Radio Digest

SELECTED RADIO TECHNICAL ARTICLES

UR • EXPERIMENTAL
EERING • SERVICE
WAVE • TELEVISION
ONICS • COMMERCIAL
OMMUNICATION
OCAST OPERATING

HIGHLIGHTS FROM THIS ISSUE

NOVEMBER, 1937

25¢ U.S.A. & CANADA

Radio Digest

Subscription Order Form

RADIO

ANOTHER RADIO PUBLICATION

"Radio" for Christmas

AN IDEAL GIFT

RADIO's annual Christmas gift rates will be in effect from November 15th to January 15th. To radio amateurs with a "fellow ham" to remember, to radio employees with a radio-minded employer who must not be forgotten, and to radio manufacturers and distributors who want to remind a favored customer repeatedly through the year of their appreciation of his business, a RADIO subscription is an ideal (and effortless) solution of that puzzling Christmas shopping problem.

ONE SUBSCRIPTION (one year)	$2.50
TWO SUBSCRIPTIONS, each	2.35
THREE or more SUBSCRIPTIONS, each	2.25
SIX or more SUBSCRIPTIONS, each	2.00
TWELVE or more SUBSCRIPTIONS, each	1.75

Subscriptions at $2.00 or less must be **cash with order**

Above rates apply for U.S.A., Canada, Newfoundland, Cuba and Mexico. To Pan-American countries and Spain, add 50c per subscription. Elsewhere, add $1.00 per subscription.

You May Enter or Renew Your Own Subscription at these Rates.

Rates for more than one subscription, as listed above, apply only on gift orders entered and paid for at one time by one individual or company. Unless otherwise requested, the subscriptions will be commenced with the January issue, which will be delivered as near Christmas as possible, together with an attractive card announcing the gift and the sender's greetings; those who are at present subscribers will automatically have subscriptions extended unless otherwise requested.

RADIO DIGEST

● NUMBER 3 NOVEMBER, 1937 ●

We present:

RADIO DIGEST • No. 3 • M. M. Lloyd, Managing Editor
Editors: **W. W. Smith, Roy L. Dowley, B. A. Ontiveros**

25c per copy. By subscription: Twelve issues for $2.00 in U.S.A., Canada, and Pan-American countries. Elsewhere $2.50 or 10s. 4d. for twelve issues. (British postal orders accepted.)

Published bimonthly by Radio, Ltd., 7460 Beverly Boulevard, Los Angeles, California.
Application for entry as second-class matter is pending.

From Bell System Technical Journal, April, 1937

Sound Recording on Magnetic Tape

BY C. N. HICKMAN

This paper describes an improved method of recording sound magnetically on a steel tape, similar in principle to that of the Poulsen telegraphone.

A SYSTEM of recording speech magnetically on a steel wire was invented by Poulsen almost forty years ago. The wire was drawn past a pair of pole-pieces surrounded by coils carrying a speech current. A magnetic pattern corresponding to the current was thus impressed on the wire. When the wire thus magnetically treated was again drawn past the pole-pieces a current corresponding to the recording current was induced in the surrounding coils. It was common practice to place the pole-pieces on opposite sides of the wire and offset with respect to each other. The magnetic pattern in the wire thus consisted mainly of a variation in the intensity of magnetization, the direction of the magnetization being substantially parallel to the axis of the wire. This method of putting the record on the wire is known as longitudinal magnetization. With such a system the wire must travel at a very high speed if high frequencies are to be recorded and reproduced. It was customary to use speeds of from six to ten feet per second. By using tape instead of wire, the recording and reproducing pole-pieces may be placed directly opposite each other so that the magnetic pattern consists of variations in the intensity of magnetization, the direction of the magnetization being substantially perpendicular to the surface of the tape. This type of magnetization will be called perpendicular magnetization. There is another method of recording in which the magnetization is in a direction perpendicular to an edge and parallel to the surface of the tape which has been called cross or transverse magnetization.

In spite of the fact that the principle of magnetic recording has been known for a long time, there there has been very little literature on the subject until recently. Several papers[1] which deal almost entirely with the longitudinal method of magnetization have been published abroad during the past two years. Cross magnetization is discussed briefly in one of the papers. Apparently, perpendicular magnetization has not been seriously considered. This paper will treat mainly the perpendicular method of magnetization with which a good frequency-response characteristic may be obtained with a tape speed of only 16 inches per second.

• *Forms of Recording Media*

Steel wire has been used as a recording medium in most of the telegraphones. This was probably because it was easier to obtain. When wire is used it is necessary to make the longitudinal separation of the pole-pieces rather large. This is done in order to minimize the distortion caused by the continual rotation of the wire about its axis. Such rotations change the relation of the magnetic patterns in the wire with respect to the reproducing pole-pieces from that which existed at the time the record was made.

When the pole-pieces have a wide separation, high linear speed must be used in order to record and reproduce high frequencies. The high speed required in this method of recording gives rise to a number of mechanical difficulties. The contacting pole-pieces wear away rapidly and it is difficult if not impossible to construct and hold them so that they will ride smoothly against the wire. The variations in contact with the wire change the magnetic reluctance of the flux path so that the signal strength varies and and excessive amount of noise is introduced.

Recording on steel discs has been investigated from time to time but no practical results have yet been reported.

Steel tape as a recording medium was suggested by V. Poulsen in his U. S. patent No. 661,619–1900. Its use eliminates many of the objectionable features of the wire recording system. The magnetic patterns in the tape pass the pole-pieces during reproducing in the same relative positions as at the time they were made. It is practical to wind the tape on reels of pancake shape. Snarling difficulties encountered when using wire are thereby avoided. Thin tape permits the use of smaller pulleys without exceeding the bending fatigue limit of the metal. The use of tape permits the perpendicular method of magnetization to be employed. High frequencies may therefore be recorded and reproduced with a relatively low linear tape speed.

• *Methods of Magnetization*

There are two methods of longitudinal magnetization in use, one and two pole-piece recording. A detailed description of these methods is given in two of the papers which have been mentioned. It will be sufficient here to consider them only briefly.

Figure 1 shows the action taking place in recording with one pole-piece. *M* is the recording medium and *P* is the recording pole-piece. It will be assumed that the recording medium has been previously magnetized by drawing it past a pole-piece so that the residual magnetization in it has a direction as indicated by the upper arrow at the

[1] *See list at end of this article of recently published papers dealing with magnetic recording.*

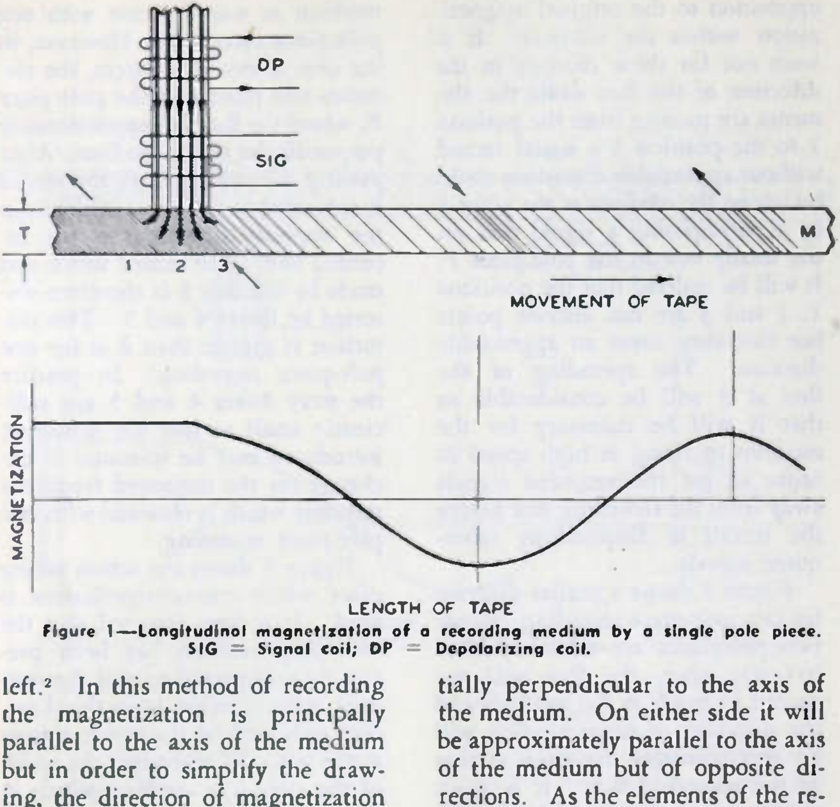


Figure 1—Longitudinal magnetization of a recording medium by a single pole piece. SIG = Signal coil; DP = Depolarizing coil.

left.[2] In this method of recording the magnetization is principally parallel to the axis of the medium but in order to simplify the drawing, the direction of magnetization in figure 1 is shown at a considerable angle. If the pole-piece *P* carries a steady flux in the direction indicated by the heavy lines, this flux will spread in the medium. At the point 2 in the middle of the pole-face, the flux will be substantially perpendicular to the axis of the medium. On either side it will be approximately parallel to the axis of the medium but of opposite directions. As the elements of the recording medium approach the pole-piece *P,* they will be subjected to the flux 1 which is in approximately the same direction as the residual magnetization in the medium so that no appreciable change will take place. When the elements are directly opposite the face of the pole-piece they will be acted on by a flux 2 which is nearly perpendicular to the residual magnetization of the medium. When the elements reach the position 3, the flux will be in

[2] *In figures 1, 2, 3, 4 and 6, the heavy lines passing through the pole-pieces represent the instantaneous recording flux. The density of the fine lines in the recording medium represents the intensity of magnetization. The arrows above and below the medium show the direction of this magnetization. The curve below represents the nature of the signal that has been recorded on the tape.*

opposition to the original magnetization within the medium. If it were not for these changes in the direction of the flux while the elements are passing from the position 1 to the position 3 a signal record without appreciable distortion could be left on the medium at the point 3 by superimposing a signal flux on the steady flux in the pole-piece *P*. It will be realized that the positions 1, 2 and 3 are not discrete points but that they cover an appreciable distance. The spreading of the flux at 3 will be considerable so that it will be necessary for the medium to travel at high speed in order to get the recorded signals away from the recording flux before the record is distorted by subsequent signals.

Figure 2 shows a similar diagram for two pole-piece recording. Where two polepieces are relatively close to each other, the flux will not spread so much in the medium and the direction of magnetization will be approximately the same as that of the recording flux. It is again assumed that the residual magnetization within the medium is mainly in the opposite direction to the motion of the medium as indicated by the upper arrow at the left. The flux 1 will have no appreciable effect on the residual magnetization. The flux 3 is in the opposite direction to the residual magnetization, and were it not for these changes in the direction of the flux while passing from 1 to 3, a modulation of the flux 3 might be expected to leave an undistorted record on the medium as was the case with one pole piece recording. However, in the case of two pole-pieces, the elements still must pass the pole-piece P_2 where the flux 4 is approximately perpendicular to the medium. After passing the pole-piece P_2 the record is subjected to the flux 5 which is in the opposite direction to the recorded flux. The record which was made by the flux 3 is therefore distorted by fluxes 4 and 5. This distortion is greater than it is for one pole-piece recording. In practice the stray fluxes 4 and 5 are sufficiently small so that the distortion introduced may be tolerated in exchange for the improved frequency response which is obtained with two pole-piece recording.

Figure 3 shows the action taking place where cross-magnetization is used. It is here assumed that the recording medium has been previously magnetized so that the residual magnetization is in the direction indicated by the upper arrows at the left. *W* represents the width of the recording medium which in this case is a steel tape. It will readily be seen that if *W* is very large there will be considerable spreading of the recording flux within the tape. The recording flux is always at substantially right angles to the axis of the tape and parallel to its surface and is in the opposite direction to the residual magnetization.

If *W* is made quite small or in other words if the pole-pieces P_1 and P_2 are directly opposite each other with the thin dimension of

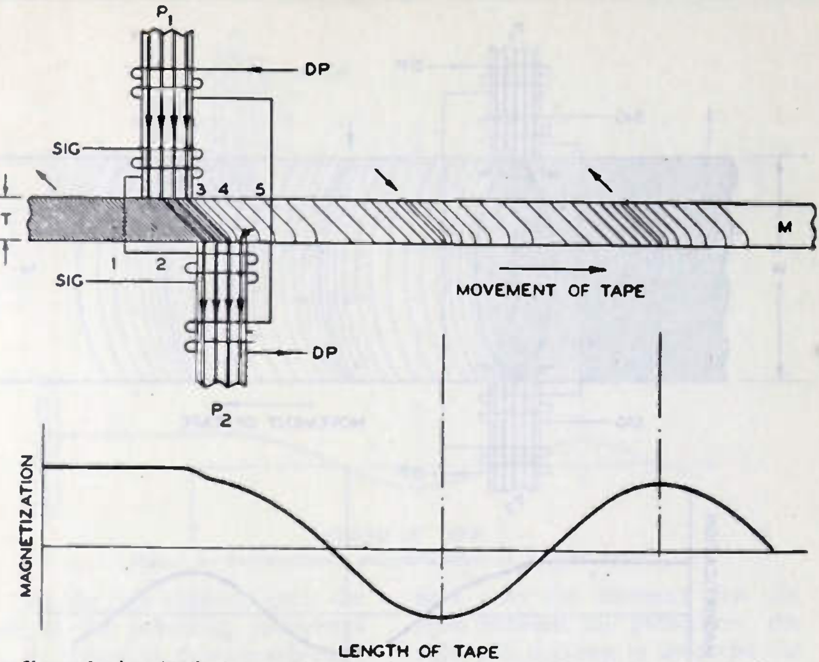


Figure 2—Longitudinal magnetization of a recording medium by two pole-pieces.

the tape between them, we have the conditions shown in figure 4. The tape is so thin that there is very little spreading of the flux so that the width of the flux path is not appreciably dependent on the strength of the signal. This type of recording is called the perpendicular magnetization in order to distinguish it from cross-magnetization, where the width of the tape instead of the thickness determines the pole-piece separation. The perpendicular method of magnetization permits a relatively low tape speed. The thickness of the pole-piece tips determines the frequency response for a given tape speed.

- *Method of Recording with Perpendicular Magnetization*

If the tape is first subjected to a saturation flux which is at right angles to the surface of the tape, it will be left with one side of north and the other of south polarity. If the tape in this condition is passed between recording pole-pieces carrying only AC flux, it is obvious that only half cycles will be recorded. The record is therefore much distorted. The current reproduced from such a record is similar to the alternating current which may be obtained from a single wave rectifier.

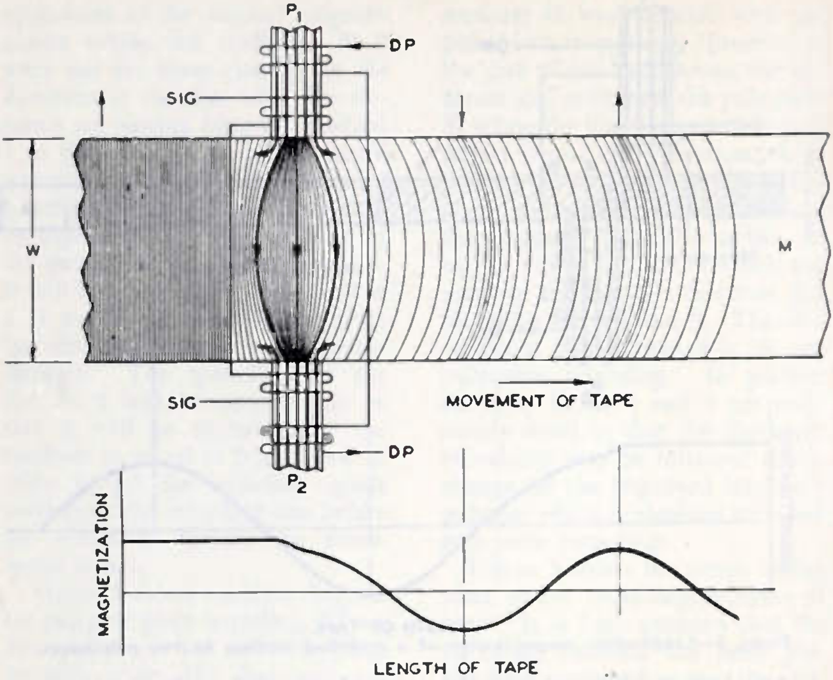


Figure 3—Transverse magnetization of a steel tape.

If on the other hand the tape is passed through an alternating high-frequency field which is strong enough to erase the record, it is left in a substantially neutral condition. If it is then passed between the recording pole-pieces, both half cycles will be recorded but there will be amplitude distortion. Figure 5 shows a magnetization curve for iron which has previously been demagnetized with alternating current. The slope of the first part of the curve is small in either direction of magnetization and then increases with increase in the flux and finally becomes smaller again. Small signals will therefore be recorded weakly and strong signals will be recorded relatively higher. Both will have wave form distortion. The same effects would be obtained with longitudinal or cross magnetization. In the past, investigators have often utilized only one side of the magnetization curve. A direct current was used as a bias to bring the recording flux to the most suitable part of the curve such as at *n*, figure 5.

The method employed here will be made clear from figures 6 and

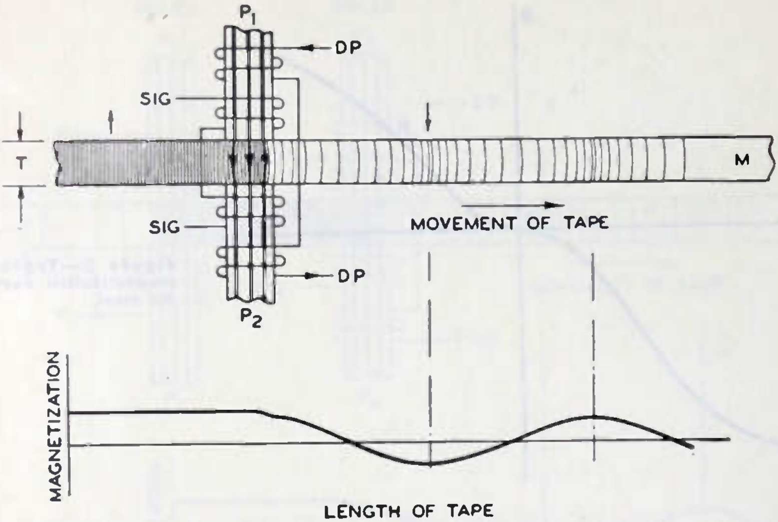


Figure 4—Perpendicular magnetization of a steel tape.

7. As the tape elements enter the field of the polarizing pole-pieces P_1, P_2 (figure 6) they are subjected to an increasing magnetizing force. The elements are magnetized to the saturation point *P* as shown by curve *a*, figure 7. As the elements leave the polarizing field they are subjected to a field of decreasing strength so that the magnetic induction drops along the curve b to *R*, this point being reached when the applied field is zero. In figure 7, the magnetizing force *H* refers to the externally applied field. The tape elements then pass between the recording pole-pieces which carry a flux in opposite direction to that of the polarizing pole-pieces. If there is no signal current present the magnetic induction will be brought down to the point *N* by the biasing field. As the elements pass out from between the pole-pieces, the field will decrease to zero and the magnetic induction will change from *N* to *O*, which is a substantially neutral condition. However, if there is a signal current present at the time the tape elements are passing between the recording pole-pieces, the magnetization will be reduced to a point *A* higher than *N* if the cycle is in opposition to the bias flux, or to the point *B* lower than *N* if the signal flux is in the same direction as the bias flux. In either case the elements will retain a magnetization value corresponding to *A'* or *B'* respectively. This system makes it possible to record over a longer portion of the magnetization curve without appreciable distortion.

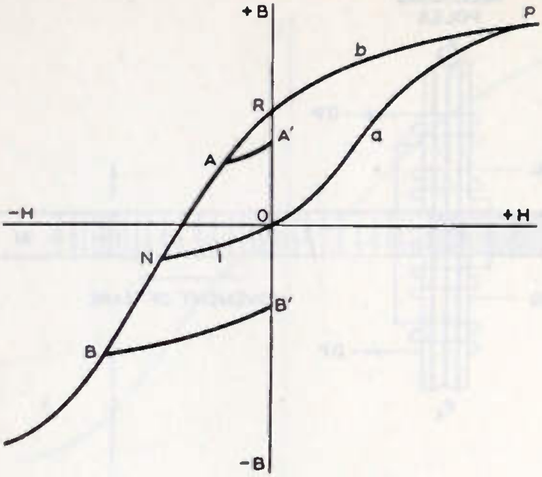


Figure 7—Diagram showing cycles of magnetization through which the elements of a steel tape may pass during the process of recording.

frequency, so that the coils may be matched to favor the lower frequencies. If a straight line frequency characteristic is desired, a corrective network may be used.

Figure 10 shows several frequency response curves. Curve 1 shows a response without the use of equalization for a tape speed of 8 inches per second. Curve 2 shows the response under the same conditions for a tape speed of 16 inches per second. Curve 3 shows the same signals of curve 2 reproduced through a suitable equalizer.

The ratio of the maximum reasonably undistorted 1000-cycle signal to the noise with typical good tape is about 38 db. The transfer loss is approximately 60 to 70 db. The maximum power required in recording is about 0.3 milliwatt.

• *Traits of Magnetic Recording*

Magnetic recording differs from other methods in several respects. Since no processing is required, the record may be reproduced without a long delay. The recording medium may be used over and over again for new records. It is only necessary to subject the tape to a strong magnetic field in order to obliterate a record. The obliteration is conveniently done at the same time that the new record is being made. Where temporary records are desired, magnetic recording therefore has some advantages over other methods. On the other hand it should be fully appreciated that the records may be kept, filed away, or reproduced thousands of times without any appreciable deterioration in the quality.

The magnetic system is very con-

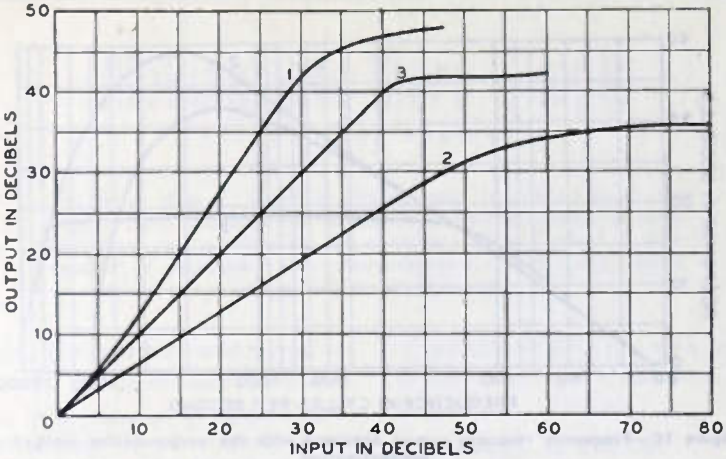


Figure 8—The effect of the biasing current on the slope of the output-input level curves.

venient for use where short delays are desired. A short loop of tape in conjunction with recording, reproducing, and obliterating polepieces is all that is required. Instead of a loop of tape, a disc or cylinder rotating at high speed may be used to carry the recording medium. The latter method makes it possible to obtain very short delays. Where perpendicular magnetization is used, very long records may be obtained from a medium which occupies a relatively small amount of space. For example, a thin coil of 2 mil tape 9 inches in diameter will give a playing time of ½ hour with a tape speed of 16″ per second.

There are no moving parts in the modulating unit. The difficulties

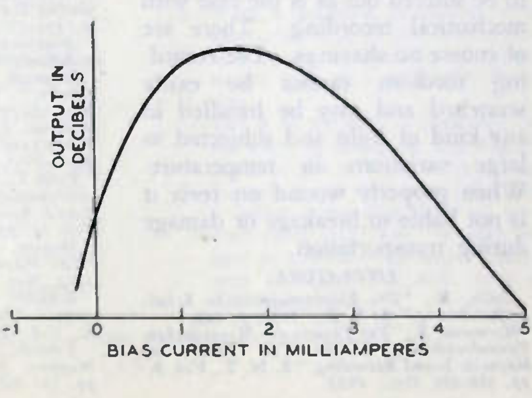


Figure 9—Effect of the biasing current on the intensity of weak signals.

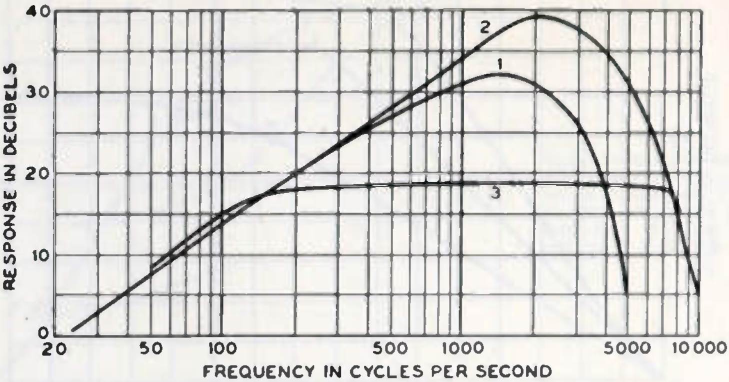


Figure 10—Frequency response curves obtained with the perpendicular method of magnetization.

of obtaining high frequencies due to the inertia of the cutting stylus in mechanical recording are therefore not present. The system is subject to the same difficulties of eliminating flutter that we find in other methods of recording; however, mechanical vibrations due to the motor and other moving parts of the recording system do not have to be filtered out as is the case with mechanical recording. There are of course no shavings. The recording medium cannot be easily scratched and may be handled in any kind of light and subjected to large variations in temperature. When properly wound on reels it is not liable to breakage or damage during transportation.

LITERATURE

Stille, K., "Die Electromagnetische Schallaufzeichnung," E. T. Z., *1930, p.* 449.

Hormann, E.,"Zur Theorie der Magnetischen Tonaufzeichnung," "On The Theory of Magnetic Sound Recording," E. N. T., *Vol. 9, pp. 388-403, Oct., 1932.*

Meyer, E. and Schuller, E., "Magnetische Schallaufzeichnung auf Stahlbander." Magnetic Sound Reording on Steel Ribbons," ZEITS. F. TECH. PHYSIK, *Vol. 13, No. 12, pp. 593-599, 1932.*

Begun, S., "Die Diktiermaschine im Grossbetrieb," E. T. Z., *1932, p. 204.*

Hickman, C. N., "Delayed Speech," BELL LABS. RECORD, *Vol. 11, pp. 308-310, June, 1933.*

"Magnetic Recording and Reproducing." The Marconi-Stille apparatus described, WIRELESS WORLD, *Vol. 34, pp. 8-10, Jan. 3, 1934.*

Russ, N. M., "Marconi-Stille Recording and Reproducing Equipment," MARCONI REV., *No. 46, pp. 1-11, Jan.-Feb., 1934.*

Frederick, H. A., "Recording and Reproducing Sound," REV. SCI. INSTRUMENT, *Vol. 5, pp. 177-182, May, 1934.*

Braunmuhl, H. J., von, "Magnetische Schallaufzeichnung im Rundfunkbetrieb," "Magnetic Sound Recording in Broadcasting Service," FUNKTECHNISCHE MONATSHEFTE, *No. 12, pp. 483-486, Dec., 1934.*

Mallina, R. F., "A Mirror for the Voice," BELL LABS. RECORD, *Vol. 13, pp. 200-202, Mar. 1935.*

Volk, T.," Magnetophon, ein Neues Tonaufzeichnungsgerat," "Magnetophone, a New Sound Recording Apparatus," FILMTECHNIK, *Vol. 11, pp. 229-231, Oct. 26, 1935.*

Hansen, W. H., "Das Magnetophon," "The Magnetophone," E. T. Z., *Vol. 56, p. 1232, Nov. 7, 1935.*

Schuller, E., "Magnetische Schallaufzeichnung," "Magnetic Sound Recording," E. T. Z., *Vol. 56, pp. 1219-1221, Nov. 7, 1935.*

Schrage, W. F., "Sound Recording on Magnetic Materials," RADIO CRAFT, *Vol. 7, pp. 537-562, March, 1936.*

¶ From RADIO, July, 1937

Making Life More Simple

BY F. ALTON EVEREST

Graphical class C amplifier design and calculation is a very simple process when one familiarizes himself with the interpretation and application of constant current charts. This method of presenting tube characteristics is extremely useful, and should be encouraged.

