmitter or exciter using an inexpensive new tube and capable of being keyed or modulated at 35 to 50 watts output on all bands from 10 through 160. It is a unit well suited to use as an auxiliary transmitter, as an exciter for the new rig, or as a complete r.f. unit for those with not too pretentious ideas of a transmitter.

U.H.F. RADIO THERAPY, *by William Reagh Hutchins*—A description of a simple and inexpensive u.h.f. therapy machine utilizing a single 24 Gammatron as the oscillator to give about 20 watts output on wavelengths from about 2½ to 4 meters. For the uses to which such extremely high frequencies are applied, this small amount of power is ample.

THE FRANKLIN OSCILLATOR CIRCUIT, *by Leigh Norton*—The Franklin oscillator circuit is a two-terminal one in which one tube is used as a phase reverser to supply the necessary out-of-phase energy to sustain oscillations. By utilizing certain advantageous characteristics of this oscillator to the v.f.o. problem, quite a satisfactory transmitter control unit is produced.

HOW ABOUT THE RECEIVER, *by Jerry Crowley*—A discussion of the simplicity with which certain of the conveniences found on the more recent communications receivers may be applied to those of older manufacture to improve their operation.

A 25-WATT TRANSMITTER IN FULL DRESS, *by Lewis Van Arsdale*—A description of a neatly built and well designed phone and c.w. transmitter operating on all bands from 160 through ten meters and giving a conservative 25 watts output on each.

RECEIVER CIRCUITS FOR FREQUENCY MODULATION, *by George W. Brooks*—A non-technical discussion of the practical considerations in the design of receivers for frequency modulation. The practical operation of the characteristic sections of the f.m. receiver which differ from those in an a.m. receiver are discussed in an easily understood style.

HIGH-GAIN MOBILE CONVERTER, *by Victor Ruebhausen*—A short description of a converter for mobile automobile use which employs an 1852 r.f. stage and mixer, and a 6C5 high-frequency oscillator. The unit is quite compactly built so that it can be made to fit into an unused space in the driver's compartment.

RADIO WORKSHOP PRACTICE, *by K. Caird*—Valuable information is given in this article on best procedure in doing the type of sheet metal work most commonly encountered in the radio shop. Especial emphasis is given on favored practice in regard to drilling since this is the most common operation performed in the radio shop.

AN EXPERIMENTAL FREQUENCY MODULATION TRANSMITTER, *by E. Seiler*—An article giving a discussion of a very simple frequency modulation transmitter; the practical operation of the unit is described in a manner which will assist the newcomer to this system of signalling in understanding the operation of reactance-tube modulation.

DETERMINATION OF ANTENNA RADIATION PATTERNS, *by W. E. McNatt*—A practical method of plotting the on-the-ground radiation pattern of an antenna array by a graphical method with the use of a field-strength meter.

A BANDSWITCHING 200-WATT AMPLIFIER, *by Ray L. Dawley*—A description of a bandswitching amplifier utilizing the new HK-257 Gammatron pentode for 175 to 250 watts output on the 80-, 40-, 20-, and 10-meter amateur bands. Capacitive coupling to the control grid of the beam pentode is used to simplify the bandswitching problem with regard to excitation.

CONTINUOUSLY ROTATABLE TWO-BAND ARRAY, *by H. L. Jenkins*—A description of an antenna array utilizing a rotary capacitor and a set of relays to permit two-band operation with continuous rotatability.

STRICTLY 80 METERS, *by W. W. Smith*—An inexpensive variable-frequency c.w. transmitter with oscillator keying which will give a note approaching that obtainable with a crystal. The 40 watts output is ample for traffic, navy or army net, with the break-in required in these services.

HOW TO OPERATE TRANSMITTING TUBES, *by Harner Selvidge*—Worthwhile information on the proper operation of transmitting tubes to obtain maximum life from them consistent with the greatest amount of power output. The general significance of ratings is clearly put forth.

A COMPROMISE ON QSY, *by Harry G. Burnett*—A description whereby only a change in the interstage coupling and retuning procedure which will allow wide frequency coverage in the conventional high-frequency amateur transmitter.

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SUPERHET TRACKING AT ULTRA-HIGH FREQUENCIES, *by E. H. Conklin*—A very useful article on the application of electrically lengthened concentric line circuits to ultra-high frequency receiver and transmitter design. Full-page charts are given for the use of 81-ohm and 139.9-ohm lines in transmitters and receivers.

AN ECONOMICAL 5-TUBE SUPER, *by Leigh Norton*—A low-cost superheterodyne combining simplicity and outstanding performance. Plug-in coils are used on all bands in the r.f., mixer, and h.f. oscillator stages. A regenerative second detector is used in an oscillating state for c.w. reception.

THE THREE-BAND ROTARY ANTENNA, *by John D. Kraus*—By applying the multi-wire doublet principle to the design of the 3-element rotary it is possible to raise the center impedance of the driven doublet to a point which permits simple direct coupling systems. Also, the selectivity of the array is reduced to a point which will allow complete band coverage without detuning, and the array can, by switching, be adapted to cover three bands.

PREDISTORTION APPLIED TO AMATEUR RADIOTELEPHONY, *by W. W. Smith*—By incorporating a standardized filter, simple and inexpensive, in all amateur transmitters and receivers, many benefits would be realized. Interference would be reduced, yet a worthwhile increase in sideband power would be obtained.

MODULATION MONITOR AND PRE-AMPLIFIER, *by Bill Davis*—A description of a radiotelephone transmitter control unit incorporating a three-stage speech amplifier and a carrier-monitoring system. Dual indicating instruments continuously show carrier shift and percentage modulation.

125-WATT 1940 TRANSMITTER, *by W. T. Bishop*—A neat and efficient all-band phone and c.w. transmitter utilizing a T55 in the output of the r.f. section and a pair of TZ-40's as class-B modulators. The complete unit is housed in a manufactured metal cabinet and includes the speech amplifier and power supplies.

PARALLEL CATHODE MODULATION, *by Ray L. Dawley*—An alternative system of cathode modulation for medium powered equipment wherein the cathode circuits of both the modulator and the modulated stage are fed through a common impedance, a modulation choke for example, across which the modulating voltage is developed.

INEXPENSIVE MULTI - TESTER, *by Lloyd V. Broderson*—A description of an easily constructed combined voltmeter, milliammeter, and ohmmeter. Inexpensive resistors and other components are used in the construction of the unit.

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THE RADIO NEWS PRIVATE FLYER'S TRANSMITTER, *by Karl A. Kopetzky and Oliver Read*—Describing a compact transmitter for private plane use. The transmitter, which employs a 6J5 oscillator, 6L6 amplifier and 6L6 modulator, weighs approximately 15 pounds, complete with its motor generator.

MAKE YOUR OWN METER SHUNTS, *by Stephen J. Varmecky*—Increasing the utility of a single meter by use of home-constructed shunts. The necessary calculations and mechanical work involved are explained.

AVIATION ALTITUDE VIA MICROWAVES, *by Henry W. Roberts*—A description of the new Western Electric terrain clearance indicator. The complete altimeter consists of a frequency-modulated u.h.f. transmitter and a u.h.f. receiver. The receiver measures the frequency of the beat produced by a signal received directly from the transmitter and a signal reflected by the ground.

VOLTAGES - REGULATED POWER SUPPLY, *by F. J. Gaffney and Gene Turney*—A dual-voltage power supply suitable for use with electron coupled oscillators and other applications where a constant voltage under varying load is required. The power supply delivers 500 volts of unregulated power, as well as 300 volts regulated by a 6A3-6SJ7 combination.

THE RADIO NEWS HIGH-FIDELITY TUNER, *by A. B. Cavendish*—Describing a tuner intended to be used with the high-fidelity amplifier previously presented in *Radio News*. The tuner consists of a converter and second detector-first audio stage together with the necessary power supply.

THE PHOTO-CELL "HAM-SAVER," *by Arthur Eidam*—Shock-proofing the amateur transmitter by means of a light beam. The photo-cell unit described will automatically remove the transmitter voltage if the operator approaches potentially dangerous portions of the circuit.

JANUARY, 1940

A RADIOMAN OF THE U.S.A., *by Charles F. Chapel*—A discussion of Army Signal Corps work. The life of a typical army radioman from the day he enlists until he reaches retirement age is described.

A SIMPLE VACUUM TUBE VOLTMETER, *by Samuel Proctor*—A description of a simple vacuum-tube voltmeter of the slide-back type. A 6E5 is used as the balance indicator and voltages are indicated by a calibrated scale on the slide-back voltage potentiometer.

THE 1940 FULL-RANGE AMPLIFIER, *by Oliver Read and Karl A. Kopetzky*—A constructional article describing a 15-watt audio amplifier designed particularly for realistic record reproduction. An unusual feature of the amplifier is the provision for expansion of either the bass or treble range, or both.

THE HOW AND WHY OF THE OSCILLOSCOPE, *by Edwards Lovick, Jr.*—A discussion of the theory and use of one of radio's most versatile pieces of equipment. The cathode-ray tube is described and the various circuits necessary for its effective use shown.

THE RADIO NEWS CROSS-HAULER, *by Raymond P. Adams*—A small portable or emergency transmitter suitable for reliable short-distance communication. The transmitter is intended for operation on the 160-meter amateur band. The output stage is a single 6V6G; modulator, 6N7, class B.

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LEARN TO SELL, *by V. E. Jenkins*—Selling ability is a very important part of successful radio servicing. Mr. Jenkins stresses the advantages of a good understanding of salesmanship.

WE EXPECT, FOR 1940, *by Robert G. Herzog*—A prediction on the future sales and technical features of radio equipment based on past trends. An increase in the number of radio-phonograph combinations sold is one of the more clearly indicated expectations. Sales increases in the battery portable, f.m., and facsimile receiver fields are also to be expected. Simplification of receiver circuits and reduction of the number of wave bands covered are among the other changes indicated.

DECEMBER, 1939

PROFITS IN MODERNIZATION, *by Arthur Roberts*—The result of a survey conducted for the purpose of determining the increase in serviceman's profit realized through the use of modern test equipment. The average profit after modernization was found to be 19.7 per cent, as compared to 6.9 per cent with the older equipment.

FREQUENCY MODULATION, PART II, *by Charles H. Yocum*—This second article on frequency modulation covers the mechanics of f.m. and discusses the essential differences between the receiver and transmitter circuits required for f.m. and those ordinarily used for amplitude modulation. The Armstrong phase-modulation and the Shelby cathode-ray tube phase shifter are both described along with receiver limiter and discriminator circuits.

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THE DESIGN AND OPERATION OF RADIO-FREQUENCY AMPLIFIERS, *by H. L. Gibson*—A simple method of ascertaining the performance of transmitting tubes in various classes of operation where plate current flows for less than a full cycle is described. The method is illustrated by design calculations for a typical tube (809).

A NEW DESIGN OF FREQUENCY METER, MONITOR AND 10 KC. SIGNAL GENERATOR, PART II, *by T. B. Wimbush*—This article describes the necessary procedure for placing in operation the multi-purpose unit described in the January, 1940, *Bulletin*.

RECEIVER STABILITY, *by J. N. Walker*—A discussion of the factors influencing the stability of receivers. Mr. Walker discusses self oscillation in r.f. stages in this installment.

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