WHILE the constant current type of curve has been used in other ways, its application to vacuum tube characteristics is a relatively new one. Their use was first suggested by Mouromtseff and Kozanowski*. To the writer's knowledge, however, the Eimac people are the only ones who supply constant current charts for amateur transmitting tubes. Curves for the Eimac 100TH and 250TH are reproduced in figures 4 and 5. Figures 1, 2, and 3, showing constant current charts for the Heintz and Kaufman 154 and 354, and the RCA 801 were drawn by points transferred from the conventional E_g-I_g and E_p-I_p characteristics. The process of re-plotting is a relatively simple one which any amateur can do for his favorite final amplifier tube. Ordinary graph paper having 20 divisions to the inch is particularly well suited. The curves shown in figures 1 to 5 may be used as a guide in the selection of suitable scales, for each square in these figures was half inch on a side before reduction.

* *"Vacuum Tubes as Class-C Amplifiers," Proc. I. R. E., July, 1935.*

• *Advantages of Constant Current Curves*

The chief advantages of using this form of tube characteristic are:

1—The grid and plate characteristics are shown plotted on the same set of coordinates.

2—Operating with a given plate voltage and bias places the operating point in a definite location on the chart.

3—The dynamic characteristic is a straight line drawn through this operating point for any mode of operation, class A, B, or C.

4—With a moderate familiarity with these charts, it is possible to determine the adaptability of a particular tube to a particular function.

5—The μ of the tube is indicated by the slope of the lines. The higher the μ of the tube the more nearly horizontal are the lines. (*Caution*—before comparing the μ of several tubes this way, be sure to bear in mind the fact that a difference of scales will also cause a shift in slope.)

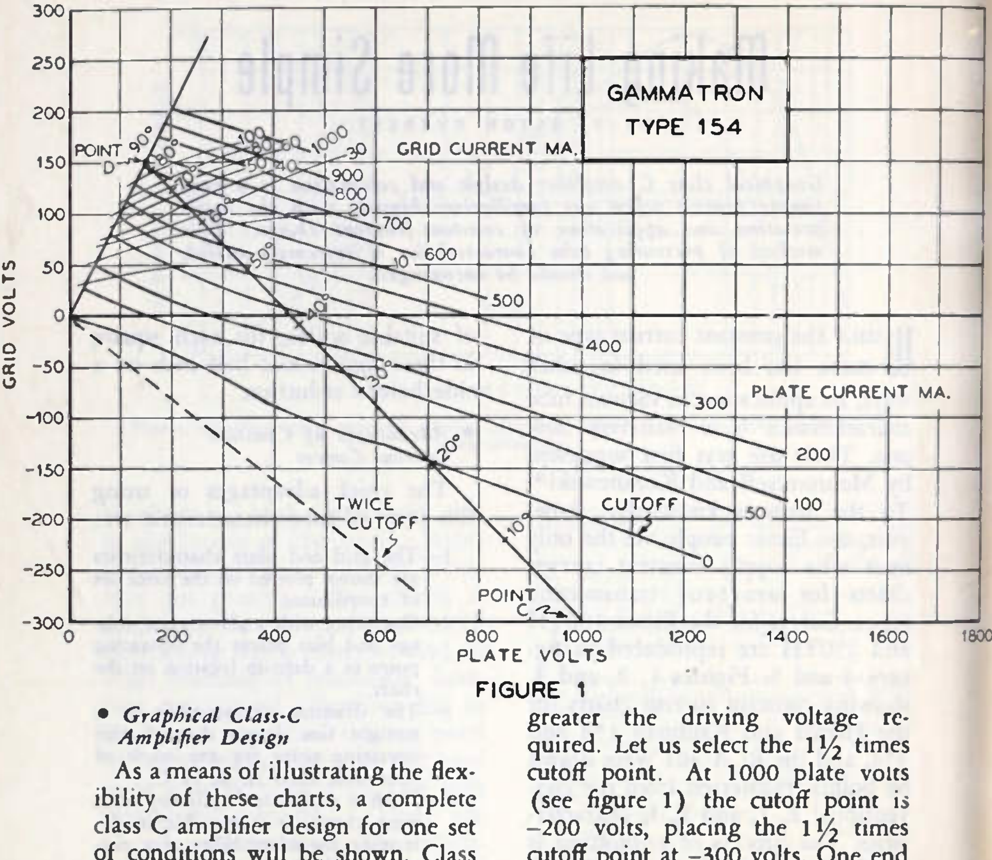


FIGURE 1

• *Graphical Class-C Amplifier Design*

As a means of illustrating the flexibility of these charts, a complete class C amplifier design for one set of conditions will be shown. Class A and B amplifier analyses follow very closely except for the location and length of dynamic characteristic.

The Gammatron 154 will be used for illustration, with 1000 volts on the plate. The bias required will depend upon the use, varying from 1½ times to several times cutoff. The greater the bias, the higher the efficiency, but the greater the driving voltage required. Let us select the 1½ times cutoff point. At 1000 plate volts (see figure 1) the cutoff point is –200 volts, placing the 1½ times cutoff point at –300 volts. One end of the dynamic characteristic will then be at $E_p = 1000$ and $E_g = -300$ volts, or point C on figure 1.

The extent to which we drive the grid positive is limited (for c.w. or plate modulation) only by the emission of the filament. The total emission current (plate current plus grid current) should never exceed the safe filament emission, which is normally about 30 to 50 ma. per

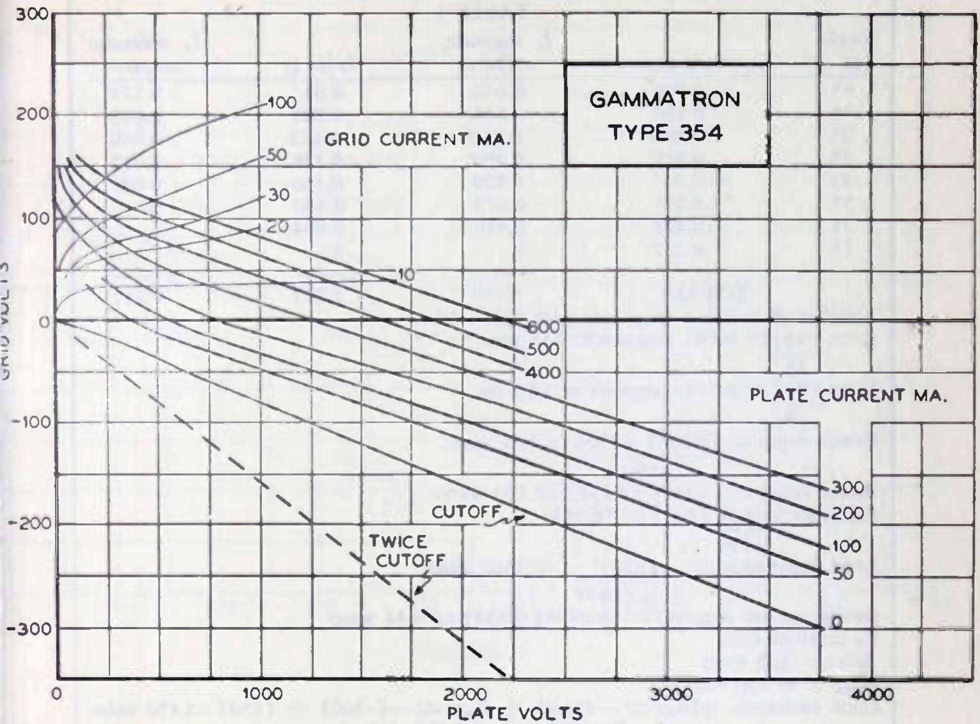


FIGURE 2

watt of filament heating power for thoriated tungsten filaments. For the 154 the filament heating power is 5 volts × 6.5 amperes or 32.5 watts. As it is a thoriated tungsten filament the maximum instantaneous space current allowable would be in the order of 100 ma. To be considerate of the tube let us set our upper limit where the sum of plate and grid currents is about 750 ma.

Another factor to remember in locating this positive grid swing point is that of minimum plate voltage. The grid should never become more positive than the plate or the plate current would be diverted to the grid, probably causing damage. With these two factors in mind, let us locate the other end of our dynamic characteristic at point D, where minimum plate voltage (E_{min}) and positive grid voltage (E_{max}) are equal to 150 volts, and where the total space current is about 750 ma. The dynamic characteristic is now completed by

TABLE I

Angle Θ	*sin* Θ	I_p *ordinate, amperes*	I_p *sin* Θ	I_g *ordinates amperes*
85	0.996	0.640	0.637	0.125
75	0.966	0.600	0.580	0.075
65	0.906	0.510	0.462	0.040
55	0.819	0.400	0.328	0.015
45	0.707	0.220	0.156	0.002
35	0.573	0.070	0.040	0
25	0.423	0.010	0.004	
15	0.259	0	0	
	TOTALS	2.450	2.207	0.257

Number of ordinate strips per half cycle—18

$I_p = \frac{2.450}{18} = 0.136$ amperes $= 136$ ma.

$I_g = \frac{0.257}{18} = 0.0143$ amperes $= 14.3$ ma.

Power input $= \frac{(2.207)\ (850)}{18} = 104$ watts

Power input $= (1000)\ (0.136) = 136$ watts

Efficiency $= \frac{104}{136}\ (100) = 76.5\%$

Load Impedance $= \frac{(850)^2}{(2)\ (104)} = 3460$ ohms

Exciter power required $= (0.0143)\ (450) = 6.44$ watts

$E_B = 1000$ volts

Bias $= -300$ volts

$E_{max} = +150$ volts

Crest excitation voltage $=$ —(bias) $+ E_{max} =$ —$(-300) + (150) = 450$ volts

DEFINITIONS AND FORMULAS

E_B = plate power supply voltage (point C on figure I)

E_o = Voltage amplitude, equal to $E_B - E_{min}$

E_{min} = Lowest value to which plate voltage swings throughout the cycle (point D figure I)

E_{max} = The most positive voltage the grid attains throughout the cycle (point D figure I)

Direct Current plate current $I_p = \dfrac{I_p \text{ ordinate total for half pulse}}{\text{total number of ordinates of half cycle}}$

D.C. grid current $I_g = \dfrac{I_g \text{ ordinate total for half pulse}}{\text{total number of ordinates of half cycle}}$

Power output $= \dfrac{(I_p \sin \Theta \text{ ordinate total for half pulse})\ (E_o)}{\text{total number of ordinates of half cycle}}$

Power input $= E_B\ I_p$

Efficiency $= \dfrac{\text{power output} \times 100}{\text{power input}}$

Load impedance $= Z_L = \dfrac{(E_o)^2}{2\ (\text{power output})}$

Exciter power required $= (I_g)$ (crest excitation voltage)

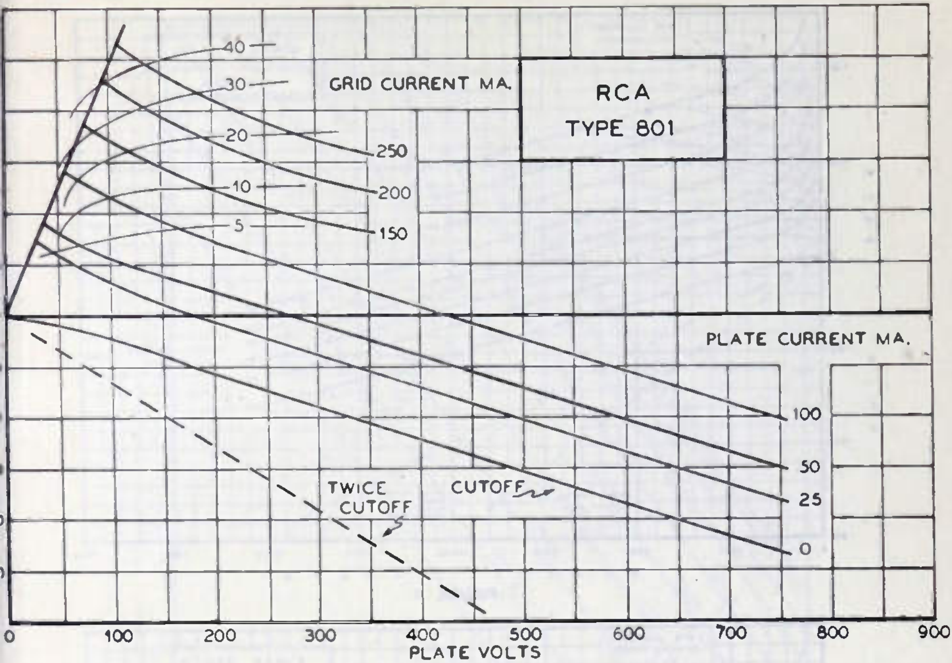


FIGURE 3

drawing a straight line between points C and D.

• *The Sine Scale*

With point C as our operating point the grid swings toward the positive direction on an r.f. cycle as the instantaneous plate voltage decreases. Going from point C to D and back to C we have completed the positive half cycle of the r.f. exciting voltage. The negative half (in class C operation) drives the grid only more negative and has no useful result and will be neglected. From the electrical viewpoint, going from C to D and back to C means a travel of 180 electrical degrees.

To aid in marking off the intermediate degree points, the sine chart of figure 6 has been devised. Its use is as follows: Place an edge of a sheet of paper along the line C-D of figure 1 and mark the distance between C and D on the paper, labelling each mark with its own letter. Now place the piece of paper on figure 6 so that point D coincides with point A. Pivoting on this, swing the paper until the

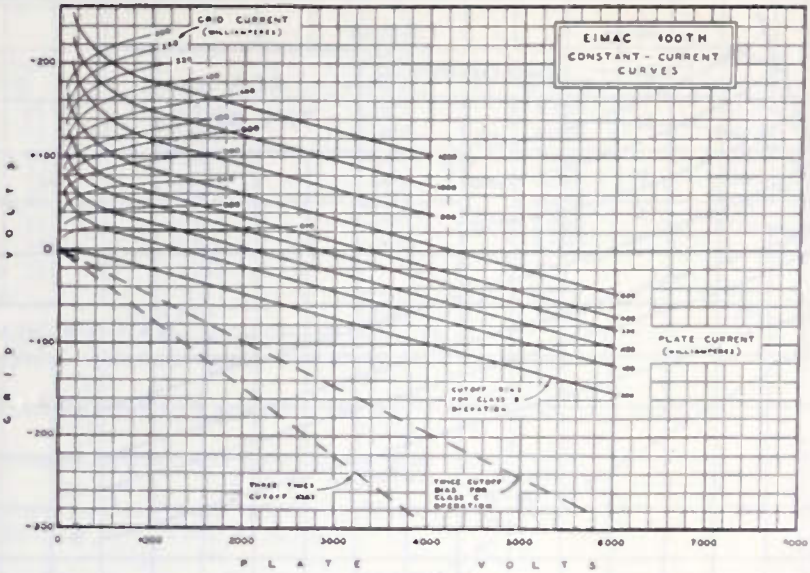


FIGURE 4

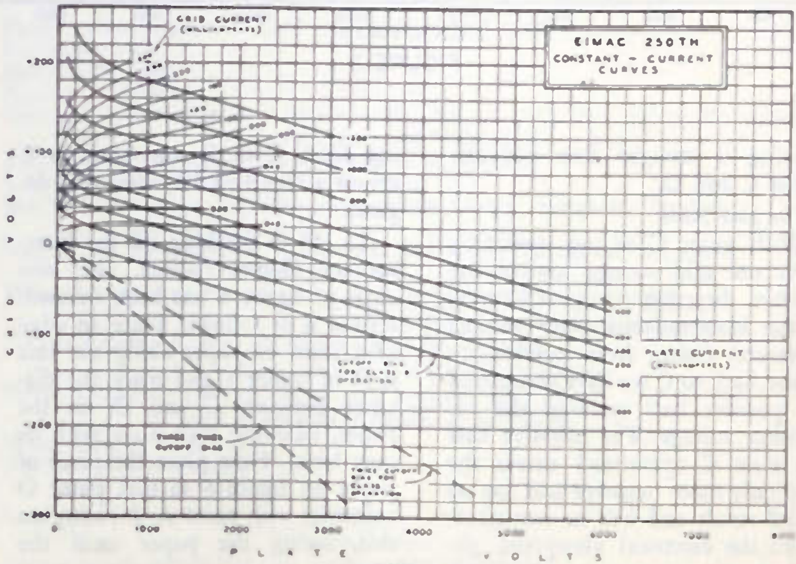


FIGURE 5

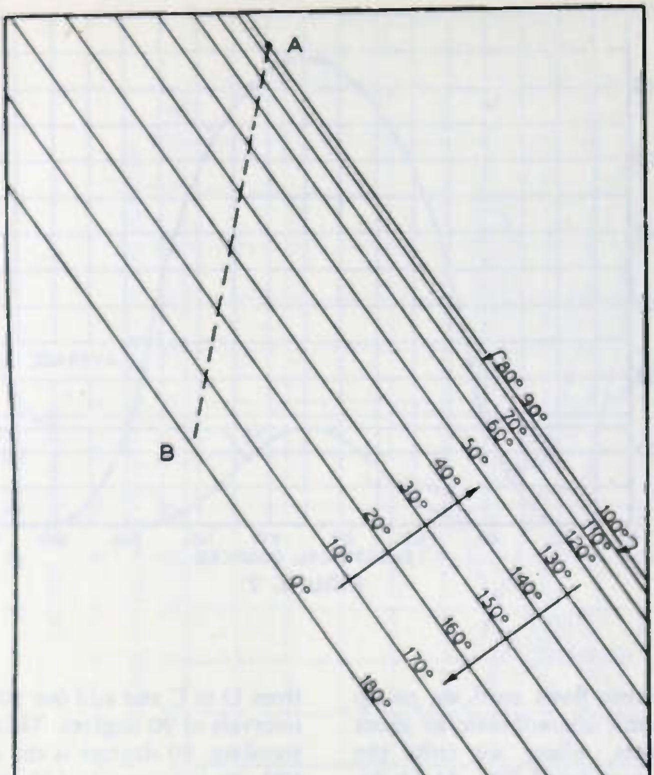


FIGURE 6

point C falls upon the 0-180 degree line near B. Holding the piece of paper in position, mark the paper where the 10, 20, 30 etc. degree lines meet the edge of the paper. We now have our length C-D divided into a sine scale and the points can be transferred to the dynamic characteristic of figure 1 as shown.

• *Plotting the Current Pulse*

When the electrical angles are marked off on C-D of figure 1 in 10 degree intervals, a plot of the plate and grid current pulses (similar to figure 7) can be made. The plot is not essential to the analysis, but for the first time it aids in the visualization of what goes on. No

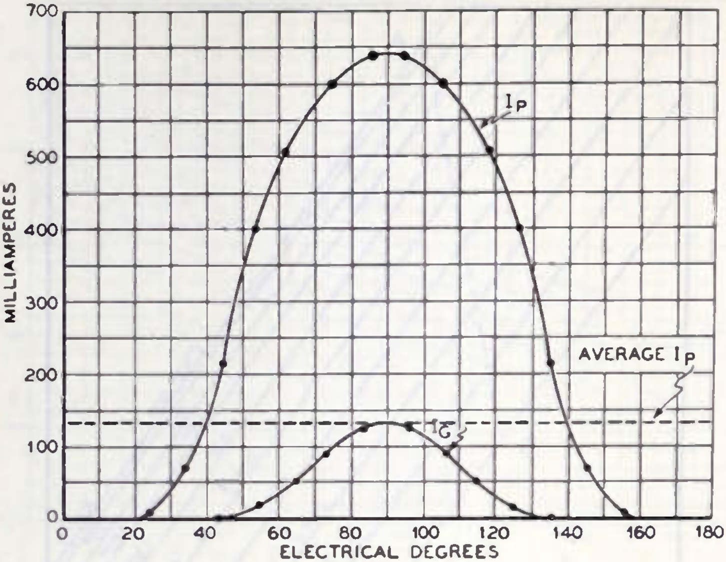


FIGURE 7

plate current flows until we go up the dynamic characteristic to about 22 degrees, where we cross the plate current cutoff line. At 35 degrees the plate current is about 70 ma., at 45 degrees about 220 ma., and so on.

At the 42 degree point the zero grid voltage point is passed and grid current starts to flow. For 55 degrees the plate current is about 400 ma. and the grid current about 15 ma. This procedure is followed to the 90 degree point, or the crest of the r.f. excitation cycle. A glance at figure 6 shows that the same scale for sines is followed from 90 to 180 degrees except that we descend from D to C and add our 10 degree intervals to 90 degrees. Thus in descending, 80 degrees is the same as 100, 70 the same as 110, etc. The simplest method, knowing the current pulses of figure 7 to be symmetrical, is to read points from 0 to 90 degrees and to plot the same current for the same number of degrees on either side of 90. Thus 600 ma. would be plotted at 75 and 105 degrees.

After plotting the grid and plate current pulses to scale as in figure 7, the average plate and grid currents (those which would be indicated by a d.c. milliammeter) are found by integration of the pulses

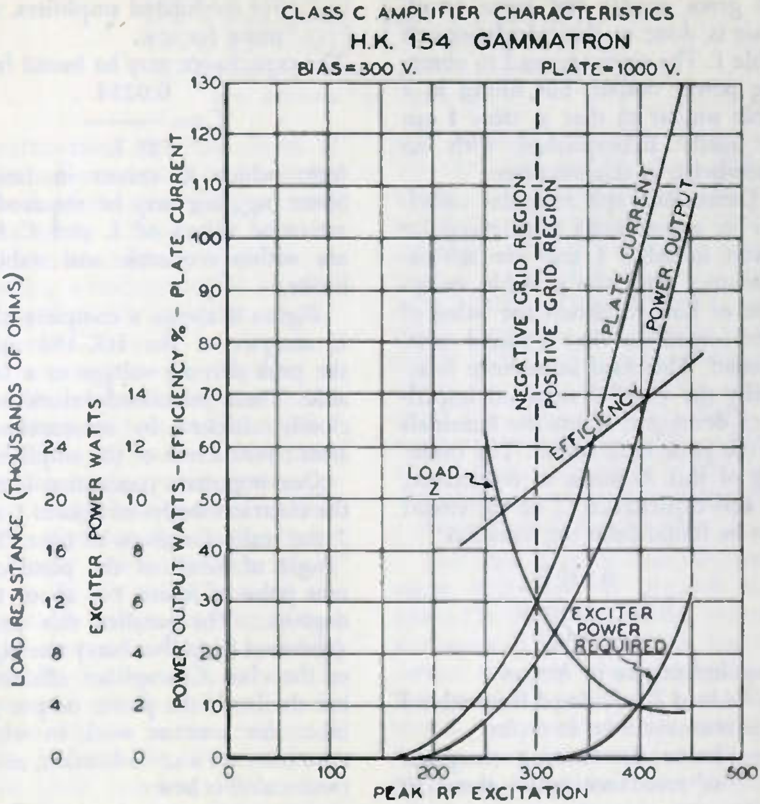


FIGURE 8

over 360 degrees, one complete cycle. This integration may be performed in many ways, one of the simplest being that of taking the value of plate and grid current for every 10 degrees throughout the complete cycle and averaging them. The height of the curve at the midpoint of each 10 degree strip for the pulse is tabulated. By dividing the number of these 10 degree strips per cycle (36) into the total value of the mid-ordinates of the strips for one complete cycle gives the average height ordinate or the d.c. plate and grid current which the intermittent pulses produce. As the pulse is symmetrical, adding up the midordinates for only half the pulse and dividing by 18 instead of

36 gives exactly the same result. This is done in the calculations of table I. The sines are used to obtain the power output, but filling in a table similar to that in table I can be easily accomplished with no knowledge of trigonometry.

Definitions and formulas sufficient for any ordinary calculations are given in table I and are self-explanatory with the possible exception of how to obtain the value of load impedance that is found to be needed. This load impedance is actually the parallel resonant impedance developed across the terminals of the plate tank circuit. The meaning of this in terms of inductance, L, and capacitance C, of the circuit can be found from the equation:

$$L = \frac{0.159\, Z_L}{f\, Q}$$

L = inductance in henrys
Z_L = load Z calculated from table I
f = resonant freq. in cycles
Q = factor determining sharpness of resonance peak—about 10 for modulated amplifiers, and more for c.w.

The capacitance may be found from

$$C = \frac{0.0254}{f^2\, L}$$

from which C comes in farads. Some juggling may be required to arrive at values of L and C that are within economic and stability limits.

Figure 8 shows a complete class C analysis of the HK-154 using the peak driving voltage as a variable. These calculated values were closely checked by measurements after construction of the amplifier.

One important conception is that the electrical angles of figures 1 and 7 are really functions of time. The "angle of flow" of the plate current pulse of figure 7 is about 130 degrees. The smaller this angle (obtained by higher bias) the higher the class C amplifier efficiency, but the lower the power output per tube. For amateur work in which tube costs are a consideration, about twice cutoff is best.

One way to find out where you are, without the aid of a compass, is to carry around a telephorus beetle with you. According to Marcel Roland of the Paris Museum, this strange little insect always places itself parallel to the terrestrial magnetic lines of force. It may be shifted about times without number and will always immediately resume a position facing one of the poles.—Ohmite *News*.

¶ From Aero Digest,
August, 1937

RESEARCH IN STATIC

BY HENRY W. ROBERTS

INVESTIGATION into the causes of rain and snow static, and into the methods of its prevention, recently conducted by United Air Lines in co-operation with a number of scientists, is unquestionably a major landmark in the progress of aircraft radio.

The aircraft radio engineer is confronted by many special problems which have no parallel in other applications of radio. To solve them, he needs special knowledge not yet available in engineering textbooks. Significantly, the search for this special new knowledge is carried on by the much harassed airlines and a few radio manufacturers who are unstintingly spending hundreds of thousands of dollars for research which could ordinarily be presumed to be the concern of public bodies. Equally significant is the close co-operation between the airlines, whose well-integrated research activities show orderly progress without overlapping, and the results of which are made available to the entire industry.

• *"Snow Static"*

The most common special phenomenon affecting aircraft radio—and one having most potential danger—is that of the so-called "snow static." It is normally experienced only in aircraft at speeds more than 100 mph and consists of a combination of noises containing frying sounds, intermittent or regular crackling, and characteristic squealing sounds throughout the audible scale which completely drown out radio reception. Although commonly called snow static, identical effects are experienced in ice, sleet, rain, and dust storms. Such a static condition frequently extends over hundreds of miles of the airway and lasts for days, constituting a major menace to air safety.

This type of static was observed many years ago at ground and steamship stations, during storms accompanied by high winds, but its nature was not then recognized. Between 1926 and 1930, it was observed that shielded-loop direction finders used in Great Lakes shipping gave reception in snow storms when ordinary antennas were rendered useless. Presuming that the static noise was caused by the impingement of charged particles, a National Air Transport radio engineer in 1930 covered aircraft antennas with friction tape, and in 1932 United Air Lines equipped their ships with rubber-covered antennas. These methods were not successful.

• ***Loop Antennas Used***

The first practical steps toward the solution were suggested in 1935 by D. S. Little of RCA Aviation Division, and TWA and UAL constructed and tested shielded loop antennas in an effort to overcome this type of static. Despite certain disadvantages, the loop antennas successfully eliminated the static except in its most severe manifestations.

In December, 1935, Prof. Homer Dana of Washington State College produced a mild form of dust static in a small wind tunnel; and in March, 1936, Dr. Marcus O'Day, of Reed College in Portland, recorded electrical charges gathered on the windshield of a UAL Boeing piloted by A. C. Ball between Portland and Salt Lake City. In November, 1936, United Air Lines undertook to make a complete study of the phenomenon, and in February, 1937, their expedition got under way. Work was carried on in a standard twin-engined Boeing 247-D transport equipped with work benches, electrometers, oscillograph, recording devices, and special radio sets and antennas.

The purpose of the expedition was to investigate: 1—the meteorological aspects of static formation and its avoidance; 2— static generating effect of the airplane and its reduction; and 3—the value of special antennas in reducing interference. As a result of their work to date, the engineers have an accurate conception of snow static production, basic knowledge on forecasting such conditions, and basic means of elimination of its effects by navigation and special antennas.

All atmospheric static is the result of disturbances in the electrostatic field which surrounds the earth. The earth—a huge sphere floating in free space—carries an electrical charge stored in the atmosphere which surrounds it. The charge near the surface is normally about 35 volts per foot of altitude, diminishing gradually, until at 20,000 ft. it is about 15 volts per foot. The total voltage between the earth and the outermost reaches of the atmosphere has been estimated at about 1,000,000 volts. An airplane in flight gradually builds up a charge equal to that of the atmosphere surrounding it; at 20,000 ft. it is charged to about 300,000 volts with respect to earth, though to zero volts with respect to the surrounding atmosphere.

The electrostatic field around the earth becomes distorted under the effect of the sun's rays which cause the warm air to rise, carrying its charge. Some of the charge is carried by the atmospheric moisture, and so long as the changes in the charge are gradual, no static is observed. The moisture condenses into fog and clouds; and if it forms rapidly, because of turbulent air currents, the charged droplets are churned about and the cloud becomes electrostatically unstable. When sufficient instability results, lightning will occur, accompanied by crash static.

• *Static Caused by Plane*

Snow static will occur long before sufficient difference in potential to produce lightning discharge occurs in the cloud, and the airplane itself, moving rapidly through the variously charged areas, is a major cause of the static which besets it. The charge of the particles through which it flies varies also with their size, the larger droplets being usually positive, while the fine spray separated from them by the wind is usually negative. Thus, the electrical charges which the airplane encounters in flight under such conditions vary in polarity as well as in potential. The variations are so rapid that a constant instability exists between the airplane and the surrounding atmosphere which, when it exceeds a certain rather broad minimum, manifests itself in a continuous stream of electrical discharges which are picked up by the airplane's antenna and are heard as static.

On the basis of the experiments, it is now possible to predict, in a measure, when such static conditions are likely to occur. Actual recordings taken while flying through dozens of clouds indicate that the ideal Simpson cloud* does not exist in nature. The interior of actual clouds is in constant churning motion, and the value of the polarity and potential between the airplane and the cloud will change rapidly several times while flying through the cloud. Meteorologically, the static condition will occur in two broad types of cloud. The first is the simple thundercloud of the warm air type which usually reaches its maximum during the afternoon and spreads out with the sunset as the air currents become less turbulent. Its static charges are usually dissipated by midnight. The second is the front type of cloud, formed by two air masses of different temperatures coming together and forming an air mass front. Lying obliquely to the earth's surface, the static-laden layer of turbulent air currents can be avoided by changing the course or altitude. It is predictable meteorologically, and the technique of its forecasting, when perfected, will become an important factor in enhancing safety on the airways.

The function played by the airplane cleaving through charged air and producing static discharges has been clarified during the months of experimental flying of the laboratory ship. It was conclusively shown that the noise in the receiver is caused by the fluctuations in the electrical charge between the airplane and the surrounding atmosphere rather than the magnitude of the charge.

To learn the distribution of the discharge, a series of points were installed on the airplane—in the nose, tail, each wing, behind exhausts and propellers, and at four

* *Humphries' Physics of the Air.*

points beneath the fuselage. The points were connected through vacuum tube electrometers to the automatic recorders, and a study of data gathered over a period of 8 weeks reveals that the airplane may be either anodic or cathodic with respect to the surrounding cloud, that at any instant one wing may be in positive cloud particles while the other wing is in negative, and that at any instant the nose of the airplane may be in positive particles while the tail is in negative, and vice versa. The maximum cross-flow from wing to wing was about 500 microamperes. Larger flows are possible, as when lightning strikes a metal airplane with wing-to-wing flow of several thousand amperes. Magnetic compass deviations of 10° were observed in thunderclouds, indicating a strong magnetic field in the cloud or a strong cross flow in the airplane's structure—about 45 d.c. amperes wing to wing, or 125 d.c. amperes nose to tail.

• ***Six Variables***

The mechanics of snow static production are quite complex, and are a summation of at least 6 variables:

1.—Plus or minus charges of the water particles in the cloud.

2.—Generation of charge caused by wings splitting particles at speed of about 260 ft./sec.

3.—Generation of charge as a result of propellers splitting particles at speed of about 800 ft./sec.

4.—Foreign matter in water particles (Portland, Oregon, tap water split by rotating propellers gives a positive charge; while Cheyenne, Wyoming, water gives a negative charge).

5.—Rectification action of the test points with different polarity of the airplane's charge.

6.—Cross current flows caused by the airplane short-circuiting sections of cloud having different potentials.

Static conditions were, therefore, duplicated on the ground under controlled conditions. With the engineers inside, the laboratory ship was mounted on insulators inside a large metal hangar, and charged up to ±100,000 volts. Characteristic snow static was present, and other phenomena encountered in flight were duplicated.

Static noise in receivers with regular antennas began as low as 30,000 volts, depending on humidity and the proximity of the artificial ground to the various points on the ship. Static squeals, beginning at about 55,000 volts, were traced to corona discharges from various points of the ship's structure, leading to the conclusion that the space charge in the ionized air around the point breaks down at an audio-frequency rate dependent on the amount of moisture in the air and the voltage gradient at the point. This musical corona can be produced at any one time at several points on the airplane, and is the cause of the snow static sound.

Since airplanes cannot be prevented from gathering electrical charges in flight, means of discharging them in a manner which would cause no interference with radio reception must be provided.

• *Static Eliminators*

The airplane itself can be made less susceptible to production of localized corona discharges by reducing the sharp points on the structure or covering them with insulators or corona shields. This would raise the minimum voltage requirements at which static would occur.

To eliminate static at voltages above these minima, a trailing discharge point, developed on the basis of the experiments, was found entirely practical. Study of the discharge indicated that it has an extremely short wave and rapidly attenuates with distance. This indicated the possibility of using a trailing discharge point, with suitable suppressor resistors, to discharge the airplane in flight. Up to 1 milliampere discharge was obtained at 50 ft. with 100,000 volts, without disturbance in radio reception, using the conventional receiving antenna; a 25 microamperes discharge 2 ft. away from the ship, without suppressors, prevents radio reception.

Since the mechanical disadvantages of a trailing wire are not desirable in aircraft operation, tests are now in progress with a series of seventeen 3-ft. 0.003" dia. wires, each having a 5 megohm resistor, attached to points on the wings and the tail surfaces.

Investigation of electrostatically shielded loops disclosed that their advantage over bare-wire antennas varies with the intensity of the corona discharge. In mild snow static, the advantage as measured by rms static output of the receiver may be 30:1; in heavy snow static the advantage drops to 5:1; and in extremely heavy snow static no range reception could be obtained on any loop antenna even 2 or 3 miles from the range station. The final solution of the snow static problem will probably involve the use of electrostatically shielded loops combined with a static discharge system and meteorological guidance.

Other research work accomplished by the UAL flying laboratory included numerous tests on various types of antenna: fixed wire, shielded and unshielded loops, tubular, etc.; as well as investigation of static charges produced by dielectric component parts of the airplane, such as windshields, de-icers, loop housings, etc. These dielectric components will spark to the airplane's metal parts, causing static. Painting them with dope and graphite, thus making the surface conductive, was found to eliminate static. However, in icing conditions, the forming ice cap acts as a dielectric, and static is again produced. It is hoped that additional work on new designs for these parts will solve the problem.

Further technical information on this subject is contained in a paper by H. M. Hucke, "Snow Static Effects on Aircraft," presented before meetings of the Inst. of Aeronaut. Sciences and Amer. Assn. for the Advancement of Science, Denver, Colo., June 22, 1937; also AERO DIGEST, *Dec., 1936.*

The "Electric Eye"

(Uses of the photo-cell or "electric eye" in modern science and industry are as many as the interesting items found on the Swedish "smorgasbord" of epicurean fame. ELECTRONICS has listed, from time to time, the following methods in which the photo-cell is employed.)

Automobile painting: Electrically-operated air valves for actuation of automatic spray-painting guns on parts conveyor lines in the automobile industry can be controlled automatically.

Mail sorting: In Dollis Hill, England, phototubes examine letters in order to determine if they are properly stamped for cancellation. Phototubes are used also in sorting the mail according to the color of stamps on the envelopes.

Solar measurements: Variations in the sun's ultraviolet radiations are being recorded permanently in South America.

Dairy industry: The effectiveness of irradiation processes used to inject vitamin D in various liquids (especially milk) can now be instantly determined by means of a specially-designed photocell sensitive to ultra-violet light.

Earthquake research: Research in the designing of earthquake-proof structures is being materially assisted by the use of a photocell which governs the vibration rate of a shaking table upon which model structures are tested. By the use of seismic recordings of former quakes, actual earthquake conditions can be reproduced. Experiments are being carried on in the Massachusetts Institute of Technology.

Mercury arcs: The ageing of mercury arcs is accurately determinable through use of the "electric eye." The color of the discharge, as measured by the "eye", is an indication of the ageing.

¶ From Radio Engineering
August, 1937

TUBES IN TRANSIT

BY STANLEY W. TODD

THERE WAS A TIME, not many years back, when it seemed well nigh impossible to ship radio tubes without a substantial amount of damage. Packing along scientific lines was unknown; cartons were made for appearance rather than for protection and the tubes themselves had basic weaknesses, which made them delicate to handle, even in and out of a radio set. The receiver itself was a "weak sister," when it came to being moved about or shipped any great distance.

How many thousands of dollars the former highly fragile character of radio and accessories cost the transportation companies in the early days will probably never be known. It became necessary in their own defense to study the underlying causes of damage and to establish tube-testing laboratories in order to determine whether breakage was not more frequently due to structural weakness and inefficient packing, than to any rough handling in transit.

They found that both receiving and transmitting tubes often had brittle filaments, poorly welded points, loose bases and the most mysterious and annoying of all—the "sagging filament."

That was encountered chiefly in receiving tubes, then packed separately from the sets. Even joint inspections of manufacturers and express representatives did not always bring out this characteristic. Yet, unless a tube was held in a vertical position and not on its side, the filament would touch the grid and cause the tube to "burn out" in the operation of the set. But tests would not tell of this condition and many a tube marked O.K. would not "work," while presumably bad tubes often functioned properly.

But today all such troubles are gone forever. The ability of the modern radio tube to withstand even rough handling is an indication of the marked advance in sturdiness achieved in designing and manufacture. Once it was thought merely inviting damage to ship receiving sets with the tubes in the sockets; today that is common practice. Even more significant is the fact that in the handling of thousands of receiving tubes as individual carton shipments and in their proper position in radio receivers, claims for breakage in transit have dropped almost to zero.

Yet proper "positioning" for shipping purposes is still of vital importance in the safe transportation of the larger and more expensive transmitting tubes. Here the manufacturers and the transportation companies have co-operated constantly to remove any practices, either in the construction of crates and containers or in handling methods, that have been found to be the cause of damage in specific instances. It has not been a simple matter to work out the proper principles of suspension of such tubes inside the shipping crate, but the manufacturers have spared no time or expense in making such shipments damage proof, with ordinary handling.

Owing to the high value of the larger broadcasting tubes and the fact that filament or glass breakage virtually destroys them, since they cannot be repaired, transportation companies are equally concerned in the use of the most advanced positioning and single-point suspension ideas in the shipping department. For the same purpose, the outside of such shipments has also received much attention. Crates used for these tubes are either pyramid in shape or equipped with extension poles at the bottom so that they must be handled upright; handles of metal are placed on top to facilitate movement in that position. The same principles are employed in fibreboard cartons used in packing the smaller types of transmitting tubes.

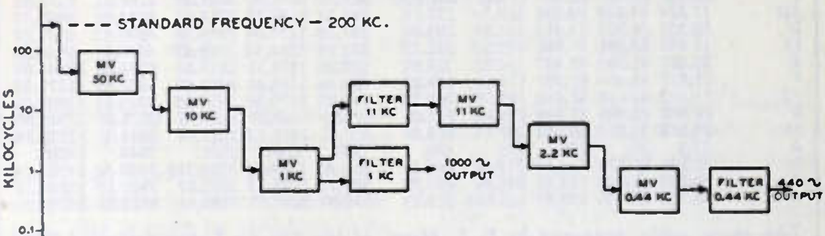
The largest tube shipped is the water-cooled 100 kilowatt introduced some ten years ago and progressively improved in design since. It is a slender 60 inches in length, of which 19 inches are of glass and the remainder metal. It must be kept upright constantly and the shipping crate built especially for it is 7 feet high, with a broad pyramid base, and is almost as impressive as the tube itself.

As it is now valued at $1500 and even slight tilting may invite damage, the necessity for extreme care in shipping is obvious. Because of its height, the chief problem is to get such shipments in and out of express cars; delivery is always made in open trucks. Many of these giants move from the factory to broadcasting stations and on arrival are promptly inspected and tested. Sometimes, when such stations are some distance from the transportation office from which the delivery is to be made, engineers test the vacuum and filament circuit right on the premises.

There is also a considerable shipping of smaller-powered transmitting tubes used by the radio amateurs. In many cases, these are second-hand tubes, in the transportation of which the damage hazard is greater for that reason. In a used tube, the filament is liable to be far more brittle and if breakage occurs, that may be the main contributing factor.

¶ From General Radio Experimenter
September, 1937

STANDARD FREQUENCIES FOR THE MUSICIAN



ON June 1, 1937, the national Bureau of Standards began a new and unique standard frequency service. Intended for musicians, the new transmission consists of a 5-megacycle carrier modulated at 440 cycles per second, the American standard of musical pitch for A above middle C.

Experimental transmissions were given in August and September, 1936, and the interest displayed by musicians, musical organizations, and manufacturers of musical instruments was sufficient to justify their continuance as a regular standard frequency broadcast.

Both the 440-cycle modulating frequency and the 1000-cycle frequency used on other transmissions are derived from a standard frequency oscillator by means of multivibrators. The accompanying block diagram shows how these modulating frequencies are obtained from the 200 kc. standard.

A frequency of one kilocycle is produced by dividing 200 kc. in three steps of 4, 5, and 10, respectively. The output of the 1-kc. multivibrator is filtered to obtain a pure 1000-cycle voltage which is then used to modulate one of the standard carrier frequencies. To produce a 440-cycle frequency, the 11th harmonic of the 1-kc. multivibrator is selected by means of a filter and used to control an 11-kc. multivibrator. Two successive reductions by factors of 5, using multivibrators of 2200 cycles and 440 cycles, are needed to produce the desired frequency. A filter is used to eliminate harmonics from the 440-cycle voltage.

From the standard frequency of A as 440 cycles, the table below will indicate the other frequencies of the equally-tempered scale and their harmonics. The frequency ratio for a half-tone interval is 1.05946309.

Frequencies of the Equally-tempered Scale. A = 440 C-P-S
Frequency Ratio for Half-tone Interval = 1.05946309

C	16.352	32.703	65.406	130.81	261.626	523.25	1046.50	2093.00	4186.01	8372.02
C#	17.324	34.648	69.296	138.59	277.18	554.37	1108.73	2217.46	4434.92	8869.84
D	18.354	36.708	73.416	146.83	293.66	587.33	1174.66	2349.32	4698.63	9397.27
Eb	19.445	38.891	77.782	155.56	311.13	622.25	1244.51	2489.02	4978.03	9956.06
E	20.602	41.203	82.407	164.81	329.63	659.26	1318.51	2637.02	5274.04	10544.08
F	21.827	43.654	87.307	174.61	349.23	698.46	1396.91	2793.83	5587.65	11175.30
F#	23.125	46.249	92.499	185.00	369.99	739.99	1479.98	2959.95	5919.91	11839.82
G	24.500	48.999	97.999	196.00	392.00	783.99	1567.98	3135.96	6271.92	12543.85
Ab	25.957	51.913	103.83	207.65	415.30	830.61	1661.22	3322.44	6644.87	13289.74
A	27.5	55.	110.	220.	440.	880.	1760	3520.	7040.	14080.
Bb	29.135	58.270	116.54	233.08	466.16	932.33	1864.66	3729.310	7458.62	14917.24
B	30.868	61.735	123.47	246.94	493.88	987.77	1975.53	3951.07	7902.13	15804.26
C	32.703	65.406	130.81	261.626	523.25	1046.50	2093.00	4186.01	8372.02	16744.03

The above table, prepared by F. E. Hunt, of the Physics Laboratories of Harvard University, gives the frequencies of all the semi-tones in the equally tempered physical scale which lie within the auditory area, (up to 17,000 cycles). Older tables have been based on the frequency of A as 435 cycles per second, whereas the physical standard now accepted is 440 cycles per second, as in the above table.

(From Electronics, September, 1937)

•

Spinning Atoms and Spinning Electrons

IN ONE OF HIS delightful articles in the series of Contemporary Advances in Physics, Dr. Karl K. Darrow writes on "Spinning Atoms and Spinning Electrons" in the July issue of the *Bell System Technical Journal*. This thirty-first paper in the series was presented at a lecture before the American Physical Society at Chicago, November 27, 1936, and before the American Institute of Electrical Engineers at New York on May 6, 1937.

Naturally any discussion of atomic physics, aside from the exceptionally rudimentary, can (and usually does) soon get into the realm of complexness. But considering the subject that it treats, this latest lecture by Dr. Darrow is highly entertaining and interesting and will probably appeal to those who do not like their atomic physics "too technical."—*Electronics.*

From QST*
October, 1937

Radio Control of Model Aircraft

BY ROSS A. HULL AND R. B. BOURNE, W1ANA

THE application of ham radio in the operation of controlled model boats, airplanes and autos has received relatively little attention to date. But it must be said that those individuals who have played with radio control of models invariably reveal a tremendous enthusiasm for their game. During the last few years, coinciding with the development of successful gasoline-engine-driven model airplanes, we have seen a steady climb in the interest in the subject.

Since we started on the problem of radio control, we have had more than a hundred flights (with some fifteen severe crackups!) and the whole equipment has been rebuilt and rebuilt until substantially nothing is left of the original. But if anyone thinks that the program was tedious work, they're crazy! We have had our full share of thrills in the amateur radio game, but the business of controlling a dizzy airplane galloping across the sky has set a new all-time high for sheer fun.

A casual glance at the problem would lead anyone to imagine that it is all a perfectly simple business. All one needs is some sort of receiver that produces enough change in the plate current of an output tube to operate a relay of some kind, the relay then being connected to a control device which produces the necessary effect. Closer examination, however, reveals a host of problems which are juicy morsels for any experimentally inclined ham. We have solved a few of them, temporarily at any rate, but it must be said emphatically that the scheme to be outlined is the result of a first try.

A brief study of the subject showed at once that the results were prone to be in inverse proportion to the complexities of the equipment and it became obvious that some extremely simple system was called for.

• *Hitting at Simplicity*

Having had earlier experience with the effectiveness and efficiency of rubber band motors, we decided to use one to supply the power for control. With a motor four or five feet long, we knew that we could "charge" the things with at least

1000 turns and obviously this would serve for several thousand control motions. The only problem then was to provide some means of triggering off this rubber power and connecting it to the control surface. A further preliminary decision was to use a single control surface only and the logical decision was to use rudder. It was obvious that any reasonably stable plane could look after itself longitudinally. The only basic need was to keep the machine flying in any desired horizontal direction. Anyway, after much fiddling, we ended up with the device shown in figure 1—a simple escapement driven by the rubber motor and controlled by an electro-magnet operated in turn from the output tube of the receiver. As can be seen from the sketch, the transmission of a series of dots would result in step-by-step rotation of the escapement and swinging of the rudder from left to right. It was simply a matter of transmitting the desired number of pulses in order to acquire the correct rudder setting. The chief disadvantage of this simple scheme seemed to be that the rudder positions were all in a continuous sequence and that once the rudder had been in the left position and had then been centralized, it was possible to get back to left rudder again only by passing through right and center rudder. In actual practice this weakness proved to be of little consequence just as soon as we had equipped an appropriate ground control system. It then became possible to whip through the undesired but necessary positions in a fraction of a second without causing more than a slight flicker in the flight path. But there were more problems to come.

• *The Receiver*

We had left the receiver itself for the last, feeling that it would certainly be a cinch. Actually, it took about a week of evenings to get a two-tube receiver that would perform with any degree of satisfaction. Even then we had to break down and admit that three tubes were really called for if all the desirable features were to be had. We cannot help feeling that this part of the job is just started. Surely there must be some way of building a simple one-tube receiver capable of operating an inexpensive relay! Fortunately, even the three-tube receiver came well within our weight limit. This sailplane was capable of carrying at least five pounds. Without even trying hard, we ended up with a complete receiver, power supply and control system that weighed slightly less than three pounds. With some refinements, even the present setup could be pulled down to 2½ pounds—a figure within reason even for single-engine models.

Some of the earlier control systems made use of the beat produced by an autodyne receiver to actuate the control tube—the frequency usually being on the 3.5-Mc. band. This procedure we ruled out at once as a result of practical experi-

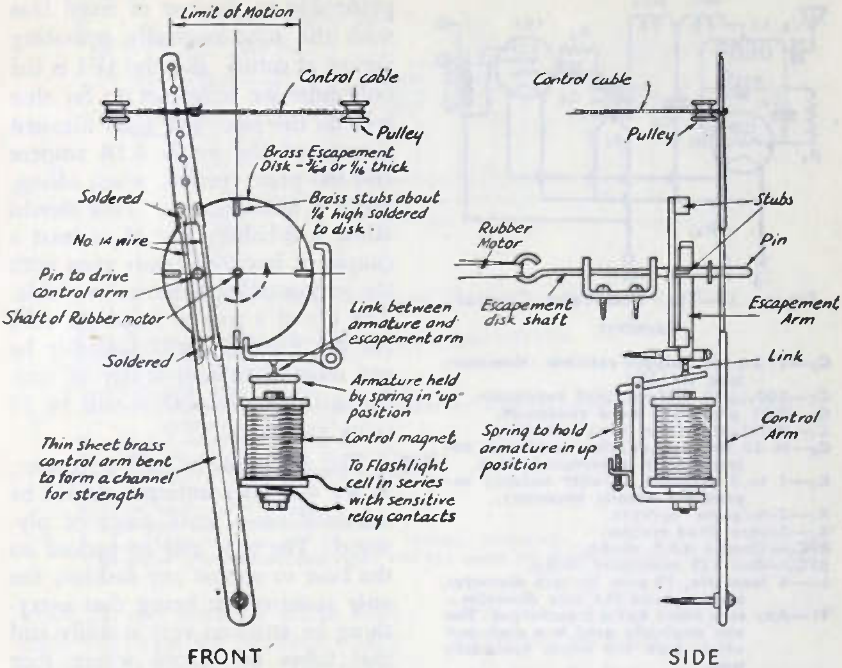


Figure 1—Experimental escapement used to convert the rubber-band motor torque into rudder motions

The escapement disc, turning clockwise in this case, is driven by four strands of one-quarter-inch model airplane rubber. The rotation is limited to steps of a quarter turn by the escapement arm controlled by the electro-magnet connected in series with the sensitive relay in the output of the receiver. The crank pin on the escapement disc carries the control arm from left to center to right, in accordance with its position. No details of the mounting of these components to the bulkhead in the fuselage are given because they will be varied to suit each individual case.

ence in attempting to obtain a sufficiently stable beat.

Since it was futile to control the model without being able to see it, and since we were aiming at the utmost simplicity, we decided to use the 56-Mc. band. There were two alternatives available—to use a continuous carrier with pulses of tone to operate the relay or to permit the characteristic rush noise of a super-regenerative detector to keep the relay open, then applying pulses of carrier to close it. It works out that the former scheme will allow a simpler receiver but that the latter method is infinitely preferable because of the negligible interference which its operation causes.

Figure 2 shows the two-tube receiver with which successful opera-

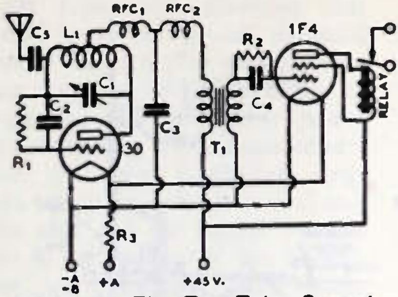


Figure 2—The Two-Tube Control Receiver

C_1—17.5-μμfd. midget variable (Hammarlund HF.-15).
C_2—100-μμfd. midget fixed condenser.
C_3—0.01 μfd. fixed mica condenser.
C_4—0.002-μfd. fixed mica condenser.
C_5—M-30 National padding condenser adjusted to its minimum setting.
R_1—1 to 5 megohm ½-watt resistor; experiment usually necessary.
R_2—2-megohm ½-watt.
R_3—5-ohm fixed resistor.
RFC_1—Ohmite u.h.f. choke.
RFC_2—Bud 125 millihenry choke.
L_1—8 turns No. 14 wire ½ inch diameter, turns spaced the wire diameter.
T_1—Any very small audio transformer. The one originally used is a push-pull affair with the whole secondary used.

The relay is an Eby Type ER12 with a 5000-ohm winding.

tion may be had if pulses of tone are used on a continuous transmitted carrier. The first part of this circuit is a simple super-regenerative detector using a 30 tube and fitted with a simple filter for the quench voltage. The output tube is a 1F4—chosen because of its high mutual conductance. The grid condenser and leak in its grid circuit allow the tone voltage to develop a negative grid bias and so produce a plate current change from about 2 to 0.5 ma. This method of obtaining a plate current change has so far proved infinitely preferable to the use of fixed bias with the tube normally operating almost at cutoff. But the 1F4 is the only tube we have met so far that will do the job. The total filament current of the set is 0.18 ampere and the plate current, when idling, about 3 milliamperes. This should allow a B-battery life of at least a couple of hundred hours even with the very smallest batteries available. The life of a pair of flashlight cells for the filaments will probably be not more than half a day of continuous operation but it will be 20 cents well spent.

The apparatus in such a receiver, as we will later indicate, should be mounted on a small piece of plywood. The gear may be packed on the base in almost any fashion, the only requirement being that everything be attached very sturdily and that tubes be placed where they cannot bump elbows with each other or with the audio transformer. A vernier dial was found unnecessary, providing a 6-inch extension rod (a piece of balsa wood) was used for tuning. No particular difficulty should be had in adjusting the super-regenerative detector though failure to super-regenerate or a desire to howl may have to be cured by a change in the value of the grid leak or in the setting of the tap on L_1. The length of the antenna and the size of the coupling condenser C_5 will also have some effect in these respects.

An antenna not more than two or three feet long should be adequate,

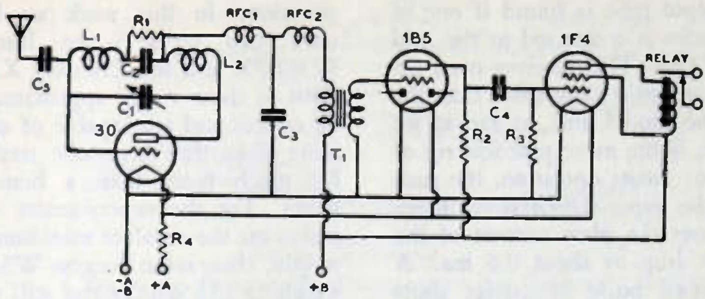


Figure 3—The Circuit of the Preferred Receiver

C_1—17.5-μμfd. midget variable (Hammarlund HF-15).
C_2—100-μμfd. fixed condenser.
C_3—0.01-μfd. fixed mica.
C_4—0.01-μfd. fixed paper.
C_5—M-30 National mica padding condenser, with the upper plate bent at right angles to the lower.
R_1—1 or 2-megohm grid leak.
R_2—150,000-ohm ½-watt fixed resistor.
R_3—2-megohm, ½-watt fixed resistor.
R_4—5-ohm fixed resistor.
RFC_1—Ohmite u.h.f. choke.
RFC_2—Bud 125 millihenry choke.
L_1, L_2—Each 4 turns No. 14 wire, ½-inch diameter.
The audio transformer and relay are the same as those described in Figure 2.

while C_5 can have its plates bent until the capacity between them would seem to be zero. The placement of the antenna appears to be of very little consequence. We used a piece of no. 28 wire taped to the outer covering of the fuselage.

• *The Three-Tube Model*

The business of leaving a carrier running did not appeal to us at all. It was decided to add three or four ounces to the receiver and include the third tube found to be necessary when the pulses were to be carrier only. Figure 3 shows the complete circuit of this receiver. The detector tube is again a 30 in a superregenerative circuit of slightly different type from that shown in the two-tube receiver. The detector circuits are actually inter-changeable in the two receivers.

It just so happens that the arrangement shown in figure 3 gave us rather better freedom from howling than the previous ones when the extra tube was added. It will be noted that the grid leak runs to positive high voltage in both receivers. This connection seems to iron out some of the howling difficulties and results in smoother operation. The 1B5 was chosen because of its high amplification factor and is considerably better than the 30 as the intermediate amplifier.

It will be seen that the diodes are not used though a very slight improvement in the operation of the output tube is found if one of the diodes is connected to the grid of the 1F4. This receiver need occupy very little more space than the two-tube model and, as far as we can see, is the more practical rig of the two. In its operation, the rush from the super-regenerative detector causes the plate current of the 1F4 to drop to about 0.6 ma. A transmitted pulse of carrier shuts off this rush noise, relieves the 1F4 from its negative grid bias and permits the plate current to rise to about 2 milliamperes. This change is ample to close the relay, providing the tension spring is adjusted carefully. Naturally, the relay contacts are connected in opposite fashion in this receiver to those in the two-tube receiver. This model is almost as economical in operation as the simpler set. The plate current of the 1B5 is a small fraction of a milliampere, its filament drain 0.06 ampere. Because use is made of the rush noise from the detector, it is important not to load the receiver with an antenna more than is absolutely essential. With this rig we are in the habit of operating without an antenna at all and still manage to get ample control signal at distances of a mile or so with a 30-watt transmitter. For our purposes this was sufficient.

• ***Batteries***

It is most fortunate that the battery manufacturers have been weight conscious in recent years, the modern midget "B" battery being really the key to the whole situation. In this work we have used two types — the Burgess W30BPX and the Eveready X203. Both of these weigh approximately 10 ounces and are capable of operating even the three-tube receiver for much more than a hundred hours. For the experimenter who insists on the absolute minimum of weight, there is the Burgess W30FL weighing 8½ ounces and still capable of almost a hundred hours of service.

For filament and control magnet batteries, we have used ordinary flashlight batteries exclusively. They have the merit of low cost and reasonably light weight and are, of course, available anywhere. The very small sizes could be used in cases where every gram counts.

• ***The Transmitter Problem***

Because model aircraft or even model boats will usually be operated at points unavailable to power lines, it is very desirable that the transmitter should be operated either from a 6-volt storage battery in an automobile or from dry batteries. So far we have used only an automobile transmitter. It consists of a pair of 45 tubes—with their filaments connected in series—in a simple fixed-tuned-grid tuned-plate circuit similar to that given on page 260 in the current *A.R.R.L. Amateur's Handbook*. A 6A6 or 6N7 tube would also serve the purpose admirably. We used the 45 tube simply because the rig was already available. We supplied plate voltage from a Mallory Vibrapack

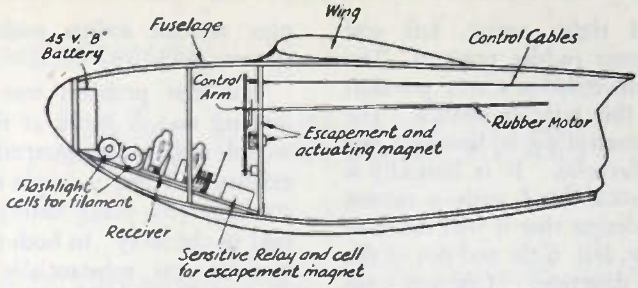


Figure 4—Showing the Placement of the Equipment in the Fuselage of the Experimental Sailplane.

Having no engine to carry the center of gravity of the machine forward, the equipment is all placed ahead of the wing. With the gas-driven model, the gear would be grouped at the center of gravity and actual arrangement would naturally be varied to suit the particular fuselage in which it is installed.

giving 300 volts at 100 milliamperes but a pack of lower power or a set of B batteries would be quite satisfactory. When operating with carrier pulses alone, the transmitter is, of course, a very simple affair. The use of tone pulses will require a modulator, the general nature of which can be decided very rapidly by anyone familiar with 56-Mc. work or anyone willing to glance through the *Handbook*. Personally, we are strong for the elimination of the tone business.

The transmitting antenna may be the usual fishpole affair or a half-wave antenna strung between bamboo poles. It may be fed either with a 72-ohm line to the center of the half-wave antenna or with a tuned line to one end. The problem of rigging this transmitter and adjusting the antenna until it is really doing some radiating will not be a problem at all to any present-day ham.

• *The Control Station*

First experiments were conducted with an ordinary key, the pulses being delivered in the necessary amounts in the usual fashion. This was a failure from the start. It was found almost impossible to remember in what position the rudder was supposed to be and several crack-ups resulting from a misunderstanding between the pilot and the plane caused us to develop some sort of control device.

The first model was a 10-inch wooden control wheel with a vertical handle mounted near its rim. Contacts were attached to its under surface so that as the disc was rotated a complete revolution, four pulses would be transmitted. A simple ratchet was attached underneath so that the disc could be turned in one direction only. Rotating this disc in a clockwise direction, and starting from a position with the handle at the center rear, produced right, center, left and again center rudder position. The device still remains a very practical one for this type of control. The Bourne control rig is, however, our current favorite. It is basically a control stick fitted with a ratchet of such design that it will move to left, right, left, right and not in the reverse direction. Contacts are made as the control arm passes from the center to either side position.

In practice, these control gadgets are connected on the end of a few hundred feet of twisted pair and mounted on a tripod. In this fashion, the pilot is permitted to adjust his location to give the best possible view of the flight.

• ***Bug Elimination***

After getting what appeared to be perfect operation of this equipment in the workshop, we proceeded with the installation in the plane. The receiver was built in a rectangular aluminum frame and lent itself readily to "shock-proof" mounting—a heavy rubber band being used from each corner of the frame to some members in the fuselage. Then began a series of preliminary experiments, hand-launching the machine for a glide of a few hundred yards. Within an hour we had decided that we should have made the equipment ten times simpler. We began to appreciate the difficulties that some of the fellows must have bumped into with complex selector switch multi-control systems.

The first problem was that in landing one or more of the tubes would usually be bumped out of existence. Then, a couple of severe crackups (the plane hitting a tree) told us the story. In both cases the receiver was substantially demolished and, in addition, the batteries were pushed through the front of the fuselage and the control equipment wrecked. It appeared that our fancy shock-proof mounting permitted the receiver to plunge forward as the plane hit, pushing the battery supply out the front then recoiling to wreck the remaining apparatus. Promptly, the shock mounting was dispensed with and the receiver built on a small piece of plywood screwed to the bottom of the fuselage. From that time on the machine has suffered equally severe crashes without a tube being broken and usually without the receiver even being knocked out of tune. But the problem of microphonic tubes then reared its head. The shock of the escapement releasing proved sufficient, with most 30-Type tubes, to generate an additional pulse of plate current, thus messing up the whole works. This difficulty has been cured simply by selecting tubes which have the least microphonic effect. Doubtless, some almost rigid shock mounting for the detector tubes would provide a complete solution. But we are still a little afraid of shock mounting.

¶ From Brush Strokes, August, 1937

Concerning Cables for Crystal Mikes

BY C. K. GRAVLEY

BEFORE the announcement of the first commercial crystal microphone in 1931, the radio or electronic engineer had little reason to concern himself with the transmission of electrical energy from relatively high impedance sources, aside from two possible exceptions: the condenser microphone and the photo cell.

There has been and continues to be a certain degree of mysticism connected with the name crystal. Actually, a piezo crystal is about the simplest form of device for converting electrical to mechanical energy or the reverse. For all practical purposes a crystal when used in a microphone, phonograph pickup, vibration pickup or a similar device, can be considered as a capacitance generator having negligible internal resistance, but high internal capacitive impedance. Since the device is a capacitance and has effectively no series resistance, a capacitance connected in parallel with it will only reduce the voltage output and no frequency distortion will occur since this reduction will be the same for all frequencies.

The expression for computing the voltage loss in db caused by a capacitance load across a crystal generator device is as follows: db loss $= 20 \log (1 + C_1/C_2)$ when C_1 represents the capacitance in µfd. of the load and C_2 the capacitance in µfd. of the crystal device. Since the impedance of a shielded cable is effectively capacitive reactance, a cable can be considered as a capacitive load on the crystal device. Thus, it is a simple matter to compute the loss that can be expected from a length of cable of known capacitance.

• *Input Resistance*

The input impedance of an amplifier is essentially resistive when connections are made directly to the grid, which is the usual case if crystal generators are being used; since the internal impedance of crystal generators is capacitive, the problem can be considered similar to that of choosing a grid resistor for a condenser-resistance coupled amplifier. Neglecting tube capacitances in the latter case, the low frequency cutoff of the stage is determined by the relationship between the coupling condenser and the grid resistor. The higher the value of the grid resistor, the lower the frequency which the amplifier stage will pass for a given coupling condenser.

The same is true of a crystal device—the crystal capacitance represents the coupling condenser. The tube measures the voltage drop in the grid resistor and this is vectorially at right angles to the reactance drop in the crystal generator. The total impedance of the crystal generator circuit is, therefore, the vectorial sum of the reactance of the crystal and the grid resistance, i.e., the square root of the sum of the squares of these values. The useful voltage is, therefore, proportional to the resistance R divided by the impedance, and the loss in decibels for a resistance R is given by the expression:

$$\text{db loss} = 20 \log \frac{\sqrt{R^2 + X^2}}{R}$$

When R = the grid resistance in ohms

X = crystal reactance $= \frac{159{,}000}{fC}$

C = capacitance of crystal in μfd.

f = frequency in cycles per second

For example, let us assume we have a grid resistor with a resistance of 500,000 ohms and a crystal device with a capacitance of 0.005 μfd., and we wish to determine the voltage loss at 60 cycles per second.

Then $X_c = \frac{159{,}000}{60 \times 0.005} = 530{,}000$ ohms approximately

and $20 \log \frac{\sqrt{500{,}000^2 + 530{,}000^2}}{500{,}000}$

$= 20 \log 1.4572$

$= 3.26$ db loss at 60 cycles per second.

It should be pointed out here that for a combined parallel capacitive and resistive load, the capacitance to be considered when determining the size of resistor to use is the sum of the crystal capacitance and cable or load capacitance.

•

At last a solution to the problem of how gently but forcibly to stop a speaker when his allotted time has elapsed—General Electric Company has announced a device expressly designed for this purpose.

When the speaker comes to the stand, the dial is adjusted to the time alloted for his speech. Two minutes before the address is supposed to be finished a small signal lamp is automatically lighted. When the remainder of the period has elapsed, the word "FINIS" is flashed and a low-toned chime notifies him that his speaking time is ended.

It would be a good idea to include a fire alarm bell, to go off after another two minutes, as optional equipment. It is feared that some banquet speakers would fail to be intimidated by a mere "FINIS" sign and a gentle-toned chime. Maybe a baseball bat, mounted above the head with a relay to trip it off at the alotted time, would be a more effective measure.

¶ From I. R. E. Proceedings
May, 1937

Voltage Stabilized
H. F. Crystal Oscillator Circuit

BY SAMUEL SABAROFF

(WCAU Broadcasting Co., Philadelphia, Pa.)

DURING the development of a high-frequency standard assembly it became evident that the usual crystal oscillator circuits were not satisfactory with frequencies in the vicinity of five megacycles or above. The frequency stability with respect to filament and plate voltage variation was relatively poor and since the usual circuit requires an impedance tuned to the vicinity of the crystal frequency, the output and frequency are quite critical with respect to the tuning of this impedance.

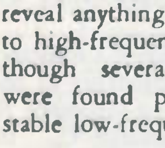


Figure 1 — Generalized diagram of circuit considered.

A search of the literature did not reveal anything definitely applicable to high-frequency crystal oscillators though several excellent articles were found pertaining to highly stable low-frequency oscillators and to crystal oscillators in general.

In one of these articles[1] a circuit was described that seemed to have some possibilities and it was decided to investigate this circuit further from the point of view of high-frequency operation. The circuit as drawn in figure 1 is essentially that described in the article. The mathematical approach will, however, be somewhat different. The crystal is connected from grid to plate, Z_1 and Z_2 are generalized impedances, and r_G and r_p are the effective grid-to-cathode and plate-to-cathode resistances, respectively. The grid-to-cathode and plate-to-cathode capacitances are incorporated in Z_1 and Z_2 and the grid-to-plate capacitance can be considered to be a property of the crystal.

Let us derive the expression for the effective impedance facing the crystal. In deriving this expression, it will be assumed that the ordinary amplifier theory is valid. Some qualitative corrections will be indicated later. The equivalent circuit is shown in figure 2. Z_G is the combined impedance of Z_1 and r_G

[1] *Isaac Koga, "Characteristics of Piezo-Electric Quartz Oscillators," Proc. I.R.E., vol. 18, p. 1936, par. 8; November, 1930.*

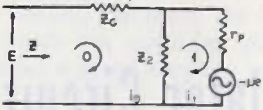


Figure 2—Equivalent net-work of impedance seen from crystal.

in parallel, e is the grid-to-cathode voltage, μe is the equivalent plate generator voltage, E is the voltage across the crystal, and i_0 and i_1 are the crystal and internal plate currents, respectively.

Ordinary circuit analysis shows that

$$\frac{E}{i_0} = Z = Z_G + \frac{Z_2 r_p}{Z_2 + r_p} + \mu \frac{Z_2 Z_G}{Z_2 + r_p} \quad (1)$$

If we let

$$Z_p = \frac{Z_2\, r_p}{Z_2 + r_p} \quad (2)$$

and

$$\frac{\mu}{r_p} = g. \quad (3)$$

where g is the mutual conductance, we have finally

$$Z = Z_G + Z_p + g\, Z_G\, Z_p \quad (4)$$

Equation (4) is the general expression for the impedance looking into the grid and plate of a vacuum tube. It is interesting to note that by a proper choice of Z_G and Z_p this impedance can be varied over a range of complex values by merely varying the mutual conductance of the tube.

If we let Z_c equal the effective electrical impedance of the crystal, then the sum of Z_c and Z must equal zero when the steady state of oscillation is reached.[2] For oscillations to start, the real part of Z must be negative and have a numerical value equal to or greater than the real part of Z_c which is, of course, positive.

If the sum of the real parts is negative, then the amplitude of oscillation will vary until the effecttive tube parameters, i.e., r_G, r_p, and g have changed sufficiently to make this sum equal zero. The variation in harmonic content[3] with oscillation amplitude will qualify the above statement to some extent but this effect will be neglected in this paper. These parameters will also change as the applied voltages are varied and as the tube ages. Our problem is to choose circuit constants or devise correction methods that will nullify or minimize the effect of these changing parameters on the stability of the oscillator.

It was felt that inductances as circuit constants should be avoided so as to minimize any possible resonance effects. It was decided then to investigate when Z_p and Z_G are composed only of resistances and capacitances.

Let Z_G be made up of a resistance R_1 shunted by a capacitance C_1 and Z_p be made up of a resistance R_2 shunted by a capacitance C_2. Incorporated in C_1 and C_2 are the

[2] *F. B. Llewellyn, "Constant Frequency Oscillators," Proc. I.R.E., vol. 19, Appendix, pp. 2092-2094; December, 1931.*

[3] *Janusz Groszkowski, "Constant Frequency Oscillators," Proc. I.R.E., vol. 21, p. 958-981; July 1933.*

grid-to-cathode and plate-to-cathode capacitances, respectively, and incorporated in R_1 and R_2 are the grid-to-cathode and plate-to-cathode resistances, respectively.

Substituting these values in (4), we find that

$$Z = K_1 + K_2 + gK_1 K_2 \ (1 - \omega^2 C_1 C_2 R_1 R_2) - j\omega[K_1 R_1 C_1 + K_2 R_2 C_2 + gK_1 K_2 (R_1 C_1 + R_2 C_2)] \quad (5)$$

where

$$K_1 = \frac{R_1}{1 + \omega^2 C_1^2 R_1^2}$$

$$K_2 = \frac{R_2}{1 + \omega^2 C_2^2 R_2^2}$$

It is also evident from (5) that it is possible, by correctly choosing the tube and circuit constants, to make the real part of Z negative. We see also that the imaginary part of (5) is a function of all the tube parameters, so that as the real part of this equation is adjusting itself, in the oscillatory state, to any varying applied voltages and tube aging, these varying parameters will also change the value of the imaginary part. If we equate the sum of the imaginary parts of Z_c and Z to zero and solve for the frequency, we would find that the frequency is a function of the circuit constants and the tube parameters.

The real parts of Z_c and Z are also functions of the frequency in order that as the tube parameters vary, the real and imaginary parts vary in a quite complicated manner together until the steady state is reached. It is possible to set up the general expressions[1] for both the real and imaginary parts using the equivalent impedance of the crystal, which we have called Z_c, but the resulting expressions become very complicated when an attempt is made to solve for the frequency and so determine the exact effect of the changing tube parameters on frequency. For the purpose of this paper, it will be assumed that the real part of Z is independent of any changes in frequency and that the frequency is influenced only by changes in the imaginary part of Z.

Our problem now therefore resolves itself into determining in what manner the imaginary part of Z can be made as nearly independent of the tube parameters as possible. The lines of attack that suggested themselves were (1) to make the imaginary part of Z zero. (2) to make the imaginary part of Z constant, (3) to devise a simple means of compensation.

Let us consider the above in order of presentation. The only manner in which the imaginary part of Z can be made zero is to make either the circuit resistors or capacitors zero or a capacitance and a resistor zero. This can be ruled out immediately as it is easily seen that the negative portion of the real part of (5) is also made zero and oscillations will therefore not be maintained.

The imaginary part of Z cannot

be made absolutely constant since the tube parameters appear directly, but it appeared that it might be possible to choose the circuit constants that any effect of changing tube parameters would be small. Let us investigate several extreme cases. Suppose that the circuit resistances and the internal tube resistance were very high. The value of Z would approach

$$Z \cong -\frac{g}{\omega^2 C_1 C_2} - \frac{j}{\omega}\left(\frac{1}{C_1} + \frac{1}{C_2}\right) \quad (6)$$

Equation (6) is indeed free from any of the tube parameters but it is easy to see that it is a practical impossibility to realize its advantages. It is possible to make R_1 high by keeping the grid current small and using a high circuit resistance, but R_2 has incorporated in it the shunting effect of r_p which

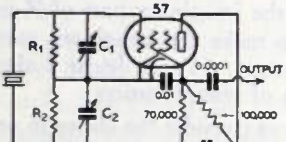


Figure 3—Circuit of oscillator tested.

is not very high when the tube is oscillating.

Another extreme case is when the circuit shunt resistors are very small. The effect of varying r_G and r_p will then be small. The value of Z for very small circuit resistors approaches

$$Z \cong R_1 + R_2 + gR_1 R_2 - j\omega[R_1^2 C_1 + R_2^2 C_2 + gR_1 R_2 (R_1 C_1 + R_2 C_2)] \quad (7)$$

In this case it is evident that the negative portion of the real part of (5) becomes zero and it will be impossible to maintain oscillation. This case can therefore be ruled out at an approach to the solution of the problem.

Still another extreme case utilizes a portion of the two cases just discussed. Suppose that R_1 be very large and that R_2 be small, and that R_2 be so small that the effect of r_p would be negligible. The expression for Z approaches

$$Z \cong R_2 - gR_2^2 \frac{C_2}{C_1} - \frac{j}{\omega C_1}(1 + gR_2) \quad (8)$$

It is seen in (8) that the negative portion of the real part is dependent on the square of a small quantity multiplied by the product of the mutual conductance and a ratio of C_2 to C_1. It is necessary then to use a tube of high mutual conductance and a fairly high plate resistance, and that the quantity of C_2/C_1 should be as large as possible.

We have already seen that the real part of Z is practically constant in an oscillatory circuit. This would mean that in the steady state the value of g would always be the same, and since g is the only tube parameter appearing in the imaginary part of (8), then this imaginary part will always remain constant and thus the frequency stability would be optimum.

It was decided as a result of these investigations that it would be advantageous to set up an experimen-

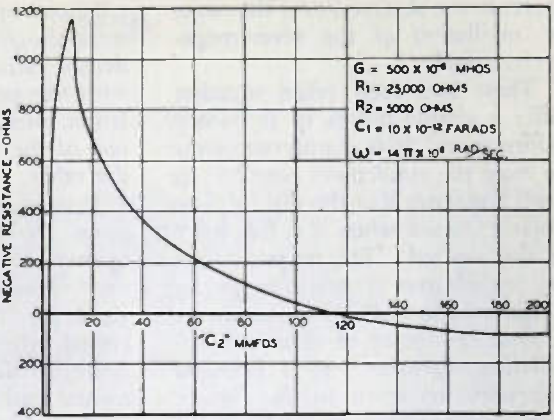


Figure 4 — Variation of negative resistance with cathode - plate capacitance.

tal arrangement which would adhere as closely as possible to the conditions of (8).

The type 57 tube was selected as fulfilling to a large measure the requirements of a large mutual conductance and a fairly high plate resistance.

Several crystals ranging from 3.6 to 7.0 megacycles were available and were used in the experimental work. The circuit arrangement is shown in figure 3. r_1 and r_2 are the circuit resistances and C_1 and C_2 are the circuit capacitances. It was finally determined that stable oscillations could be secured, over this frequency range, with r_2 equal to 2000 ohms and r_1 equal to six megohms. The maximum values of C_1 and C_2 were 50 μμfds.

It was noticed that for every value of C_1 there was a definite value of C_2 that would give the maximum intensity of oscillation, as indicated by the degree of dip in the plate current. A sample set of values were inserted in the real part of (5) and the result plotted against C_2 as shown in figure 4. It is evident that the negative resistance varies with C_2 and does pass through a maximum. The capacitance range which makes the real part of (5) negative was found by experiment to contain the capacitance range over which the circuit oscillates. The point of maximum intensity of oscillation corresponds approximately to the value of capacitance that gives the maximum negative resistance in (5).

It was found that with one of the condensors fixed, the position of the dip in plate currents as found by varying the other condensor did not vary more than one in 500,000 as the plate and filament voltages were varied 10 per cent either separately or together. There is quite a variation of frequency as the condensors are varied, as much as 100 cycles being observed over the range of oscillation of the seven-megacycle crystal.

These two facts taken together offer a simple means of frequency adjustment. It is simply necessary to vary the condensors together in such a manner that the dip in plate current occurs when the frequency is that desired. The frequency can be varied over a small range by varying one of the condensors around this point of maximum oscillation intensity. If it becomes necessary to return to the former setting, to within an accuracy of about one in 500,000, it is merely necessary to return the condensor which was moved to the point of maximum dip in plate current. This cannot be carried on over a large frequency range since there is an optimum ratio of C_1 to C_2 which gives the greatest intensity of oscillation. As the ratio is moved from this point, the intensity of oscillation will decrease and finally cease altogether. This optimum condensor ratio must not be confused with the point of maximum oscillation intensity as found by fixing one of the condensors and varying the other.

It must be brought out here that some crystals made for high-frequency operation are so ground that they operate on some other mode than the fundamental. Such a crystal, when used in the circuit described, will oscillate on the fundamental and not on the higher frequency for which operation they were sold.

The frequency stability was very good. It was found that, using the seven-megacycle crystal with a standard B supply of 200 volts and a filament supply of 2.5 volts, a 10 per cent variation in either or both voltages did not vary the frequency more than about one in twenty million.

The broadcast industry has invested a total of $40,000,000. Also, a recent census shows that 24,500,000 homes in the United States are equipped with sets and 4,500,000 receivers are installed in cars.

TELEVISION TRANSMITTERS

●

These photographs are the figures referred to in the article "Television Transmitters Operating at High Power and Ultra-High Frequencies" on pages 83-90 of this issue.

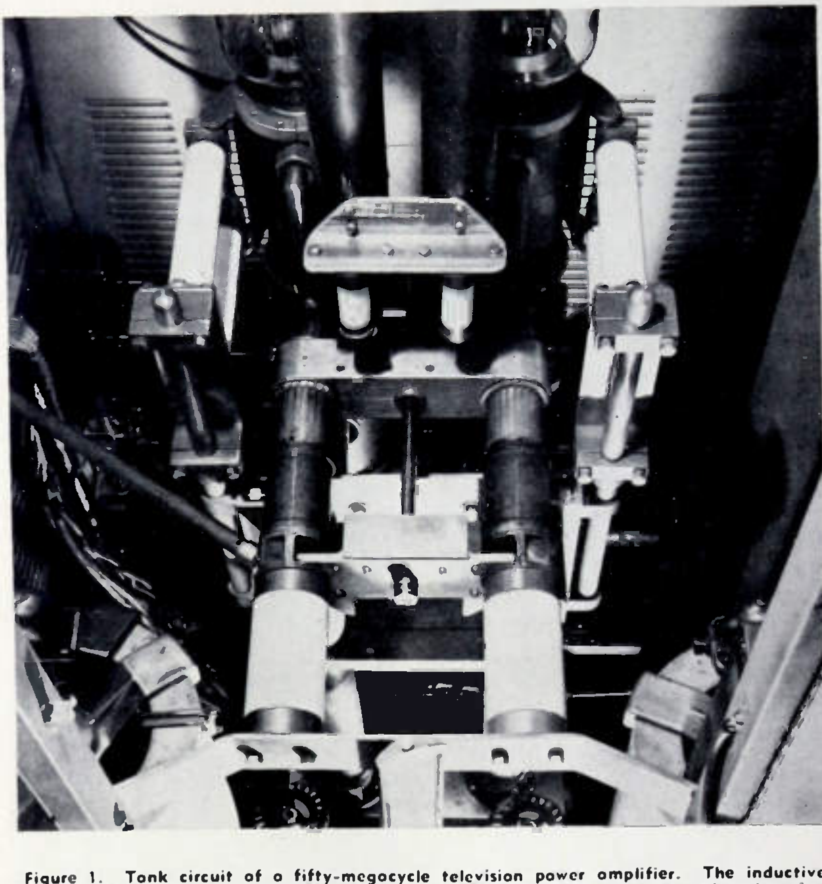


Figure 1. Tank circuit of a fifty-megacycle television power amplifier. The inductive section is very short and tuned by an adjustable shorting bar. The two tubes dropping from the top carry the antenna coupling leads.

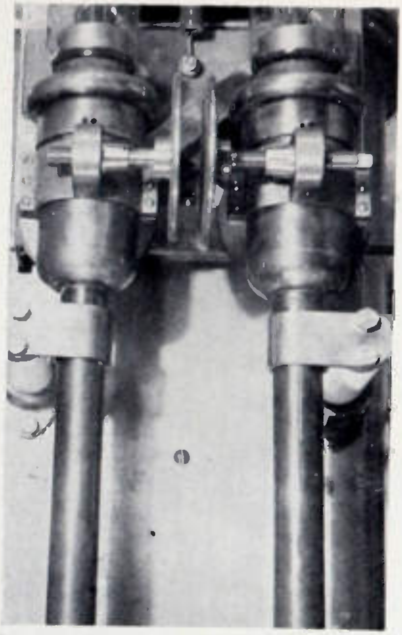
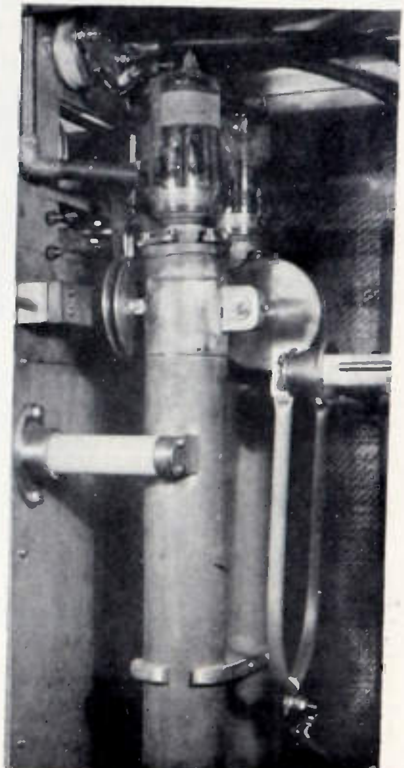


Figure 2. A 50-megacycle amplifier. Tank circuit is of the parallel-line type using a small disc condenser for fine tuning adjustment. Compare the size of the tank conductors with those of the 90-megacycle unit shown in figure 3.

Figure 3. A five-kilowatt power amplifier adjusted for operation at 90 megacycles. Note length of tank circuit as a result of using large diameter conductors.



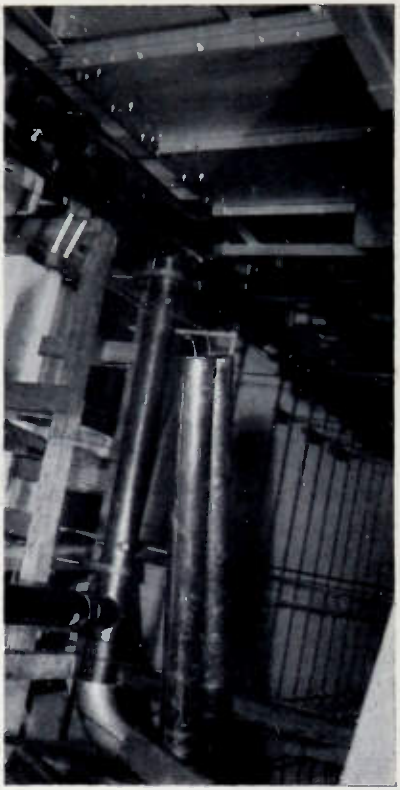
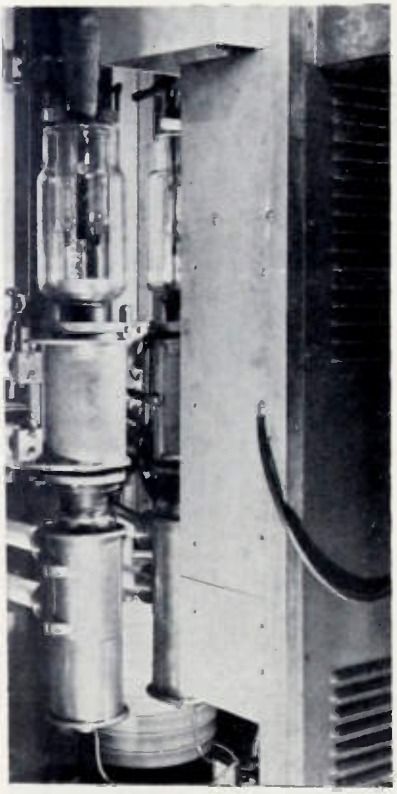


Figure 5. Quarter and half-wavelength line sections used to form high-"Q" filter elements to prevent cross coupling between the "sound" and "picture" transmitters. These two transmitters are separated only a few percent in frequency and are operated into a common antenna.

Figure 4. The neutralizing sleeves enclosing the grid ends of the type 899 tubes can be seen in this photograph. The tubes are operating in a 50-megacycle neutralized power amplifier. Note the air blowers above and below the tube for cooling the glass parts.



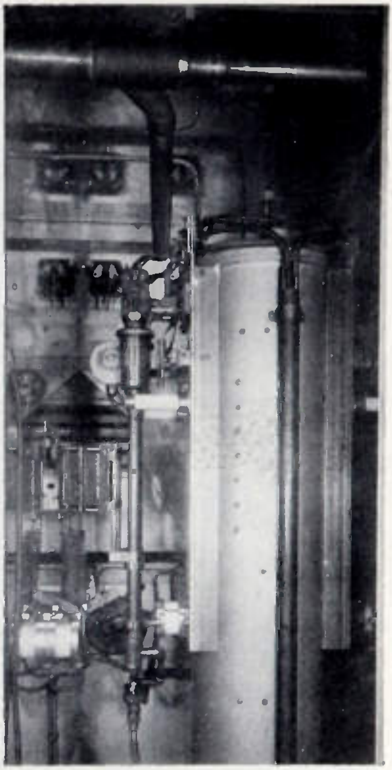
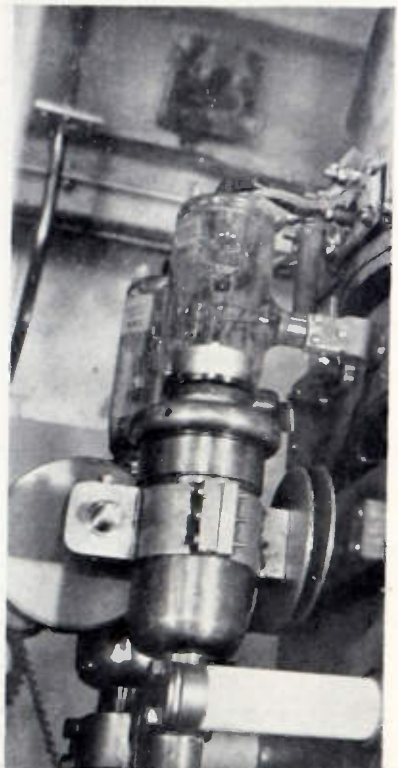


Figure 6. A 50-megacycle "power" master oscillator. The frequency is stabilized by means of the quarter-wave coaxial line.

Figure 7. A close-up of the oscillator shown in figure 6. The mechanical arrangement is simple and rugged and provides short and direct electrical connections.



From Service, September, 1937

Tapped Transformer Impedances

BY MAURICE APSTEIN

WITH THE ADVENT of so-called universal output and input transformers, and the general acceptance of the fact that published impedance relationships of several windings of a transformer are more or less flexible, considerable practical material has been published outlining methods for impedance matching, calculation of impedance ratios from experimental voltage readings, and in general, the use of transformers at impedances somewhat different from the manufacturers' ratings.

There seems to have been, however, a complete disregard for one of the most common practical problems with regard to impedance matching which confronts the service man or public address installer. It is quite often necessary in the field to determine the impedance of some unknown winding on an output transformer without the necessity of measuring the transformer itself. For instance, a p.a. installation man, in adding several additional speakers to an existing system, finds himself with an output transformer tapped at 4, 8, 16 and 500 ohms, none of which values match his speaker network after the additional speakers are added. It would be very handy in such a case to be able to determine what the impedance would be between the 4-ohm tap and the 8-ohm tap, the 8-ohm tap and the 16-ohm tap, the 16-ohm tap and the 500-ohm tap or any other combination of taps available on the transformer.

The usual method for finding these values would be to apply a known a.c. to one of the known windings or sections, and measure the voltage across the unknown winding. The unknown impedance is then calculated from the relation,

$$\frac{Z_2}{Z_1} = \left(\frac{V_2}{V_1}\right)^2$$

where Z_2 is the known primary impedance; Z_1 is the unknown impedance; V_2 is the known applied voltage and V_1 is the voltage measured across the unknown winding.

The above formula uses the assumption that the voltage ratio will be proportional to the turns ratio and that the impedance of a winding varies as the square of the turns; both assumptions are legitimate under the conditions of test for the accuracy desired. Unfortunately, however, the above measurements are made with 60-cycle a.c. as the signal source. Unless the transformer under test has very good response at 60 cycles the relationship may introduce serious error. Several small output transformers of the type used to match 6- and 8-inch speakers have been measured using the above method, and reasonable results have been obtained only when the signal frequency was in the neighborhood of 500 to 1000 cycles. At 60 cycles the poor response introduced such serious errors that the measurements were worthless. Another disadvantage of the above method is that it is often awkward to make the measurements required for the calculation, and sometimes impossible because operation of the system would have to be interrupted for a considerable length of time.

• *General Formula*

At any rate, a general formula which would allow the calculation of the impedance of the unknown section of a winding in terms of the impedances of the known sections would be extremely helpful, and would eliminate the necessity for operating on the amplifier in any way. It would be especially helpful if the formula did not require the primary impedance at all since in many cases this information is not available. It was with these considerations in mind that the relatively simple algebraic expression was evolved for the impedance of an unknown section of a tapped winding when the impedance of two other sections is known. It is believed to be the first time that the information has been presented in this form.

Considering a typical transformer as indicated in figure 1, with unknown primary impedance and an overall secondary impedance of Z_t, tapped at Z_a. It is desired to find the impedance between taps a and b, or the impedance Z_x in terms of Z_t and Z_a.

It can easily be shown that this impedance is equal to

$$Z_x = Z_a \left(\sqrt{\frac{Z_t}{Z_a}} - 1 \right)^2$$

As a practical example the original problem may be offered for solution.

Given a 500-ohm winding tapped at 4, 8 and 16 ohms, what is the impedance between the 4- and the 8-ohm taps, between the 8- and the 16-ohm taps and between the 16- and the 500-ohm taps?

To find the impedance between the 4-and 8-ohm taps the whole winding is taken as 8 ohms and the known fraction as 4 ohms. In other words the remaining section of the winding is disregarded for the time being.

Substituting in the formula:

$$Z_x = 4\,(\sqrt{8/4} - 1)^2 = 0.686$$

Similarly, for the impedance between the 8- and 16 -ohm taps:

$$Z_x = 8\left(\sqrt{16/8} - 1\right)^2 = 1.37$$

And for the impedance between the 16- and 500-ohm taps:

$$Z_x = 16\left(\sqrt{500/16} - 1\right)^2 = 339.$$

Thus without even seeing the transformer we can tell that the impedance between the 4- and 8-ohm taps is approximately 0.7 ohms, or that the impedance between the 8- and 16-ohm taps is approximately 1.4 ohms. The impedance of any other combination of taps can be computed in exactly the same manner.

To save the service man from the necessity of making troublesome calculations the accompanying chart has been computed for various tap combinations found on commercial input and output transformers.

Some caution is necessary in using these values, however, since they apply only to *tapped* windings on the same core. Some of the impedance combinations on universal output and input transformers are obtained by connecting two or more windings in parallel. These exceptions are usually easy to identify since the parallel connections are made externally.

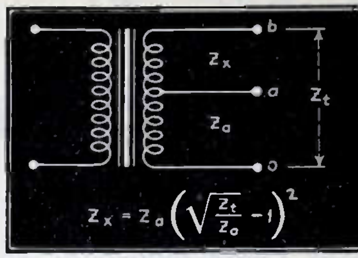


Figure 1. Illustrating the impedance of an unknown section of a tapped winding in terms of the whole and of the other section.

	2	3	4	5	6	7	8	9	10	25	50	100	125	250	500
2	0	0.097	0.33	0.67	1.07	1.52	2.0	2.52	3.08	12.9	32	73	95	208	436
3	0.097	0	0.064	0.25	0.50	0.84	1.2	1.6	2.0	10.6	29	68	88	198	426
4	0.33	0.064	0	0.058	0.19	0.41	0.66	1.0	1.34	9.0	25	64	85	191	417
5	0.67	0.25	0.058	0	0.05	0.18	0.34	0.58	0.84	7.7	23	61	80	184	405
6	1.07	0.50	0.19	0.05	0	0.049	0.12	0.29	0.51	6.6	22	57	77	181	399
7	1.52	0.84	0.41	0.18	0.049	0	0.034	0.14	0.28	5.5	20	54	72	175	385
8	2.0	1.2	0.66	0.34	0.12	0.034	0	0.029	0.11	4.6	18	51	70	168	381
9	2.52	1.6	1.0	0.58	0.29	C.14	0.029	0	0.023	3.9	16	48	68	164	375
10	3.08	2.0	1.34	0.84	0.51	0.28	0.11	0.023	0	3.4	15	47	63	160	368
25	12.9	10.6	9.0	7.7	6.6	5.5	4.6	3.9	3.4	0	4.2	25	39	116	301
50	32	29	25	23	22	20	18	16	15	4.2	0	8.4	17	77	233
100	73	68	64	61	57	54	51	48	47	25	8.4	0	1.4	33	154
125	95	88	85	80	77	72	70	68	63	39	17	1.4	0	21	125
250	208	198	191	184	181	175	168	164	160	116	77	33	21	0	42
500	436	426	417	405	399	385	381	375	368	301	233	154	125	42	0

Calculated from Formula $Z_x = Z_a\left(\sqrt{\frac{Z_t}{Z_a}} - 1\right)^2$

Figure 2. Approximate impedance between taps of commercial transformers. For example: the impedance between an 8-ohm tap and a 125-ohm tap, as read from the chart, would be 70 ohms.

¶ From Bell Laboratories
Record, Oct., 1937

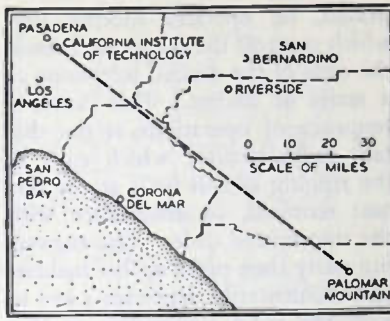
An Ultra Short Wave Circuit for Mt. Palomar Observatory

THERE is under construction on the top of Palomar Mountain, in Southern California, a new astronomical observatory in which the world's largest telescope is to be installed. The establishment of the observatory represents a major construction project, for which a telephone "order wire" is required between the mountain top and the headquarters in the California Institute of Technology, situated about ninety miles away.

Members of the staff of the California Institute proposed establishing the desired telephone connection by means of an ultra-short wave radio link. As this seemed to be a favorable opportunity to try out ultra-short waves for telephone purposes over an unusual and difficult transmission path, the engineers of the Laboratories became interested in it, and the project was undertaken on a coöperative basis.

The transmission path is characterized by its considerable length, ninety miles, and the fact that the peaks of an intervening range of mountains protrude into it. The situation is illustrated by the profile chart, figure 2, where the solid line indicates the shortest path and the dashed one represents the mean path which the ultra-short waves would be expected to take under average conditions, were no barriers present. The curvature is due to atmospheric refraction which is caused primarily by water vapor in the air. It is difficult to predict results on a theoretical basis, but preliminary studies indicated that the obstruction of the mountains might insert a transmission loss of about eighteen db. The indications were that five-watt transmitters might serve if the local noise conditions were not too severe and if antennas of reasonable gain were employed.

The circuit has now been established and is used thirty or forty times on each work day. The transmission to Palomar Mountain proves to be fairly satisfactory with the five-watt transmitter and the directive antenna which were erected; but with similar equipment the transmission in the reverse direction, to the Institute, has been subject to considerable interference. This arises largely from the ignition systems of automobiles in nearby streets. For purposes of



BY AUSTIN BAILEY

convenience and for economy, the Institute desired to locate the receiving antenna on a building in Pasadena rather than in the outlying country, where greater freedom from such interference could be obtained. To over-ride this noise and to fortify the circuit in general, the California Institute engineers have recently constructed forty-watt amplifiers which have been added to the five-watt transmitters at both terminals.

The equipment provided by the Laboratories consists of modified Western Electric apparatus of the type which was developed principally for mobile use and for operation in the frequency band of thirty to forty-two megacycles. One of the requirements of the project was that the transmitters and receivers be so stable in operation that contact could be maintained between the two terminals without continual attendance. The transmitters have quartz-crystal oscillators which maintain the frequency well within 0.025 per cent of the nominal value for a temperature range of zero to sixty degrees Centigrade. Each crystal is also provided with a thermostatically controlled heater which becomes operative for temperatures below zero. The receivers are a.c. operated superheterodynes with beating oscillators which are crystal-controlled. A third d.c. operated receiver was provided for mobile testing.

Arrangements were provided to connect several telephone stations to the radio circuit, and code ringing features were included to enable a person at any telephone to ring any of the other telephones, local or distant. Other arrangements permitted connection of extra telephones to the local circuit without access to the radio circuit.

Certain telephones were provided with special features which permit them to control the radio circuit. In placing a call over the radio circuit, the calling party, if he finds the circuit idle, holds his handset and operates a key to energize the radio transmitter. After pausing for a few seconds until the filaments are heated, he operates another key, which controls the carrier and sends the code of the desired telephone as a series of dashes. This causes a sequence of operations at the distant radio receiver which ends in the ringing of call bells at the distant terminal, in accordance with the transmitted code. The answering party then picks up his handset and momentarily depresses a key to start the radio transmitter so that conversation may begin. Power is automatically disconnected from the radio transmitters as soon as the respective parties replace their handsets, and a single ring on the magnetos by each party then indicates that the circuit is idle.

An important part of the project was an investigation of the advantages of directional antennas for increasing the effectiveness of transmission. Both horizontally and vertically polarized signals from Palomar Mountain were investigated by means of a simple half-wave antenna and reflector at Pasadena. For vertical polarization the antenna was supported about thirty feet above the roof of the penthouse on the laboratory at Pasadena and for horizontal polarization the height was about twenty-five feet. The results showed that both the signal strength and the automobile noise were lowered with horizontal polarization by about the same amount, so that there was no decided preference between the two orientations.

Experiments were made with the receiver and a simple half-wave vertical antenna on the roof of the Optics Shop on the campus. These tests showed a maximum signal with the center of the antenna sixteen feet above the roof of the penthouse, and a gratifying decrease in noise from all sources. The advantage of this location was probably due to its being somewhat shielded by the building from nearby automobile traffic. To gain this improvement, the radio equipment was removed from the Astrophysical Observatory and installed in a convenient room on the first floor of the Optics Shop. A new permanent antenna has been installed sixteen feet above the penthouse roof. This height was redetermined and checked the optimum value previously found for vertically polarized signals. A concentric conductor transmission line connects this antenna to the radio equipment. The antenna consists of two vertical half-wave driven radiators spaced twenty feet apart at right angles to the line of transmission. A quarter wavelength behind these are two parasitically excited half-wave antennas which form a reflector. A back-end null for this combination is directed toward the High-Voltage Laboratory when the two driven antennas are excited in phase. Final adjustment of this system has not as yet been completed, but considerable improvement over the previous location of the apparatus has already been realized.

Experimental antennas were also

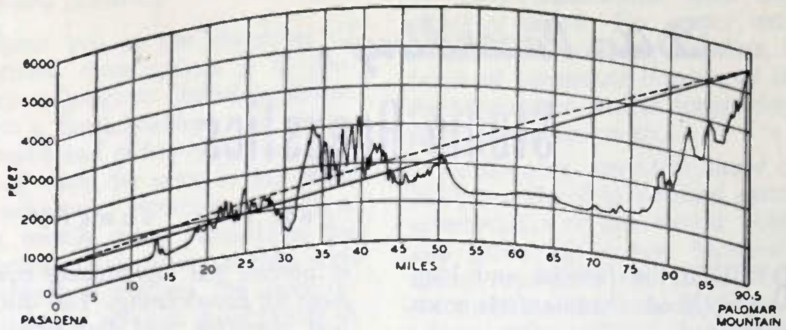


Figure 2. Mountain peaks between Pasadena and Palomar force the radio waves to deviate somewhat from a direct course.

installed at Palomar Mountain. A single-wire line 342 feet long was supported above the ground on thirty-foot poles down the slope in the direction of Pasadena and connected to the radio set through a quarter-wave matching section of line. This was about the proper height above ground to obtain phase reinforcement of the direct waves and waves reflected from the slope, but the length of the antenna was not the optimum required to use the maximum of the cone of receptivity. The topography of the ground prevented obtaining a wire length sufficient to place this cone correctly. The results were inferior to those obtained with a half-wave vertical and a reflector.

An eighty-five-foot water tower with a metal tank provided a location at a still higher elevation. The receiver and equipment were taken to the platform on the tower and a half-wave length vertical antenna mounted about 4½ feet out from the tank, using the tank itself as a reflector. A null was found for a vertical antenna at a point about eight to nine feet from the tank. The local noise level was low and the results were so good that the antenna was located permanently on the tower. A single half-wave vertical in front of the tower is now in regular use.

This project, being a coöperative one, has been participated in by a number of individuals in California and New York, particularly Dr. S. S. Mackeown and Emmet M. Irwin of the California Institute of Technology, who have charge of the system, and by D. K. Martin and F. A. Polkinghorn, of the Laboratories, who were concerned with the apparatus that was required and the experimental program.

¶ Condensed from Communications,
September, 1937

Disc Recording . . .
Studio Acoustics

BY T. L. DOWEY

BESIDES the familiar and long-established home-entertainment field, today there exists another commercial application of disc recording which is rapidly becoming very important. This is the relatively new field of electrical transcription.

During the few years since its introduction in its present form, experience has made it obvious that electrical transcription is an invaluable element of the broadcasting business, chiefly because of the many advantages that accrue from the ability to broadcast programs from records.

When the two fields of disc recording are considered side-by-side, we see that the home entertainment field is, without question, pre-eminent as regards the *quantity* or production. But the other field, that of transcriptions for broadcast use, is greatly in the fore as far as *quality* of production is concerned. This is because, necessarily, the quality of the latter must be kept at a uniformly high standard and because there is always a skilled personnel available to operate the reproducing equipment for broadcasting. This discussion, therefore, will deal with disc recording primarily from the electrical-transcription standpoint.

- *Why Transcriptions?*

One of the most important factors that has led to the present general usage of electrical transcriptions is the fact that better results can practically always be secured by the use of transcription than is possible with direct pickup. This is, of course, providing that the program is one that permits rehearsal. The reason for this situation is that, no matter how many previous rehearsals have taken place, mistakes made on a direct broadcast cannot be recalled or corrected. With a transcription, the program may be repeated, corrected, or altered; parts may be taken out, re-arranged or removed much as a cutter edits a motion picture film.

A secondary consideration, but one worth mentioning, is that it is frequently desirable to have a permanent record of a program. A disc transcription is exactly the type of document required.

• *Studio Acoustics*

Since one of the objectives of electrical transcriptions is to produce a program indistinguishable from a direct broadcast, the studio-acoustic and pickup technique is in many ways the same as for direct broadcasting. However, since there are usually more possibilities for repetition and correction than with a broadcast program, the transcription studio also has many points in common with a scoring studio for motion picture work. In fact, it is more closely related to the latter than to a typical broadcast studio.

While it is sometimes said that it is the purpose of broadcasting to take the artist to the home of the listener, it is also true, under certain other conditions and with other types of programs, that the listener should be transported to the studio or to the imagined scene of action. In other words, with a program of the "fireside talk" type, it is desirable to have studio acoustics of the type that would bring the program into the home. With other types of programs—one whose setting is a busy office, a large hall, a battlefield, or a street corner—it is desirable to have studio acoustics that will transport the listener to the simulated scene of action.

It is well recognized today that the acoustics of a room are a definite part of the sound produced in it. It has been shown that a larger part of the acoustical energy affecting the ear reaches it by reflection from the various room surfaces than by direct transmission from the source of sound. The proper control of reverberation is, therefore, a factor of paramount importance in the acoustics of studios for making electrical transcriptions.

Furthermore, since this sound is to be reproduced in a second room, reverberation at this second point also enters the picture. However, recent experience has shown that the reverberation times of the two rooms are not additive. In practice, it has been found that the most pleasing effect is attainable when the apparent reverberation is that of the source room. Insufficient reverberation in the source room causes the sound, as heard by the listener, to appear cramped and as if it were coming from a small point rather than from an extension of the listening room.

• *Monaural Pickup*

Consideration must also be given to the apparent added liveness of monaural pickup. In the present state of the art, the most practical means of compensating for the added liveness of this type of pickup is the creation of a zone acoustically more dead than the average reverberation period of the total enclosure.

The accomplishment of these above requirements is related to studio design by a determination of the size, shape, reverberation, and distribution of absorbing materials. Ideally, the size of a studio should be determined by the character of program which will customarily be produced.

The feeling that a certain size of room should be associated with a certain type of music may be partly due to our being accustomed to hearing orchestras in halls whose size is dependent to a certain extent upon the number of instruments. On the other hand, this feeling may be more largely due to a certain "space effect" or auditory perspective, similar to the depth of a picture as viewed by the eye. The space effect may be destroyed by lack of sufficient reverberation, by improper frequency characteristic, by the wrong mode of delay, and, in proper surroundings, even by improper pickup.

• *Studio's Shape*

The shape of a studio is important in obtaining best results. Certain ratios of length, width, and height with respect to volume have been found to yield the most desirable results. Figure one, which is reproduced from Messrs. Stanton and Schmid's paper[1], indicates these optimum ratios.

With the size and shape of the studio fixed, the degree and amount of reverberation is the next consideration[2]. Figure two, which is reproduced from the paper by D. P. Loye just cited, shows a relation between optimum reverberation time and volume, based on a large amount of experience by that author. These values were determined under conditions approximating those most desirable, that is, relatively live surfaces surrounding the music with the microphone located in a relatively dead region. All of these values refer to time of reverberation in seconds at 512 cycles.

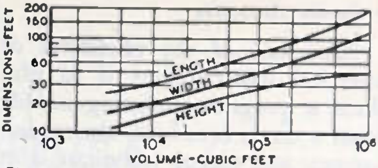


Figure 1—In determining the shape of the studio, the ratios above have been found to yield the best results.

It is of equal, if not greater, importance that the relative amounts of reverberation for the different frequencies be properly balanced. If this reverberation be such that sounds of equal loudness at the different frequencies decay to the threshold in equal times,[3] a condition satisfying a theoretical requirement for ideal balance is reached.

• *Air Resonance Considered*

In small studios, consideration must be given to the phenomenon of air resonance; the frequencies of maximum resonant response are in the register of the base instruments. In determining the absorption characteristic of materials to be employed in a small studio, careful con-

[1] "Acoustics of Broadcasting and Recording Studios" by G. T. Stanton and F. C. Schmid, *Journal of the Acoustical Society of America*, July, 1932.

[2] "Acoustic Considerations in the Construction and Use of Sound Stages" by D. P. Loye, *Journal of the Society of Motion Picture Engineers*, September, 1936.

[3] "Optimum Reverberation Time for Auditoriums" by W. A. MacNair, *Journal of the Acoustical Society of America*, January, 1930. (Part 1.)

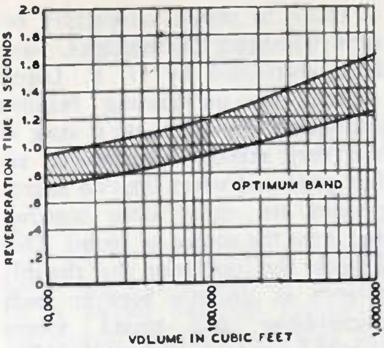


Figure 2—Showing a relation between optimum reverberation time and volume.

sideration should be given to compensating, so far as practicable, for the resonance effect. It is, of course, assumed that the construction of the walls, floors, and ceilings is such as to avoid sharp resonance in these structures.

With the amount of absorption at the various frequencies pre-determinated by the selected reverberation time and characteristic, it is necessary to consider the distribution to be made of the absorption. The shape and size of the studio, plus the necessity for correct liveness for the production of music and the minimum interference at the point of pickup, will determine this distribution. Allowance should be made for the acoustical absorption presented by the musicians or performers in the location which they occupy. The rest of the absorption is customarily located upon walls, ceilings and, to some extent, on the floors. Obviously, the absorbing areas must be of sufficient size to accomodate the requisite amount of absorption to give the desired reverberation period and be distributed about the studio so as to provide an unbalance of liveness between the performance and pick-up ends of the studio.

• *The Absorption Coefficient*

The desired absorption coefficient is best determined after the location of treatment is decided. With the areas to be made absorbent and the total amount of absorption known, the necessary coefficient for each frequency is determined. The departure from the exact areas considered desirable for treatment is determined by the degree of agreement obtainable between the coefficient of a suitable material and the ideal coefficient. The departure of the actual from the desired coefficient will require further re-balance between desired reverberation time and desired areas to be treated.

In recording orchestral music it is desirable, wherever possible, to use one microphone at a time rather than two or more connected through a mixer to the recording channel. By suitable placement of the microphone, a desirable balance can be attained between the various instruments of the orchestra. Those instruments that must be most prominent should, of course, usually be closest to the microphone. This applies also when a soloist and chorus are present as well as an orchestra. When the orchestra is used for accompaniment, the soloist is usually placed nearest the microphone, the chorus next, and the orchestra somewhat farther back.

• *Using a Single Microphone*

Acoustic-perspective control can be achieved to some extent by adjusting the relative distance from the microphone of the soloist, chorus, and orchestra. The use of a single microphone probably represents the most natural arrangement, with the microphone taking the place of the listener.

When sufficient time is not permitted for rehearsals and adjustments, auxiliary control methods may be used which involve the use of more than one microphone. However, although the use of more than one microphone introduces many complications, the necessary conditions which must be fulfilled in order to obtain satisfactory results with two microphones, have been elucidated by D. P. Loye.[4] Among the outstanding features established by Mr. Loye's work is the very marked interference effect produced when the two microphones are rather close together and near the source of sound. This leads to the conclusion that the difference in distance between each microphone and sound source should be at least 10 feet, that they should not be too close to the source, and that the sound volumes picked up by them should be adjusted to differ as widely as practicable.

[4] "Acoustic Considerations in the Construction and Use of Sound Stages" by D. P. Loye, *Journal of the Society of Motion Picture Engineers*, Vol. XXVII, No. 3, 1936.

Clear Frequency for I.F.

The R.M.A. is attempting to establish 455 kc. as the standard intermediate frequency. Since interference on the i.f. channel is an important item, the R.M.A. has attempted to have the F.C.C. set aside the band of frequencies from 450 to 460 kc. as a protected i.f. band.

A letter, setting forth the following policies, was sent to and accepted by the F.C.C.:

"1. That the Commission will endeavor not to authorize any new frequency assignments in the band 450-460 kc.

"2. That no change in existing assignments within this band will be made by the Commission.

"3. That in case a change of policy in regard to numbers 1 and 2 above is necessitated at a later date, the Commission will notify the Radio Manufacturers' Association of any contemplated action."

¶ From RADIO,
October, 1937

The New Ionosphere Broadcasts

BY ELMER H. CONKLIN

THE NATIONAL Bureau of Standards has added another service[1] to its several Standard Frequency Broadcasts. Each Wednesday the Bureau now broadcasts information about high frequency radio transmission conditions, based on its continuous measurements of the ionosphere at Washington, D. C. Transmission is by 'phone from its relay station WWV each Wednesday at 1:30 p.m. E.s.t. on 10 Mc.; at 1:40 on 5 Mc.; and at 1:50 on 20 Mc., using about 20 kilowatts with 30% modulation.

The object of these broadcasts is to make current ionosphere information available on the day of observation. This should aid in choosing optimum frequencies for long-distance communication and in interpreting results. It supplements published information giving long-time trends and averages.

The broadcasts include statements of critical frequencies for normal incidence and virtual heights of the layers of the ionosphere, followed by estimated skip distances for a number of frequencies, all based on observations made at Washington on the day of the broadcast. The data are given for noon and midnight, and estimated variations from these values for other hours are also given. Any unusual conditions during the preceding week, such as those accompanying magnetic storms, are described briefly. The service may be extended later, if the demand warrants, to a more frequent dissemination of ionosphere data and the inclusion of data from other parts of the world.

• *Sample Broadcast*

This is station WWV of the National Bureau of Standards. We have just completed a standard-frequency emission on .... kilocycles, which will be repeated on .... and .... kilocycles. We now give a summary of radio transmission conditions.

Based on observations at noon, today, March 3, 1937, the normal-incidence critical frequencies and virtual heights of the ionosphere layers at Washington, D. C., latitude 39° North, were as follows: For the E-layer, critical frequency 3940 kilocycles, height 120 kilometers. For the F_2-layer, critical frequency 13,-700 kilocycles, height 240 kilometers.

The frequencies corresponding to several skip distances are approximately as follows:

[1] *National Bureau of Standards Letter Circular LC499, dated May 15, 1937, from which we have quoted liberally in the preparation of this discussion.*

300 kilometers for a frequency of 14,400 kilocycles.
800 kilometers for a frequency of 18,000 kilocycles.
1500 kilometers for a frequency of 25,800 kilocycles.
2500 kilometers for a frequency of 33,900 kilocycles.

The frequencies corresponding to the skip distances lie approximately between the values given and 10 per cent less, from about 10 a.m. to 6 p.m. local time.

At midnight last night the normal-incidence critical frequency of the F layer was 7600 kilocycles and the minimum virtual height 270 kilometers. The night skip distances for several frequencies are approximately as follows:

300 kilometers for a frequency of 7,800 kilocycles.
800 kilometers for a frequency of 9,500 kilocycles.
1500 kilometers for a frequency of 13,600 kilocycles.
2500 kilometers for a frequency of 17,900 kilocycles.

The frequencies corresponding to the skip distances hold from about 9 p.m. to 7 a.m. within about plus 15% and minus 25%.

During recent weeks the day-to-day variations of ionosphere conditions have been small except during occasional magnetically disturbed days. No sudden ionosphere disturbances were observed during the past week.

This announcement will be given again at .... p.m. Eastern standard time, on .... kilocycles.

A New "Sound Projector"

RCA has announced an improved type of loud speaker, the "sound projector", which is capable of concentrating a beam of sound in any particular direction. The sound "beam" is very directive and, due to the high acoustic efficiency of the device, it can be clearly heard at distances up to a mile or so from the "projector".

One of the chief values of the new development is that lifeguards will be able to maintain more complete control over the beach areas and adjoining waters by directing the powerful beam of sound on a movable swivel to the desired spot. By this means, bathers and even watercraft can be warned away from dangerous tides, order maintained on the beaches, lost children located and other beach patrol services greatly facilitated. Other possible uses for the new sound projector, which recently received its first public test, are for communicating with the ground from airplanes, directing harbor craft, supervising boat races, and addressing great outdoor audiences in ball parks, stadiums, and fairs.

The new "sound projector" utilizes only 100 watts of audio power. Heretofore, power speakers have required almost five times as much power to cover similar distances with far less intelligibility of speech and music. Its remarkable distance range and tone quality is made possible by the development of what is probably the world's largest permanent magnet ever made for the purpose. It weighs 25 pounds and measures 8½" in diameter.

¶ From the General Electric Co., 1937

RESEARCH ON LIGHTNING

THE artificial lightning and high-voltage laboratory of the General Electric Co., under the direction of K. B. McEachron, has made a number of interesting and valuable discoveries in the course of their experimentation on the effects and methods of controlling lightning.

In the first place it has been definitely proven that lightning will take the path of the least resistance or the path of the shortest total jump in the course of its path to ground. It will do this irrespective and regardless of how many detours and individual jumps it must make in keeping to this path. A number of actual cases have been cited to prove this fact.

In one case, lightning came down a 90-foot pine tree and plowed up a furrow in the ground until it reached a pole supporting telephone wires. It went up the pole leaving some splintered wood behind, and finally found its ground connection after passing through the telephone wires.

In another case, in New Hampshire, lightning followed down a tree, traveled a distance of approximately 50 feet over the earth to pass up another tree, then jumped approximately one foot to a 110-volt lighting circuit, from which it dissipated itself in lightning arresters connected to the power circuit.

In a case but a month ago, the lightning discharge traveled through devious paths finally to reach the ground by way of an apple tree, 37 feet of earth, two metal beds, the body of a boy, a radio aerial, a secondary power line, and finally a telephone circuit. The boy was killed, several of the electric light circuits were put out of commission, and some damage was done to the telephone system. The boy was standing in a bunk house between two windows, apparently watching the storm. His body showed burns on his chest and one foot. How the accident happened was a mystery until the investigation was made from which it was determined that the bolt had first struck a tree 37 feet from the bunk house, stripped off the bark as it traveled down to the base, followed a root of the tree for a few feet, then a small stream of water caused by the rain which carried it to the foundation of the bunk house. Here it tore off a patch of tarpaper along the foundation, came up through the floor and a bed, and passed through the boy's foot, up his body and left by way of his chest to an aluminum cooking pan hanging from a shelf but an inch or two from his body. It next jumped to a radio antenna strung under the eaves and then to an electric light lead just inside the building. From this, the lightning traveled over the electric light wires out the building to a nearby building in which the cord from a desk telephone was hanging over the metal part of a bridge lamp. Burns on the insulation of the wires and on the metal of the bridge lamp at this point indicated the lightning entered the telephone system and gradually dissipated itself to ground over the lightning arresters connected to the telephone system.

If a person is familiar with lightning, it is not difficult to trace its path; it generally leaves its mark wherever it goes.

In the case of the boy, the lightning discharge was seeking a good ground connection, and was only partially satisfied by the ground at the base of the tree. It followed the path of the least resistance, which was by way of the boy, antenna, light wires, and finally the telephone conductors to ground.

When providing grounds for transmission towers, power stations, or lightning rod systems on buildings, grounds are provided by driven rods, buried wires, or pipes, often covering a considerable area. Lightning is discharged into such a low resistance system without damage.

This illustrates again the three main hazards of standing under a tree, which are: 1, the discharge may side-flash from the tree; 2, the discharge in passing through high-resistance soil at the base of the tree may pass considerable current up one leg of a person and down the other. This is often the reason why cattle are killed under trees; 3, the tree may explode and a person may be injured by the flying debris.

It has been definitely proven that well-grounded lightning rod systems will protect buildings against damage from lightning in the majority of cases, and that persons in such buildings will be in just about as safe a spot as it is possible to find during a lightning storm.

The Federal Communications Commission has asked the cooperation of the radio manufacturing industry in regard to the sale of transmitter kits or built-up transceivers. The manufacturers of the kits are requested to include in each unit a form letter prepared by the F.C.C. advising the purchaser that a federal license is required for the operation of the equipment. The manufacturers also were asked to include a statement to this effect in their catalogs or descriptive literature concerning such equipment.

¶ From All-Wave Radio
July, 1937

"Multiband" System of I. F. Selectivity

BY McMURDO SILVER

DURING recent months the author has engaged in considerable research in an analysis of the means of obtaining selectivity in superheterodyne receivers. The purpose has been to evolve means which would, in a single radio receiver, provide the extreme and intermediate degrees of selectivity today recognized as desirable if not essential, and particularly to devise means of improving the still elemental orders of *selectivity ratio* which have had to be tolerated in obtaining extreme selectivity for voice and music reception.

• *Choices of Selectivity*

In terms of high-quality, all-wave broadcast receivers, practice to date has indicated that four choices of selectivity are desirable. These four choices, to be available at the wish of the operator through a simple control knob, involve bandwidths in terms of substantially flat audio response of 32 kc., 12 kc., 8 kc., and 4 kc., which choices correspond to audio tone modulation ranges of 16,000 cycles, 6000 cycles, 4000 cycles and 2000 cycles. (This is because the selectivity curve must be twice as wide as the desired audio tone range in order to admit both upper and lower modulation side bands).

These four choices obviously satisfy every practical broadcast reception need. The 32-kc. bandwidth will accept modulation up to 16,000 cycles, higher than can today be profitably used on the great majority of "high-fidelity" stations modulating only up to 9000 to 10,000 cycles. More important, such selectivity is broad enough to make the tuning to and holding of none-to-stable ultra-high-frequency stations easy and practical. The audio response range between 16,000 and 6000 cycles, the next selectivity choice, is most easily regulated to the listener's taste by a treble audio tone control. This next choice of 12-kc. bandwidth is the most generally usable one for "high-fidelity" reception, involving as it does a 6000-cycle audio tone range. This range is dictated by two factors. The first is that 6000 cycles is the customary upper limit of chain broadcasting, and most programs are so brought to the listener. The second governing factor is the prevalence of deep modulation by broadcast stations, resulting in regular overmodulation causing most annoying harmonic distortion in the range above 6000 cycles, even in the rare cases when modulation frequencies above 6000 cycles are present in programs.

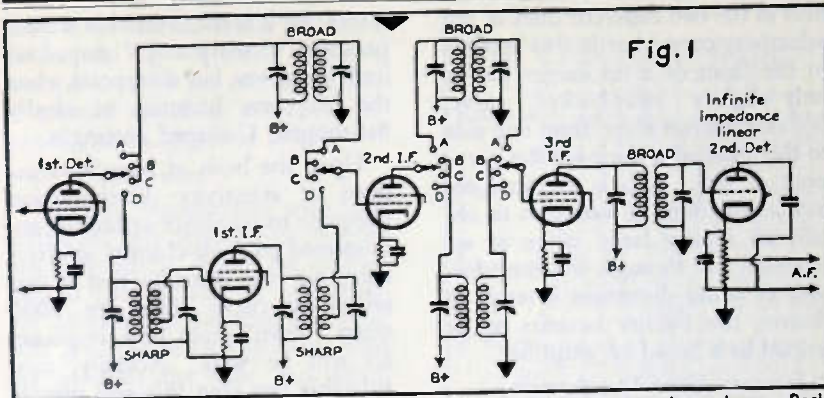
The next choice is the one most valuable to all except urban listeners, for it gives to rural listeners dependent upon relatively distant stations for their entertainment, the ability to select clearly one station at a time without interference from, in their case, comparatively strong adjacent-channel signals. This third choice will be an 8-kc. bandwidth, giving the full 4000-cycle fundamental audio tone range and clean elimination of adjacent-channel interference. The fourth choice must be a 4-kc. bandwidth giving a 2000-cycle audio tone range to satisfy the dx fan who demands the ability to split 5-kc. channels, and cleanly pull out of the crowded 49-meter band, for example, the very maximum of stations free from customary interference due to excessively close station spacing.

• *"Selectivity Ratio"*

Previous selectivity measurements and ratings have almost completely ignored the vital factor which the author chooses to term *selectivity ratio*. In rating selectivity as "absolute 10-kc.", only the bandwidth at (say) 10,000 times "down" has been considered, with little thought given to the *breadth* of the curve peak. It is this breadth of peak that conveys signal intelligence, bandwidth 10,000 times down measuring only the degree of adjacent-channel interference rejection.

Of what value is it to reject interference if so doing, desired signal intelligibility is badly impaired or ruined? Yet this is exactly the price heretofore paid for extreme selectivity—the loss of intelligence. So considered, it is apparent that a new and additional method of rating selectivity is necessary to paint a true picture. This rating may be "selectivity ratio," or the ratio of the width of the intelligence-conveying peak of a selectivity curve to its width 10,000 times down. The lower this ratio, the closer the approach to the ideal band-pass rectangular curve. The higher the selectivity ratio, the poorer is the tone quality obtained for any extreme degree of selectivity. The best previously obtained selectivity ratios have been about 8:1. The new system described herewith improves this by over double, giving a selectivity ratio of better than 4:1 where it is most needed at extreme selectivity. It improves both direct adjacent-channel selectivity and gives an entirely new conception of intelligibility or program brilliance at this greater selectivity.

Satisfying as they do every present and probable future selectivity need of broadcast and even amateur voice reception, the question is how to obtain these four orders, not



The fundamental switching circuits of the "Multiband" I.f. system are shown here. Position A gives curve A of figure 2, position B curve B, and so on. It will be seen that separate I.f. transformers are used to obtain varying degrees of selectivity.

of side-band cutting V-shaped, but of flat-topped true band-pass selectivity. Examining the maximum-to-minimum ratios involved, we find the result to be 4 to 32-kc. bandwidths, or a ratio of 8:1. Using the conventional methods of varying i.f. amplifier selectivity by varying primary-to-secondary coupling of i.f. transformers either mechanically or electrically by switching auxiliary coupling coils, the answer is far from ideal. Transformers of high enough coil "Q" to give the desired maximum will, when over-coupled to give the minimum selectivity of 32-kc., show two very pronounced double peaks with an excessively deep valley in between them. They are capable of giving in good practice only three of the necessary four selectivity choices. Additionally, it is next to impossible in actual use to avoid detuning as coupling is varied, which results in lop-sided curves.

The next method of varying i.f. amplifier selectivity would be to detune in opposite directions either successive primaries and secondaries or successive i.f. transformer stages. This, being essentially only a variant of the coupling variation method, still fails to give an adequately flat-topped curve to insure absence of audio discrimination when adjusted to 32-kc. bandwidth if coil "Q" is initially high enough to give maximum desired selectivity.

Regarded in this light, it is apparent that no single cascaded sequence of i.f. transformers in a conventional i.f. amplifier can be varied to give acceptable flat-topped curves over the desirably wide 8:1 selectivity range of 4 to 32-kc. What is needed is individual and different i.f. amplifiers, one for each selectivity choice. This is further indicated by the increasing lack of symmetry which disadvantageously creeps in as i.f. transformer selectivity is broadened. Not only does this appear as quite dissimilar steepness in the two different sides of the selectivity curve, but it also appears in the form of a no longer flat or only slightly "sway-backed" curve, but as a distinct slope from one side to the other of a none-too-flat curve peak or top. This is the final objection to coupling variation to obtain an ideally large range of selectivity, for through the introduction of audio distortion it tends to destroy the fidelity benefits to be gained by a broad i.f. amplifier.

• *Separate, Fixed Transformers*

All these disadvantages may be eliminated through separate fixed, not variable, i.f. amplifiers or transformers switched into circuit to vary selectivity, and vitally important additional benefits may be obtained. These have to do with *selectivity ratios* at maximum selectivity, as in the 8-kc. and 4-kc. bandwidth choices. Intelligibility and brilliance of speech and music are a direct function of the degree to which high audio frequencies are admitted. Interference rejection is the function of how far "down" the sides of the selectivity curve are immediately outside the desired admittance band. The ideal selectivity curve will have a flat top and vertical sides—it will be a rectangle in shape, not the usual V-shaped curve. If we can obtain such an ideal band-pass curve, we can realize an entirely new order of intelligibility and tone quality at extreme selectivity. Additionally, we can eliminate that old bug-a-boo of microphonic howling on short waves, for it is the invariable accompaniment of sharp and V-shaped selectivity curves, but disappears when the i.f. curve becomes an ideally flat-topped, U-shaped rectangle.

Upon the basis of recent evaluations of selectivity discrimination adequate to eliminate ordinarily-encountered adjacent-channel interference, we may consider that if our selectivity curve sides are 5000 times "down" from peak response, all will be well. Actually, considerably less than this will usually do the job. But let us take the doubly safe assumption that the curve "skirts" should be 10,000 times down to insure elimination of adjacent-channel interference. We cannot obtain such discrimination with a flat-top to our curve 4-kc. wide (to give the 2000-cycle audio tone range essential to good speech intelligibility free of "boominess") even with four under-coupled i.f. transformers using coils of the highest currently available "Q" of about 130. If we are to obtain this ideal useful audio tone range at maximum selectivity, together with steep interference-rejecting skirts, we will need coils of a "Q" much higher. Coil Q's of 200 can be had from iron-cored i.f. tuning with such coils. This first guess of permeability tuning must be rejected because of the absence of adequately stable fixed tuning condensers. For high-quality circuit stability, air tuning condensers may not be escaped. But much work was done to develop air-core coils with a "Q" of

200, with success finally obtained. With this "Q" or merit improvement of over 50 per cent more than is usually available, the ideal becomes within practical reach.

- ***I.F. Transformers***

Three i.f. transformers with their primaries and secondaries coupled below optimum, where the double-peaked characteristic of over-coupled circuits just becomes apparent, will give the selectivity curve with the perfectly flat 4-kc. top which we are seeking. The extraordinary coil "Q" of 200 will cause the sides or skirts of this curve to fall off almost vertically, but not quite vertically enough to satisfy the ideal goal sought. So, in a three-stage amplifier, a fourth i.f. transformer is used, so broad as not to narrow the flat top, but a considerable help in pulling down the skirts on either side of this flat top, and to keep them symmetrical (to prevent the high-frequency skirt from straying out and failing to duplicate the steepness of the low-frequency skirt.)

The receiver, of course, must follow the finally established good practice of using two tuned r.f. stages to eliminate unavoidable first detector-oscillator noise by the only known method of using high r.f. amplification in conjunction with low i.f. amplification. If this two-stage r.f. amplifier departs from the customary practice of seeking only to improve image selectivity, we can obtain a considerable degree of adjacent-channel selectivity from it. This departure from current practice will materially steepen the sides of our flat-topped i.f. curve, and through careful design will not impair this flat-top.

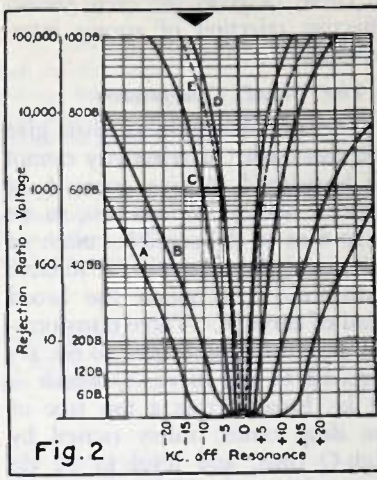


Fig. 2

Selectivity curves obtainable with the new system. The letters correspond to those on the switch positions in figure 1.

The next result will be curve D of figure 2. The extraordinary aspect of this curve is its *selectivity ratio*. Its intelligence-conveying flat top is 4 kc. broad where it is flat to 6 db (easily compensated in audio amplifier circuits) and then it falls off almost vertically to a width of only 15 kc. at 10,000 times down. This is an intelligence-to-interference, rejection ratio of 3.75:1, coupled with the flat-top that eliminates microphonic howling. The improvement this represents is seen by a comparison with the dotted line curve E, a composite of several of the most selective receivers. Curve E shows a top only 2 kc. broad, resulting in the very poor to almost in curve D gives for even greater effective rejection of strong interference.

• *The "Broad" Transformers*

The i.f. transformers that give this new order of selectivity cannot be broadened to give curve A of figure 2 without serious loss, so we must turn to the sensible course of using entirely different and suitable transformers to obtain the broad band of curve A. Three transformers, with coil Q's reduced to 60, are required to get curve A, which is 32 kc. broad across a top free of the deep center valley caused by high-Q coils, and level to 12 db across this top. This 12 db departure from an ideal flat top is easily made up by providing a 12-db treble rise in the following audio amplifier. But to keep it this flat, all tuned r.f. circuits but one must be cut out, for no method of broadening them that will not introduce stray couplings and capacities through long leads and incidental associated parts is practical. This is desirable in any case, for upon the broadcast band such a wide admittance band may only be used in reception of strong local stations, and switching out of r.f. gain will insure only such use. On short waves the selectivity of the r.f. amplifier, necessarily decreasing with increasing frequency, may be employed satisfactorily when its additional gain and necessary image rejection may be desirable.

Having now two different i.f. amplifiers by virtue of two different and symmetrical sets of fixed i.f. transformers, together with selectable degrees of r.f. selectivity, we may through discreet joining of the two systems obtain the two remaining choices of selectivity required to qualify the system as ideal.

• *"Multi-Band" Selectivity*

Through substituting one sharp i.f. transformer for one of the three broad ones of curve A, we get curve B 14 kc. wide across its top which is flat to the easily audio-compensated level of 6 db. It insures the 6000- to 7000-cycle audio tone range which will be most useful in day-in and day-out "high-fidelity" reception of regular broadcast stations.

Curve C is obtained with this same i.f. system to which is added the two-stage r.f. amplifier. This curve, 8 kc. broad across its top flat to 6 db, (rendered perfectly flat through audio amplifier compensation) is the most generally useful of the entire four choices, for it is the one which will be used in broadcast band and short-wave reception to give the maximum of tone quality with the maximum of selectivity for stations separated 9 to 10 kc. Its flat band-pass top and extremely steep sides "down" 1000 times for the 10-kc. separated adjacent channels give the selectivity which has heretofore only been obtained at the expense of the tone impairment necessarily associated in the past with side-band cutting.

More Uses of the Electric Eye

Astronomy: When finally established in the next three or four years, the 200-inch Mount Palomar telescope will be used in conjunction with a photocell detector for registering the presence of extremely faint illuminations.

General research: The color reflection and transmission properties of any material can be analyzed by a machine which employs polarized light along with a single photocell and plots the complete spectral response in three minutes.

Telegraph delivery: Automatic indications of trouble in connection with the conveyor belt system of one of the larger Western Union offices is made available by strategically-placed photocells.

Silk manufacture: Photocells are now responsible for the smoothness and hence the sheen of women's silk hose.

Cotton making: A new weft straightening control, which has phototubes to detect skew in cotton cloth, has been developed by G. E.

Burglar alarm: Successful in its every test, a phototube burglar alarm, which has an infra-red beam and automatically notifies the police by a spoken alarm played from a record, should prove effective in the apprehending of certain "master" criminals.

Ship guidance: Photo-cell controlled, motor-operated rudder-control devices are being increasingly used as robot pilots for motorship guidance.

Refining industry: The "compensating calorimeter", a phototube device, measures the color of anything transparent or translucent, and is thus being used for color measurements which control various industrial processes such as sugar or oil refining, heat treatments in the metal industry, and so forth.

Spark plug manufacturing: The proper gap in spark plugs can be obtained very accurately by controlling with a phototube the vibrating hammer used to bend one of the electrodes.

THREE AUTHORITIES

David Sarnoff

RCA President

Perusal of technical and popular journals alike reveal an increasing interest in television.

"Is television really here?" "What are the problems involved in the transmission and reproduction of the moving scene?" "What are 'they' in United

Mr. Sarnoff, upon returning from Europe, comments that the major problem of television, in both the United States and England, is to provide a program for the home that will meet public requirements and maintain public interest.

To place television on a commercial basis in the United States, Mr. Sarnoff says that it is necessary to establish a sufficient number of sending stations, that must be interconnected and able to furnish a regular service at least to the population residing within the principal market areas of our country. The erection of such stations, the provision of necessary interconnecting facilities, and the establishment of a regular program service that would meet public requirements and hold public interest, call for vast financial expenditures before any returns can be reasonably expected.

In comparing the television facilities of United States and England, one finds that the television receivers installed in the homes of our experts, who have been carrying on field tests during the past year, are of the same order of performance as those in use in England. The range of the RCA television transmitter atop the Empire State building, now operated by the NBC from its television studios in New York City, is approximately the same as that of the B.B.C. station in London.

The system employed in England is known abroad as the Marconi E. M. I. Television system, which is fundamentally based on the RCA Television system first developed in the United States, Mr. Sarnoff states. Under an exchange of patent licenses, this British company may use RCA patents in England and in turn, RCA and its American licensees may use British patents in the United States.

Dr. Alfred N. Goldsmith of RCA, who has been actively interested in the development of television for more than a dozen years, has discussed the problems of programming television. He believes that television must develop its own program technic. The ultimate characteristics of such programs must be spontaneity, for television must capture images of the world in action.

Television networks of stations comparable to those existing in sound broadcasting must await the development of either the co-axial

DISCUSS TELEVISION

States and abroad doing about it?"

In answer to some of these queries, Radio Digest herewith presents a group of articles chosen from technical publications and press releases. Further information may be found on pages 51, 81, and 83.

The television center for the Columbia Broadcasting System's visual programs will be located in the Grand Central Terminal Building in New York City. This will place the pickup studios quite close to the television transmitter; it will be located across the street in the Chrysler Bldg.

The large main studio, measuring 225 feet in length, 60 feet in width, and 40 feet from floor to ceiling, will be located directly above the Grand Central waiting room and will overlook 42d Street.

cable or automatic radio relay stations. Meanwhile, if public service should be inaugurated, the individual station has recourse to three classifications of program material: local talent, motion picture films, and "road shows" of live talent travelling from studio to studio. In the instance of the last, it was pointed out that "stock companies" would face the necessity of developing a new make-up technique, since the television camera does not "see" its images in the same values of color and tone as does the eye or motion picture camera.

Allen B. DuMont

Cathode Ray Tube Pioneer

Mr. DuMont, after visiting television stations and laboratories in Europe, observes that countries abroad are pioneering in commercialized television and are pulling ahead of us rapidly.

Mr. DuMont believes that the English, by going ahead with regular television broadcasting, have learned more in six months of practical effort than we can learn in six more years of continued laboratory work behind more or less sealed doors.

"As I see it," he remarks, "television is an evolution and not a single invention. It is a development that must come out of practical experience, since we cannot be sure of the right answers relative to technique, program, service areas, networks and economics until we have made a real 'try'. The sooner American television goes on a regular program basis, with television sets made available to the public,—regardless of obstacles,—the sooner we are going to realize practical television."

The British Broadcasting Corporation operates a television station in Alexandra Palace, overlooking London. The palace is surmounted by a mast about 300 feet tall, making a total height of about 600 feet. The 17 kw. television transmitter sends out its programs on 6.9 meters.

The English have somewhat shattered the theory that signals do not go beyond the horizon on the short waves used, with the London transmitter covering a service area of better than 100 miles' radius. On freak occasions signals have been picked up as far as South Africa. The great covering power of television signals is undoubtedly due to the high power, the sensitivity of the receivers, plus the fact that there is very little static inference on such short waves.

Another fetish destroyed up by the practical British workers is the absolute need for special coaxial cables for the transmission of television programs from pickup source to remote television transmitter and to associated stations of a network. The BBC sends out each day its three television pickup vans, in search of interesting news and sporting events. These trucks comprise a complete remote pickup unit equipped with cathode-ray tube cameras, microphones, amplifiers, and low-power transmitters operating on about 3½ meters. Sight-and-sound programs are flashed back to Alexandra Palace for rebroadcasting to the audience. A 405-line screen, with 25 pictures per second, interlaced scanning, is used. There is no flicker, nor is there apparent screen pattern when viewed at the same *relative* distance as a theatre screen. By holding one's hand at arm's length, with outstretched palm just masking the screen, we obtain the proper viewing distance for television.

Quite a large number of television sets, supplied by some 15 manufacturers, have already been sold in England. The average price for an excellent sight-and-sound receiver is about $350.00 There are cheaper sets, especially those without the dual receiver arrangement for sound as well as sight reception. Sets are on display in radio shops, music and department stores, and are available for home demonstrations. One British manufacturer charges the equivalent of $20.00 for a set installed in any home on a demonstration or trial basis. If the set is purchased, that sum is applied on the payment; if it is returned, the $20.00 becomes a rental fee.

France, Belgium and Holland, DuMont found, are lagging behind the British, but they are keyed up to television possibilities. He visited the laboratory of the pioneer worker Barthelmy, outside Paris, where he found a well-equipped laboratory and studio.

The smaller countries are following the lead of Germany as well as Britain. Results of German television as demonstrated at the Paris Exposition, are splendid, even though the Germans are using 375 lines as compared with the British 405. Germany plans to adopt the American 441-line standard.

TELEVISION . . . at Home and Abroad

UNITED STATES

COLUMBIA Broadcasting System's new television transmitter, construction of which was begun almost a year ago, is being given its first power tests at Camden, N. J. The final tests will probably be completed in the next few months to allow the transmitter to be delivered to New York shortly after the first of the year.

When all the "bugs" have been eliminated, the transmitter is to be shipped to New York for installation on the 73rd and 74th floors of the Chrysler Building. There it will provide television programs from the nearby Grand Central Station studios now being built by Columbia. The new transmitter is expected to cover a radius of approximately 40 miles from its location; this coverage will amount to about 4800 square miles of thickly populated territory.

The new transmitter will consist of two separate units: a high fidelity sound unit designed to cover a range up to 10,000 cycles and a picture transmitter which will be able to handle modulation frequencies up to 2,500,000 cycles. These extremely high modulation frequencies are necessary to transmit the 441-line interlaced pictures that will be emitted.

Water-cooled tubes of a new de-

(Continued on Next Page)

ENGLAND

THE first television broadcast from a point some miles distant from the London Television station was undertaken by the B.B.C. when the coronation procession was visually transmitted from Hyde Park on May 12 of this year. The broadcast was made by remote control from a portable pickup installation especially constructed for such remote work. The entire equipment used is housed in three specially constructed, oversized "busses".

The first vehicle is, in effect, a mobile television control room. In it are housed all the scanning and amplifying equipment necessary for the operation of the three television cameras. These cameras, the scanners of which are electronically-operated devices called "Emitrons", are connected to the control bus by special multi-wire shielded flexible cables. In these cables are carried the scanning and framing impulses for the image dissector, the supply voltages for the various tubes used in the camera, and the audio currents of the pickup microphones. This truck also houses the audio equipment, amplifiers, mixers, and so forth, for use with four different microphone input sources.

The video energy may be conveyed from the pickup truck to the Alexandra Palace Transmitter either

(Continued on Next Page)

UNITED STATES

sign will be used in both transmitters and both will have a carrier output of about 7500 watts, 30,000 peak watts on modulation peaks. The total drain of the two transmitters will be in the vicinity of 0.4 megawatts. A large air-conditioning installation will be made to dissipate the tremendous amount of waste heat.

The main power units, transformers, motor generators, and so forth, will be located on the 73rd floor while the transmitter itself will be housed on the 74th.

Program interest centering around New York's great railroad terminal, a central location, and proximity to the CBS television transmitter in the Chrysler tower were influential in the choice of the Grand Central as site for the new television studios.

ENGLAND

by means of a co-axial cable, tapping positions of which are provided at strategic points throughout London, or by means of a 1 kw. ultra-high-frequency television relay transmitter which is incorporated in the second of the trucks. This truck has a beam antenna mounted upon its roof which is directed at another beam receiving antenna mounted on a mast atop the Alexandra Palace. Upon reception at the Palace, the energy is rebroadcast through the usual channels.

The function of the third truck is to render both the control truck and the television relay transmitter independent of local a.c. supply lines. It contains an especially regulated gasoline-engine-driven generator capable of supplying the needs of the other two trucks.

Radio servicemen of the country have organized themselves into a national body—the RSA—with T. P. Robinson of Dallas, Texas, as their first president. Through the anticipated support and cooperation of manufacturers, it plans among other things, to distribute to its members advance circuit diagrams, instruction material and information normally furnished by manufacturers by less direct methods.

¶ From RCA Review, July, 1937

TELEVISION TRANSMITTERS

(Illustrations given on pages 51-54)

BY J. W. CONKLIN AND H. E. GIHRING

THE ADVENT of high-definition television, involving modulation frequencies up to several million cycles, has necessitated the development of high-power, ultra-high-frequency transmitters. The unique tube and circuit problems encountered and the practicability of line sections as circuit elements has resulted in radical departures from conventions in transmitter design as may been seen from the accompanying illustrations, showing features of high-power, ultra-high-frequency television transmitters.

• *Vacuum Tube Problems*

In ultra-high frequency development the vacuum tubes have always been one of the major sources of difficulty. Vacuum tubes developed for lower frequencies have a number of limitations rendering them unsuitable for u-h-f applications. For low-power u-h-f transmitters and receivers, special tubes having low internal capacities, short leads, and other features are available, permitting conventional designs insofar as tubes are concerned. Television transmitters with carrier powers between five and ten kilowatts require tubes with dissipation capabilities of the order of thirty kilowatts. The Type 899 is one of the tubes now used in these applications. Some of the problems of high-power u-h-f transmitters are due to the large physical size of tubes now available.

Water cooled tubes have glass envelopes to provide insulating supports for grid and filament structures in high-power tubes. For manufacturing reasons, these envelopes are made of considerable length since the resulting lengths of filament and grid leads do not present serious difficulties at low frequencies. At ultra-high frequencies the inductance of the leads, plus the loading effects of the inter-element capacities, result in potential and phase differences between the actual internal elements and their external terminals, which increase roughly with the square of the frequency. There exist, in effect, standing waves on the leads and as the frequency increases, a condition is reached where the voltage nodes move inside the envelope, i.e., the effective lengths of the internal leads are greater than a quarter wavelength. In common high-power, water-cooled tubes, this condition occurs at frequencies from 30 to 50 megacycles. As a result, at ultra-high frequency it is impossible directly to ground the filaments for radio frequencies or achieve satisfactory neutralization, because of the length of the grid and filament leads.

- *Reactance of Filament Leads*

In operation the reactance of the filament leads is common to the plate and grid circuit and in tubes of large physical size, the internal reactance is great enough to make satisfactory neutralization difficult when the filaments are grounded directly. Even when satisfactory neutralization can be achieved, this filament-lead reactance prevents attainment of 100 per cent modulation of a modulated stage, as it permits radiation of the excitation power on negative-modulation peaks.

For several reasons to be discussed later, push-pull circuits are used almost entirely for large high-power u-h-f transmitter stages. This permits a simple method of overcoming the reactance of the filament leads by interconnecting the filaments of the opposing tubes through a pair of parallel conductors. These are inter-connected at a point effectively one-half wavelength from the actual cathodes, giving an effect substantially the same as a direct inter-connection between filaments. In practice, the inter-connecting bar is made adjustable and the correct setting determined as a part of the neutralizing procedure. At 50 megacycles these filament lines are of the order of 10 feet in length and for convenience they are doubled back on themselves to reduce the size of the inclosure required.

- *Neutralization Problems*

Long internal grid leads result in difficulties in cross-grid, cross-plate neutralizing, which may be further increased by necessarily long external neutralizing leads. In the case of Type 899 the internal grid lead is effectively a quarter wavelength at 50 megacycles and this makes neutralization difficult through connections to the external grid terminal. Fortunately, the grid end of this tube is of such construction that it was found feasible to form the cross-grid or cross-plate neutralizing capacity directly between the internal grid-lead and external concentric-sleeve fitting over the glass envelope. These neutralizing sleeves may be seen in figure 4. Even with this arrangement it is not possible to form a true reactance bridge, because there is still left a considerable length of free grid reactance and the circuit is neutralized only over a small band near the operating frequency and has to be heavily loaded to prevent oscillation.

- *Inter-Electrode Capacities*

Inter-electrode tube capacities impose a number of u-h-f limitations on tube performance. In the case of high-power transmitting tubes, these limitations are of a different nature than those generally associated with low power and receiver applications. Large water-cooled tubes have high inter-electrode capacities, output capacities ranging from 25 to 50 μμfd. These capacities do not impose serious tuning difficulties as the physical size of the tube makes it convenient to use large tank circuits having very low inductance. Figure 4 is a view of a tank circuit of the parallel-line type, using an adjustable shorting bar with a small vernier condenser to cover a tuning range from 40 to 90 megacycles. However, from the standpoint of neutralizing, high grid-plate capacities are awkward as the physical size of the neutralizing condensers necessitates long leads and increases stray capacity effects.

At ultra-high frequencies, the inter-electrode capacities have very low reactance values and, as a result, the circulating currents in the tubes become unusually high. These high currents cause excessive heating of the elements, leads, and seals and in general necessitate extra precautions in air cooling of all glass parts, particularly the seals. This heating is also increased at ultra-high frequencies by the increase of the radio-frequency resistance because of skin effect.

In television applications, inter-electrode capacities have a more serious effect particularly in r-f power amplifiers required to pass modulation side bands, which under present standards may be 2.5 megacycles from the carrier. It is not generally realized that for a desired tank-circuit frequency response, the tube, neutralizing and associated stray capacities, automatically determine the load resistance regardless of carrier frequency. In practical cases, this has generally necessitated operating tubes into load resistances considerably lower than normal with resulting poor plate efficiency.

In television power-amplifier applications, tube efficiency in one respect depends upon the ratio of tube capacity to plate conductance. Unfortunately, this ratio is a fundamental inherent relation in practical vacuum tubes of the triode type, and while tubes may be improved, it is doubtful if the present conception of a triode r-f power amplifier is the final answer for high-definition television applications.

The high side-band frequencies do not require 100 per cent modulation of the transmitter. It is thus possible to compensate partially for discrimination against high frequencies occurring in the radio-frequency circuits by equalizing at low levels in the video amplifier. However, excessive compensation of this type usually introduces objectionable phase shifts and transients. The problem of relaying a picture from the studio to the radiating transmitter and amplifying it to modulation power is of itself a sufficient problem. It is therefore desirable that the radio-frequency circuits of the transmitter have a flat characteristic over the frequency band to be transmitted.

In one case of a 7.5-kilowatt, 50-megacycle television transmitter, in order to obtain a power-amplifier frequency response flat within 3 decibels over a 1.5-megacycle band, it was necessary to overload the power amplifier to a point where the plate efficiency was less than 15 per cent. The power amplifier used two Type 899 tubes in push-pull and the total plate input was approximately 60 kilowatts when delivering 7.5-kilowatts carrier-wave output.

New tube developments increasing the ratio of output conductance to output capacity may partially alleviate the poor power efficiency at present obtainable in television transmitters. However, the difficulty is more or less fundamental with tubes of the triode type, and the ultimate solution will, more likely, be the development of entirely new types of power-amplifying tubes and modulation methods.

Because of the difficulties in producing high modulation power at the high side-band frequencies involved in television transmission, grid modulation in the power amplifier has been the most practical method of modulating high-power u-h-f television transmitters. Absorption modulation has been used successfully on low-power transmitters of one or two kilowatts carrier power. The principal advantage of absorption modulation as applied to television is that it removes the band-pass requirements from the power-amplifier circuits and consequently makes possible higher plate efficiency.

• *Circuits*

At ultra-high frequencies, wavelengths reduce to a few feet and in high-power transmitters this fact introduces difficulties, but makes practicable circuits not adapted for lower-frequency design. In general, it becomes convenient to regard all circuit elements as sections of transmission lines and analyze them as such.

To begin with, at frequencies above 40 megacycles, it is found economical to use resonant line-controlled master oscillators as the primary frequency source. In such oscillators, the equivalent of a quarter-wavelength low-loss line resonator is used as the primary oscillatory circuit with power-oscillator tubes. Such resonators become of convenient size in the ultra-high frequency band and it has been found that the total transmitter tube complement is much less than would be required with a conventional frequency source such as a crystal oscillator and subsequent frequency multipliers and amplifiers.[1] Figure 6 shows a 50-Mc. quarter-wave, line-controlled power oscillator.

Enclosures or mounting frames used for the high-power stages of u-h-f transmitters, because of their size approach major fractions of the operating wavelengths in dimensions. A true common r-f ground for the inclosed circuit is thus difficult to obtain, and considerable difficulty is experienced with single-tube circuits which necessarily are asymmetrical with respect to an enclosure. Troubles from this source largely disappear when push-pull circuits are used and mounted symmetrically in relation to a large plane-conducting surface. For these reasons, push-pull types of circuits are generally used in preference to single-tube circuits where the physical size is a major part of a wavelength.

At ultra-high frequencies quarter and half-wavelength line sections become reasonably short in length and it is practicable to take advantage of some of their particular properties. Thus in u-h-f transmitters quarter-wave line sections are used as impedance transformers, "metallic" insulators, and impedance inverters. In figure 5 is shown an assemblage of quarter and one-half-wave, coaxial-line sections forming a cross-coupling filter to permit the operation of both the picture and sound transmitters into a common antenna without objectionable cross modulation. A U-shaped section of coaxial line serving as a transformer to couple the 72-ohm coaxial line to a 500-ohm, two-conductor, open-wire line is also shown. Short sections of lines having open or short-circuited terminations are conveniently used as efficient reactances at ultra-high frequency. Examples of this type of application of stub-line sections are the use of parallel tubular conductors having lengths less than a quarter wavelength to form the inductive component in high-power tank circuits. Several such assemblies are shown in the accompanying illustrations.

At ultra-high frequencies in circuits of large physical size all currents may be assumed to flow in the surfaces of the conductor, that is, constrained to a skin of less than a thousandth of an inch deep. This makes possible the construction of circuit members from inexpensive, easily fabricated materials such as steel which is subsequently plated with a highly conductive metal such as silver. A frequency-controlled resonator may be constructed entirely of cold-rolled steel and invar and silver plated. The actual conducting surface is thus formed of silver which has a very low electrical resistance, and at the same time, the structure is lighter and stronger and has a lower thermal coefficient of expansion than copper, which formerly has been used for these devices. As the practical thickness of plating of this type is limited to a few thousandths of an inch, this type of construction could not be used at lower frequencies where the depth of penetration is greater. It is necessary to consider skin effect and current distribution in the design of u-h-f transmitter components, as these phenomena are of much more importance at these frequencies.

• *Auxiliary Apparatus*

The difficulties encountered with

tubes for u-h-f work have been previously discussed. Other apparatus such as condensers, resistors, meters, insulators, etc., also have serious limitations.

• *Condensers*

Variable condensers of the conventional type cannot be used at ultra-high frequencies primarily because both minimum and ground capacity values are too high and insulation paths are not very long. For most u-h-f work two circular disks arranged so that the distance between them can be varied continuously have been found to be satisfactory and can be mounted directly on a tank circuit without requiring insulating mountings. In most u-h-f circuits the tube and neutralizing capacities form the major part of the tank capacity. External capacities are added only for tuning purposes. Suitable fixed condensers for by-passing, and coupling present serious difficulties. It is frequently desirable directly to couple the plate circuit of one stage to the grid circuit of the next. A coupling condenser is required to block the d-c plate voltage from the bias voltage of the next stage. In high-power u-h-f transmitters the radio frequency currents in this circuit may reach magnitudes of 30 to 40 amperes or more. At 50 megacycles, 1000 μμfd. are required to obtain 3.2 ohms of reactance. A value as high as 15 to 20 ohms may be tolerated in coupling or by-passing, but a higher reactance will cause difficulties. Ultra-high-frequency circuits are usually constructed of low-reactance components, and higher-reactance blocking condensers will greatly disturb the circuit operation.

The condensers usually available for this service consist of a stack of copper sheets with mica insulation impregnated with wax. The dielectric losses in the wax and mica go up rapidly with frequency, resulting in excessive heating of the condenser at values much below its rated current. Another disadvantage with this type of construction is that it often results in having considerable inductance in series with the condenser proper. One alternative is to use high-current-rating condensers and operate them considerably below their rating. This is undesirable because of the bulkiness of the condensers, which is detrimental to good circuit design. Other dielectrics may have possibilities and a suitable condenser may be developed in the future.

Air has proven to be the most reliable dielectric, but has the disadvantage of having a dielectric constant of one, which results in bulky condensers for the conditions mentioned above; namely, 40 amperes r.f. at 50 megacycles, 10,000 volts d.c. and from 200 to 1000 μμfd. Compressed air condensers may offer a solution to this problem since the spacing may be decreased approximately as the pressure is increased. However, at ultra-high frequencies compressed air condensers present insulation difficulties that offset their advantages.

Vacuum condensers similar in construction to vacuum tubes have been tried in an effort to obtain high voltage rating in small physical space. These failed by going "gassy" as they do not have the "clean-up" feature of vacuum tubes in operation. It is relatively easy to find standard condensers that will stand up for by-passing purposes, since for this condition the r-f current through the condenser is usually small. In many cases, however, the condenser will have considerable impedance to ground, because of its inductance. A case was encountered in which a parasitic oscillation existed with all types of standard condensers used for bypassing. A large parallel-plate condenser of extremely low inductance finally cured this condition.

• *Insulators*

Closely associated with condenser problems is the problem of insulation. Any insulator is in a sense a capacity with the insulating material as the dielectric. For lower frequencies, the admittance of an insulator is so slight as to be negligible, but at u.h.f there are many cases in which the radio-frequency currents flowing through the insulator are of such magnitude as to shatter the insulator, due to the internal heat produced. Points of contact with metal were found to be glowing at white heat. The above conditions as a rule are true only when a metal button or screw extends into the insulating material. This results in internal heating of the insulator, causing it to shatter. A simple remedy lies in the use of a corona shield. The corona shield tends to divert the path of the r-f currents along the outside of the insulator where cooling may take place.

No really suitable insulating material is available for u-h-f high-power transmitter work combining good insulating properties with mechanical strength. For this reason u-h-f transmitters must be constructed to eliminate insulation in high-frequency fields.

• *Meters*

The measurement of u-h-f currents is a difficult problem. The ordinary calibration of thermocouple ammeters does not apply at u.h.f because the skin effect in the couple causes the meter to read high. This, however, can be taken into account by applying a suitable correction factor.[2] A further difficulty, however, arises when the meter is actually placed in the circuit. In many cases the circuit is disturbed by the presence of the meter, resulting in erroneous readings. Lack of satisfactory voltage and current indicators increases the difficulties of studying problems in connection with u-h-f transmitters.

• *Resistors*

Resistors are often desirable in u-h-f television circuits. It is difficult to build good non-inductive resistors at lower frequencies and at u.h.f the problem is still more difficult. Types that are satisfactory at lower frequencies develop "hot spots" through the presence of standing waves. Carbon resistors become capacities at u.h.f because of their granular structure. Metal coated resistors are satisfactory for low-power work, but no satisfactory resistors of this type have been developed for high-power work. A pure resistance, free from reactance, is practically impossible to obtain at u.h.f. A possible exception to this statement may be an infinite line having no reflections.

Another method of obtaining a resistance free from reactance is to tune it out. For instance, load circuits have been constructed using a high-resistivity material as the inductance element of a tank circuit. This circuit may be tapped at any two symmetrical points and a pure resistance obtained, the value depending on the tapping points. This method may be used as an artificial load by circulating water through the conductor and measuring the temperature rise and water flow. It has been found desirable to arrange such loading circuits to avoid all coupling with associated circuits since the energy stored is extremely high and its field may interfere with the function of other circuits.

It has been the purpose of this article to give a general description of the problems encountered in the development of high-power television transmitters, and some of the methods used to overcome them. New vacuum tubes and equipment are now being developed with features intended to simplify these problems.

---

1 *"Frequency Control by Low-Power-Factor Line Circuits" by P. S. Carter and C. W. Hansell. Proc. I.R.E., April, 1936.*

2 *"Thermocouple Ammeters for Ultra-High Frequencies" by John H. Miller, Proc. I.R.E., December, 1936.*

Phototube Aids High Speed Printing

IN HIGH SPEED PRINTING, when sheets are printed much faster than the eye can count them, the sheets are piled one upon the other immediately after printing. If the ink is not dry, the pressure in the pile will result in the transfer of ink from the front of one sheet to the back of the other. This difficulty, known to printers as "offset", has resulted in the use of quick-drying ink, but in high speed work, additional preventative means are required. One method consists in spraying each newly printed sheet with a dry mist of fine particles from an automatic gun. It is necessary, however, that this gun be shut off immediately after the paper is covered. The gun aids the ink to "set" before the next sheet drops on top of it.

In order to control the timing of the gun, a phototube is fixed so that the passage of the paper through a light beam controls the gun. In this way the spraying is restricted to the proper timing interval between printing impressions. By this means it is possible to increase the speed of presses far beyond former limits and so reduce the cost per printing impression.—*Electronics.*

¶ From Successful Servicing
March, 1937

Why . . .
SENSITIVITY TESTING?

BY JOHN F. RIDER

TWO BASIC METHODS of approach are in use today in finding the cause of trouble in a defective receiver. One is the method which is too widely used—that which depends upon the hit-or-miss checking of every single part in the receiver. On the utter inefficiency of this method we need not dwell. Naturally sooner or later the defective part will be located, but the amount of time consumed is out of all proportion to that which is really required.

The second method recognizes the simplification and saving of time which can be brought about through a preliminary examination to determine the approximate location of the trouble. Such methods have always been used by wide-awake servicemen since the earliest days of radio. Many of you will recall in this connection the tests which are fairly well established in service practice for determining approximately the operating condition of the various sections of the receiver.

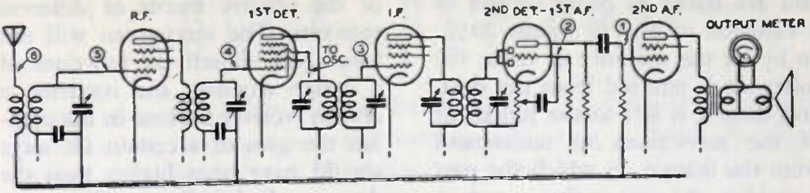
Analogies can be pushed too far, but the following should serve the purpose of indicating the great amount of time which can be saved by progressively limiting the possible places where a defective condition can exist. It is just as time consuming to test blindly every condenser, resistor, and coil in a receiver until the defective condition is found, as it is to examine every single name in a telephone directory until the one desired is found. In the same way that the name is first located alphabetically in a certain section of the directory, so the trouble should first be localized as being in a particular section of the receiver,—such as the power supply, the audio system, the i.f. system, or the r.f. system. Having found the trouble to exist in one of these principal sections of the receiver, a further series of tests will indicate just what part of the section is inoperative or abnormal, and in this way a progressive narrowing down of the zone in which the trouble can lie, finally culminates in the location of the actual defective part or condition.

While it is not our intention in this article to go into great detail as to just how this localization of trouble is accomplished, reference to the accompanying figure will make clear the general procedure which is suggested. Basically the method operates by feeding a known signal to each of the points in the receiver, which are designated on the typical skeleton diagram by the circled numbers from (1) to (6). In this way the trouble is localized by comparing the signal voltage which is actually required to produce the standard output as indicated by an output meter, with the values which should be necessary when the receiver is operating normally.

For example, if the signal voltages required at points (1) and (2) are in accordance with the data supplied for the particular receiver, and an abnormally high voltage is required at (3) to produce the standard output, then it follows that the stage between (2) and (3) is not functioning. Just why this stage (i.f., in this case) is not amplifying the signal to the extent that it should, can be found by the application of conventional testing methods to the i.f. stage alone (strictly speaking, the diode detector should be included). By conventional testing methods we mean the ordinary voltage, current, resistance, and capacitance measurements. Obviously, the saving in time comes about because the complete checking of component parts need be made only in connection with the known failure of a *single* stage to function properly.

While radio manufacturers have recognized the efficacy of gain-per-stage measurements in troubleshooting on their own production lines, very few released this information in their service literature. In talking over this question with several organizations, the opinion expressed was that unfortunately the service industry as a whole is not in a position to profit by the release of such information, both on the basis of the lack of adequate equipment and, in many cases, insufficient knowledge to interpret properly the manifold conditions which can arise in the course of sensitivity checking.

Let us take up these considerations one at a time. As far as the lack of knowledge on the part of the serviceman, there is a great deal of truth in this. But taking a broad view of present day conditions, we would say that many servicemen are in a position to profit from the release of such sensitivity data, and that the good which would be accomplished in increased efficiency and better servicing would more than compensate for the small amount of trouble involved in making sensitivity data an integral part of service notes. As for those who would not be able to use the data because of insufficient knowledge of basic radio principles, experience has shown that the service industry is in process of evolution, and that



Skeleton diagram with numbered points at which signal voltages are introduced. By comparing the voltages needed to give standard output readings, defects are localized.

those who would survive must keep pace with developments in the art and acquire the knowledge.

The cost of equipment required for making sensitivity tests is one that has been mentioned as being almost prohibitive. Calibrated signal generators it is true, cost in the neighborhood of four hundred and fifty dollars and this price is beyond the reach of even the above-average equipped service shop. We will grant this, but fortunately gain-per-stage measurements can be made without the use of a calibrated attenuator—with the *ordinary* signal generator—by noting the change in audio output—on an *ordinary* output meter—when the *same* signal voltage is applied to the grids of two successive stages. The gain is then equal to the ratio between the two audio outputs or, if an attenuator (audio) is used between the output meter and the receiver, then the gain is numerically equal to the attenuation required to keep the output meter reading at the same value when the signal generator is switched from the grid of the one stage to the grid of the one preceding.

To our way of thinking, a precision, calibrated signal generator constitutes a luxury and convenience in making gain-per-stage tests, and as such is not absolutely necessary. However, it so happens that the introduction of sensitivity testing will automatically bring about an increased demand for signal generators with calibrated attenuators, and we have it on good authority that on a quantity production basis such generators can be sold for under one hundred dollars.

One of the objections which has come to our attention in connection with the inclusion of sensitivity data in service notes is that it is impossible to supply accurate figures on the various gains-per-stage, because of the variation in these figures among individual receivers of a particular model. The objection is a valid one to a certain extent; however, it is quite possible to specify the sensitivity and gain-per-stage figures in terms of an average value with the tolerance indicated. This is a fairly common practice in service data, as we often find that resistors and condensers are specified in terms of an average value and are stated as being subject to a variation of plus or minus 20%. In by far the majority of cases, the tolerance is omitted from the data, and then it is left to the judgment of the serviceman to understand from the manner in which the part is used in the circuit that a certain variation from the stated value is permissible.

The same sort of reasoning applies to the inclusion of sensitivity and gain-per-stage data in service notes. The serviceman must understand or must be taught to understand that the figures given are subject to variation as a result of manufacturing tolerances, humidity, temperature changes, and other factors. Almost invariably, however, when a fault occurs in a receiver, the effect upon the gain is so marked that the question as to whether the variation is due to a real defect or whether it is a permissible one and therefore not a significant variation, is one that will seldom arise.

In connection with the use of sensitivity and gain-per-stage data, there is a natural and understandable tendency on the part of the serviceman to use this information as a basis of comparison among different receivers. This has been an objection voiced by some manufacturers and while a basis for the objection exists, it certainly is not an insurmountable obstacle. The service industry can be made to understand that the purpose of sensitivity data is to expedite service operations, and not for the comparison of the relative merits of different receivers. The serviceman will not take upon himself the functions of a design engineer and condemn a certain receiver because in his opinion the gain of a certain i.f. stage should have been higher than the data supplied indicates. Too many other considerations are involved in a receiver besides that of sensitivity and gain-per-stage, to enable the serviceman to pass judgment on a receiver on this basis. *The only function which sensitivity data has in servicing is that of reducing the amount of time required to restore a receiver to its original operating condition.*

The sensitivity method of checking is no panacea for the problems involved in the servicing of present day receivers. However, based on our own experience and the experience of manufacturers who have for a long time used this obvious and logical method of troubleshooting, we are led to the conclusion that the widespread use of this method will go far toward putting radio servicing on a scientific and systematic basis. After a careful consideration of all the factors involved, we find that servicing has much to gain by adopting sensitivity checking as a means for the rapid localization and isolation of defective conditions. Naturally many considerations are involved in the correct use of this method, and many problems must be worked out and explained. This will come later on.

BOOK REVIEWS

BOOKS submitted to the Review Editor will be carefully considered for review in these columns, but without obligation. Those considered suitable to its field will also be reviewed in RADIO.

AUTOMATIC FREQUENCY CONTROL SYSTEMS, John F. Rider. Published by John F. Rider, Publisher, 1440 Broadway, New York City, N.Y. 142 pages; illustrated; $1.00 in U.S.A.

A.F.C. systems require a rather specialized method of treatment for their adjustment and alignment. In this book Mr. Rider completely analyzes their theory of operation and the correct procedure in their servicing.

The book is divided into six main divisions: General review, the discriminator, the oscillator control circuit, commercial a.f.c. circuits, aligning a.f.c. circuits, and servicing a.f.c. systems. Ample information is given to allow the receiver-design engineer to employ the system in new receivers or to assist the service engineer in the proper adjustment of existing receivers incorporating the system.

•

TELEVISION, VOLUME II. Published by RCA Institutes Technical Press, 75 Varick Street, New York, N.Y. 435 pages, printed in U.S.A., available from the publishers.

"Collected addresses and papers on the future of the new art and its recent technical developments," to quote from the complete title of the work. The book is a compilation of some 29 recently published works and papers of the RCA Manufacturing Company concerning television itself and the various factors associated with the art.

•

TUBE COMPLEMENT BOOK. Published by Hygrade Sylvania Corporation, Sylvania Radio Tube Division, Emporium, Pennsylvania. 165 pages, 4½" by 9", $0.25 in U.S.A.

A new-type reference book, pocket size, for the service man. Tube complements are given on over 10,000 radio receivers, i.f. frequencies for those that are superhets and information on tube replacements for all receivers from early models to the 1938 sets. Other additional information on sets, their manufacturers, and the addresses of the manufacturers is given.

•

RADIO ENGINEERING, F. E. Terman. Second edition, 813 pages, 6"x9", 475 illustrations. Published by McGraw-Hill Book Co., Inc., 330 W. 42nd St., New York. Price $5.50 in U.S.A.

Prof. F. E. Terman's first edition of Radio Engineering needs little mention to radiomen throughout the world. Its acceptance as the standard reference text has been unanimous. The second edition has been almost entirely re-written—with the exception of the first few introductory chapters—in the same high standard as the first edition. A new chapter on television has been introduced and a great many subjects throughout the book have been more exhaustively treated.

The new edition has been brought up-to-date so thoroughly that many owners of the first edition will find ample material in the second to justify its purchase.

•

THE INTERNATIONAL BROADCAST AND SOUND ENGINEER; editor, A. L. J. Bernaert, assoc. I.R.E. Distributed in the Americas by Pilgrim Electric Corp., 44 W. 18th St., New York, N. Y. 225 Pages, illustrated, $1.50 in U.S.A.

A compilation of information of interest to the broadcast and sound engineer from authoritative sources throughout the world. Some of the more universally interesting articles are translated (in resumé) into the more generally used foreign languages. All the technically active European and North and South American countries are represented by articles written by authorities in their fields. All the works appear in English; some have been made into resumés in other tongues.

•

TELEVISION CYCLOPEDIA, A. T. Witts, A.M.I.E.E. Published by D. Van Nostrand Co., Inc., 250 Fourth Avenue, New York, 152 pages; illustrated; $2.25 in U.S.A.

A comprehensive though concise treatment of all terms commonly encountered in television work. The author does not stop with a discussion of only the electrical terms used in the field; television optics, chemistry, and photography are thoroughly covered under the various headings in which they fall. This book is not a mere compilation of a number of definitions; the writer has attempted to make it as complete as possible though the matter under each heading has been limited to a maximum of two pages.

This book should be a valuable aid to anyone interested in the technical side of the new art, and it should be found a worthwhile addition to the reference library of all persons connected with the field.

A GUIDE TO AMATEUR RADIO; editor, John Clarricoats, G6CL. Published by The Radio Society of Great Britain, 53 Victoria Street, London, S. W. 1, England. 162 pages, adequately illustrated; price 9d. postpaid anywhere.

A complete handbook on amateur radio, similar to the RADIO and A.R.R.L. handbooks as published in this country, although considerably smaller in editorial content. The entire field is covered after an outline similar to the ones used in the above mentioned books, the main difference being that the subject is discussed from the European standpoint. A quite comprehensive chapter is devoted to television from the modern standpoint, iconoscope image dissection, cathode ray reproduction, etc., and another chapter to the useful data and formulae that may be used in amateur radio work.

A number of transmitters and receivers are described that use American tubes or can easily be adapted to use them. Directional antennas for both transmitting and receiving are comprehensively treated in the chapter devoted to antennas.

The book is a thoroughly worthwhile work and should prove of great interest to the American amateur who is interested in amateur radio from the British point of view.

The following is an extract from the ancient and honorable *Operators Wireless Telegraph and Telephone Handbook:*

"The Audion has proven very sensitive for use in wireless telephony, yet it is doubtful if it will ever come into wide use, owing to the difficulty in manufacture and short life. Usually quite a number of Audions have to be tested out before one sensitive enough for general use is found."

THE TECHNICAL FIELD

in Quick Review

•

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

All-Wave Radio

OCTOBER, 1937
Manson Publications Corp.
16 E. 43 St., N.Y.C.
25c a copy—$2.50 yearly

THE ORTHOTECH UNIVERSAL SUPER, *by Raymond P. Adams*—In this first installment of his article describing a flexible 10-tube superhet receiver, Mr. Adams takes up the basic unit of the set. The receiver includes Lamb noise suppression, a separate a.v.c. circuit, volume range expansion, beat oscillator, phone-radio switching facilities, dual a.f. preamplifier channels for fader selection of crystal mike or phone-radio input, and 30 to 60 watts output. It is unusually efficient on both short and long-wave reception.

INTERSTATE 5-METER NET—A short discussion of the aims and past activities of the Interstate 5-Meter Net started by W2HUT in November, 1935. The article indicates the necessary requirements for any amateurs who would like to join the group.

WIDE RANGE PHONO-RADIO UNIT, *by Chester Watzel and Willard Bohlen*—This receiver described by the authors is the balance of the wide range system for music reception, the audio amplifier of which was described in detail in the September issue of *All-Wave Radio*.

September, 1937—

WIDE-RANGE MUSIC FOR THE HOME—1938 VERSION, *by Chester Watzel and Willard Bohlen*—Wide-range reception ordinarily implies a reproduction from radio or record of the complete band of musical frequencies. The authors, however, include in their use of the term "wide-range musical reproduction", a relatively flat reproduction of all audible frequencies, no particular tone being amplified out of proportion to others; a high "safety factor" to prevent distortion due to mechanical or electrical overloading; volume expansion to extend the volume range of recorded music to more nearly reproduce a replica of the original, and provisions for eliminating the bad effects on both tone and volume level of the "back door" acoustics of the average loud speaker system. This first installment deals only with the amplifier and loud speaker system. The receiver is to be discussed in the October issue.

PORTABLE OR QRR SELF-POWERED C.W. XMTTR.-RECEIVER, *by Myron C. Morris*—Another portable rig designed to operate from a 110-volt a.c. line or from a 6-volt storage battery. The transmitter uses a 6L6 tetrode oscillator and the receiver employs a 6K7 as a regenerative detector, followed by a 6F6.

ARMCHAIR TUNING WITH REMOTE CONTROL ADAPTER UNIT, *by Clifford E. Denton*—The small self-powered unit described by Mr. Denton can be installed with any of the older t.r.f. or superheterodyne types of receivers, thus to bring them quite up to date. Two tubes are used, a 6A8 as a mixer tube and a 25Z6 as a rectifier for supplying plate voltage to the 6A8. Tuning and volume control from a remote point is made possible with this unit.

BOXING THE ELEMENTS—By means of two, new, especially-designed testing rooms which can simulate any of the unusual conditions to which radio equipment might be subjected, G. E. engineers now are able to determine accurately the mechanical fitness and electrical efficiency of recent aeronautical transmitting designs. The effects of snow, sleet, wind, extremely low and high temperatures, high altitudes, and excessive pressures can be duplicated within a few hours.

o

COMMUNICATIONS

SEPTEMBER, 1937
25c a copy—$2.00 yearly
Bryan Davis Pub. Co., Inc.
19 E. 47 St., N.Y.C.

CONSOLE TYPE SPEECH-INPUT EQUIPMENT, *by John P. Taylor*—In recent months console speech-input assemblies have come increasingly into prominence. This type of assembly more or less is a development of the past two years. Before this time the accepted speech-input design was a rack-mounted, panel-type affair. The economy requirements of the smaller stations and their increasing number accelerated the development of the newer type assembly. The author describes more or less in detail, five of these commercial console arrangements.

SPECIAL EMERGENCY STATION, *by Maurice E. Kennedy*—Following repeated interruptions of telephone communications with various key control positions as a result of storms or floods, the Los Angeles County Flood Control District has set up an emergency radio system to insure against further interruptions. The key of the system is the central 500-watt transmitter located in the city proper. At the San Gabriel Dam, in the valve-control house, a Collins type 30-FXC transmitter, modified for 2726- and 3190-kc. operation, is available. A portable unit, for use with the emergency truck, will be self contained with a 110-volt alternator geared to the truck's engine. In addition, cars and trucks of field engineers are equipped with 2726 kc. fixed-band receivers. These intermediate frequencies are found to be more suitable than higher-frequencies to this work because of the rugged country between communication points.

MIDGET REMOTE AMPLIFIER, *by Loyd C. Sigmon*—The midget remote amplifier described by the author employs acorn tubes, compact high-fidelity audio transformers, and other high quality compact components. It has a frequency response within two db from 50 to 9,000 cycles; harmonic distortion of 0.15% rms at 0.006 watts output power; background noise and hum level of -45 db; gain per channel with output pad in of 107 db. It measures 9¾ x6¼ x6½ inches weighs 9 pounds and is a.c. or d.c. operated.

METHOD OF ANALYZING ACOUSTIC-FEEDBACK HOWL, *by C. O. Caulton*—An informative analysis of the causes and remedies of the four most common sources of acoustic howl, (1) radio frequency stages, (2) oscillator, (3) intermediate-frequency amplifier and (4) the audio frequency stages.

•

electronics

OCTOBER, 1937
50c a copy—$5.00 yearly
McGraw-Hill Pub. Co., Inc.
330 W. 42 St., N.Y.C.

SCANNING IN TELEVISION RECEIVERS, *by Frank K. Somers*—"Scanning-circuit design has no counterpart in present broadcast receiver practice, a fact which makes it an important subject for radio engineers who soon may be faced with the problem of television receiver development." Written by an engineer of Farnsworth Television Inc., the article outlines some of the important features of television-receiver scanning and shows why certain precautions should be taken in the design of the scanning circuits to avoid image distortion and loss of picture detail. It is illustrated by charts of the action of the scanning wave under different conditions of operation.

TELEVISION IN GREAT BRITAIN, *by H. M. Lewis and A. V. Loughran*—Two engineers of the Hazeltine Corporation relate their observations in the comparative technical advances of American and British television practice, the result of their setting up a laboratory in London to study the situation at first hand. The discussion deals with practical reasons for the apparent superiority of television practice in England. Also discussed are their receivers which are available to the public, technical details of British and American circuits and scanning and focusing methods. Charts of operating characteristics and related circuit diagrams for transmission are shown.

September, 1937—

SHIP TO SHORE COMMUNICATION, *by R. H. Riddle*—The title of this article refers to telephone service to and from shore for passengers as inaugurated in 1929 by the American Telephone and Telegraph Co. It is a complete description of the mode of operation of the system at the present time. The many lines of communication necessary for this service are shown by block diagrams. Included are brief descriptions of the transmitting shore stations and receiving stations, with some information as to the antennas used. Several types of standard transmitters are dealt with in some detail. The equipment on the "Queen Mary" used in this service is described as representative of that used on modern liners for ship-to-shore telephone service.

TELEVISION IN EUROPE, *by M. P. Wilder*—As this inspection trip was just recently made to Europe for the specific purpose of reviewing the television apparatus in use, this is an up-to-date report on the various apparatus and methods in use at the present time. Scanning methods, picture detail and manufacturing methods are discussed, and pictures of British and German television sets are shown in this 3-page article.

PUSH BUTTON STATION SELECTION, *by B. V. K. French*—A discussion of the systems now in use and those in sight for this method of automatic tuning. Schematic diagrams are shown of motor-tuned and condenser substitution methods and of the apparatus related thereto.

QST devoted entirely to
AMATEUR RADIO

NOVEMBER, 1937
25c a copy—$2.50 yearly
American Radio Relay League
West Hartford, Conn.

10-WATT SPEECH AMPLIFIER WITH VOLTAGE-REGULATED PLATE SUPPLY, *by George Grammer*—A description of a high-gain amplifier unit designed to be used with the voltage-regulated power supply described in August QST. The 4-stage amplifier is capable of ten watts output normally and by substitution of fixed bias the output can be raised to around 15 watts. The input end is so designed that either a crystal microphone or, without circuit changes, a double-button carbon microphone can be used.

NEW I.F. AMPLIFIER SYSTEM WITH INFINITE OFF-FREQUENCY REJECTION, *by Karl W. Miles and J. L. A. McLaughlin*—Descriptive of a new system of attenuating i.f. sidebands by coupling units which are individually infinitely selective as to the rejection of off-frequency interference. The article deals with the theory involved and is illustrated with photos and circuit diagram of the experimental infinite-rejection i. f. amplifier. Curves showing its performance at adjacent frequencies are given. Photos of response curves as produced on a cathode ray oscilloscope are also shown.

MAKING THE MOST OF DIRECTIVE ANTENNAS, *by Don Wallace*—A description of the numerous directive antennas at W6AM, the well known amateur station of the author. Practical pointers are given on the best procedure in operating a number of such antennas in a limited space. The arrays dealt with include half-waves in phase and modified Sterba curtains and all are bi-directional. The author also tells of experiences in getting the antennas to really point where they should and the resulting improvements.

•

RADIO

NOVEMBER, 1937
30c a copy—$2.50 yearly
RADIO, Ltd.
7460 Beverly, Los Angeles

PEAK COMPRESSION APPLIED TO THE SPEECH AMPLIFIER, *by Ray L. Dawley*—As a result of recent work which has been done on a method of limiting audio peaks in amplifiers to increase the usable gain without danger of overmodulation, this speech amplifier was designed for amateur radiotelephone use. Complete data is given on the operation of the peak rectifier circuit, phase inverter and other essentials in the circuit. The article is illustrated with photos showing the physical layout of a speech amplifier of this kind and the circuit diagram thereof.

IMPEDANCE MEASUREMENTS WITH A MATCHING STUB, *by Robert M. Whitmer*—The measurement of the terminal impedance of an antenna or a beam array always has been somewhat of a closed subject as far as the amateur was concerned. The amount of expensive measuring equipment required has always been prohibitive. In this article Mr. Whitmer shows a method whereby such measurements may be made with nothing more expensive than a quarter-wave matching stub. Although the mathematics in the first part of the article may seem prohibitive to some, they are there merely to prove the validity of the measurements and no mathematics are required in making the actual measurement; all calculations have been made and set down in chart form so that it is only necessary to refer to the chart to find the value of impedance.

HORIZONTAL RHOMBICS, THEIR PROPER ADJUSTMENT, *by Morton F. Moore and F. L. Johnson*—Besides the scope of this article as indicated in the title, much data is given on the general design of such an antenna, the importance of terminating it properly, methods of determining the proper terminating impedance and some information on the construction of several terminating devices. The article includes a number of photos and charts and several pages of mathematical derivations pertaining to the points which are dealt with in the article.

REVIEWING U.H.F. PROPAGATION, *by H. H. Beverage*—An article providing information on the propagation characteristics of frequencies above 30 Mc. Propagation within optical distance, equations relative to the angles thereof, ground wave propagation beyond the horizon, and sky wave propagation are discussed. A chart shows the attenuation of ground-wave field strength beyond the horizon with respect to frequency. At the end of the article there is an extensive bibliography of the subject.

October, 1937—

THE GRAND ISLAND MONITORING STATION, *by Rufus P. Turner*—To the U. S. radiomen the importance of Grand Island, Nebraska, rests upon the fact that it is the location of the central monitoring station of the Federal Communications Commission. Mr. Turner describes the location and equipment of this important "traffic policeman" of the air. The described equipment includes the primary and secondary standards of frequency and the recording equipment. Methods of measurement of frequency and recording of field intensities, progress and code signals are also treated.

IMPEDANCE MEASURING DEVICE FOR HIGH RADIO FREQUENCIES, *by Morton E. Moore and F. L. Johnson*—The authors discuss the theory and difficulties of measuring frequencies as high as 30 Mc., particularly as related to antennas and their feeders, and describe the construction and method of use of a high frequency oscillator and an impedance measuring unit. Equations for calculating the various types of measurements are shown and the article is fully illustrated by circuit diagrams and photos of the measuring apparatus.

•

RADIO NEWS
AND
SHORT WAVE RADIO

NOVEMBER, 1937
25c a copy—$2.50 yearly
Teck Publications, Inc.
461 Eighth Ave., N.Y.C.

THE COMMUNICATION 14, *by Clifford E. Denton*—The first part of a constructional article on a large 14 tube, 5-band receiver of professional appearance but built entirely from parts available on the open market. As far as practicable, every recent advance in receiver design is incorporated, and wherever it was to advantage to use variable control, a control was brought out to the front panel. Although this results in 11 variable controls, the greatest efficiency is had in controlling the receiver for different conditions of reception.

BLACK LIGHT BURGLAR ALARM, *by Guy Forest*—As a profit-making item for the service man, this application of the photocell is cited by the author. Constructional data of light transmission and reception units, with circuit diagrams and sheet metal layouts are shown. By means of a simple glass filter, infra red rays, which are invisible to the naked eye, are the actuating light source.

THE T&R BULLETIN
A JOURNAL FOR RADIO EXPERIMENTERS

SEPTEMBER, 1937
12s. 6d. yearly
Radio Society of Gt. Brit.
53, Victoria St., London

THE 1937 OLYMPIA TRANSMITTER, *by G. McLea Wilford*—In this third and concluding installment of his article, Mr. Wilford describes in detail his speech amplifier-modulator unit. Either a carbon or crystal microphone may be used, and changing from one to the other is possible simply by the throwing of an s.p.d.t. switch. The unit will deliver at least 100 watts of audio output.

A MODERN U.H.F. SUPERHETERODYNE RECEIVER, *by J. N. Walker*—Mr. Walker justifies the use of a superheterodyne receiver for U.H.F. work, and then proceeds to describe one. Band spread by means of small tuning condensers is included, as is an r.f. amplifier stage and a.v.c. The local oscillator employs a British-made acorn triode. Plug-in coils permit operation on the 28 Mc. band as well as on 56 Mc.

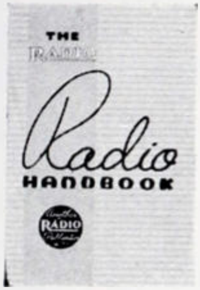
DIAMOND AERIALS, *by Byran Groom*—A discussion of the trials and tribulations encountered during a series of experiments with various sizes and heights of a diamond antenna. The author describes the arrangement finally decided upon and includes some data on its directivity as well as some practical constructional suggestions.

AUGUST 56 MC. FIELD DAY, *by J. N. Walker*—It is encouraging to note the progress being made in 56 Mc. work throughout the world. This article, and another one devoted entirely to this band, provides some interesting information concerning the conditions of 5-meter activity in England.

A D. C. TEN-WATT TWO, *by V. O. Hawkins*—The author's only source of power is the 110 d.c. which is distributed in his district. The transmitter that he has evolved is interesting; it operates from the 110-volt d.c. line. The set uses American tubes; a type '43 as a regenerative crystal oscillator and a type '48 as a neutralized power amplifier. The cathode regeneration circuit employed in the oscillator is that of Frank C. Jones.

Soon to be Released...

THE GREATEST BOOK OF ITS KIND
EVER PUBLISHED



THE 1938

Radio

HANDBOOK

By

Frank C. Jones and
the Technical Staff of **Radio**

$1.50 IN CONTINENTAL U. S. A.
Elsewhere, $1.65* or 7s*.

*Canadian postal notes and British postal orders accepted. All other remittances should be payable at par in continental U. S. A.

Postage
Will Be Paid
by
Addressee

No
Postage Stamp
Necessary
If Mailed in the
United States

BUSINESS REPLY ENVELOPE

First Class Permit No. 7241, Sec. 510, P. L. & R., Los Angeles, Calif.

RADIO, Ltd.

TECHNICAL PUBLISHERS

7460 Beverly Boulevard

Los Angeles, California

*Canadian postal notes and British postal orders accepted. All other remittances should be payable at par in continental U. S. A.

Another
RADIO
Publication