

The GENERAL RADIO EXPERIMENTER

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An Effective Method of Measuring Amplification

By L. B. ROOT, Engineering Department

The first years of development in radio broadcasting were devoted mainly to the improvement of the sensitivity and selectivity of the receiver. The best set was the one that could pick up a station perhaps two thousand miles or more away, and amid tube hisses and crashes of static, enable a careful listener to discern the call letters. Perhaps a moment later the station had faded out completely, but the enthusiastic fan was happy in the knowledge that his set was capable of the unusual.

The trend of feeling toward distant reception has changed, and though there are many exceptions, the great majority of people are now content to listen to the nearby stations.

This change was brought about mainly by two things, the advent of chain broadcasting and the improvement in quality at both transmitter and receiver. The former made it unnecessary to go outside of one's immediate locality to listen to a good program by well known artists, while the latter gave such good reproduction from the local stations that more distant reception was decidedly unsatisfactory from the viewpoint of quality and certainty of nearly constant volume.

These developments have made the set manufacturer alert to design speakers that would more faithfully reproduce the studio program in the home. In order to do this, the audio



Figure 1
The General Radio Type 355
Amplifier Test Set

frequency amplifier must do its part in passing the detector output to the speaker, increased in volume, but undistorted. It is here that poor quality generally, but not always, originates.

The Associated Manufacturers of Electrical Supplies were confronted with the problem of obtaining characteristic curves on transformer, impedance and resistance amplifiers. Several more or less satisfactory methods were in use, each having its advantages and disadvantages. Roughly they were divided into two classes, those methods which included the tube in the measurement, and those which did not. For simplicity, it was decided to eliminate the tube, and use for comparison, curves which showed the performance of the coupling device only.

Of course, it was necessary that

operating conditions be closely approximated if not actually obtained, in order that comparisons might be fair.

The General Radio Type 355 Amplifier Test Set is built around that idea and permits the accurate determination of performance. It is as simple in construction and operation as is consistent with correct results. It permits testing with a resistance in series with the input circuit of the coupling device which corresponds to the plate impedance of any ordinary tube, and the corresponding direct current which that tube would draw in use. The output circuit carries a tube capacity not greatly different from most tubes, and this may be increased by adding a very small variable capacity if desired. Of course the secondary should not carry any direct current, and this condition is made certain by so designing the tube voltmeter that it is impossible to take amplification readings if the grid takes current.

The Test Set is nearly self-contained, having only a 6-volt storage battery and the source of audio frequency external to it. It may be used with any audio source, either variable or fixed in frequency. The General Radio Type 377 Oscillator is particularly suited to the purpose.

The diagram on page 2 shows the operation of the set when measuring transformers.



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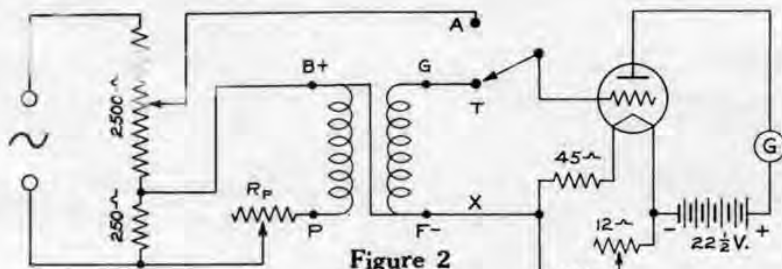


Figure 2

The audio frequency is applied across the two resistances of 250 and 2500 ohms respectively. The primary of the transformer is connected across the 250 ohm section, with the variable resistance R_p in series to represent the plate impedance of the tube with which the transformer is to be used. This may be 5000 to 25,000 ohms. The secondary is connected to a UX 199 tube which is being used as a tube voltmeter. A six-volt storage battery supplies the filament through a 45 ohm resistance, giving three volts across the filament and a three-volt negative bias on the grid. Even with the comparatively high bias and only 22.5 volts on the plate, some current will flow and deflect the galvanometer G. To correct this the suspension of the galvanometer is twisted so that it reads zero with the tube lighted. When the filament is out, the pointer goes off scale below zero, of course. This galvanometer is partly calibrated, in that the scale is marked to show the deflection obtained when one volt A. C. is impressed on the grid of the tube.

The 2500 ohm resistance is a potentiometer which has a direct reading scale, calibrated from 0 to 10, each main division corresponding to 250 ohms. The calibrated 1 volt point on the galvanometer applies only when the potentiometer reads 1. In this case it is obvious that the voltage across the transformer primary (including plate impedance R_p) is the same as that applied to the grid of the tube, and when the potentiometer reads 2, the voltage input is .5, etc. With this relation in mind, any reasonable input voltage may be applied using only the one known point on the tube voltmeter.

TRANSFORMER CHECKING

To check the amplification of a transformer the procedure is as follows. Suppose that the curve is desired at .5 volts input. R_p is set at a value corresponding to the plate impedance of the tube with which the transformer is to be used. The input frequency is set to a known value, and with the switch on point

A, and potentiometer scale reading 2, the voltage is increased until the galvanometer indicates one volt. Then the switch is thrown to T, so that the vacuum tube voltmeter is excited by the transformer secondary and a certain galvanometer deflection is obtained. The switch is then

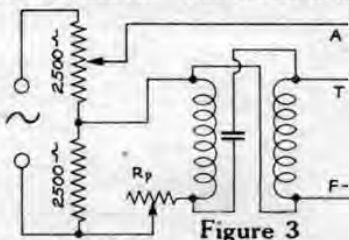


Figure 3

returned to A and the potentiometer adjusted to obtain the same deflection as while on point T. The potentiometer scale reading now indicates the voltage amplification directly.

The sensitivity of the galvanometer is such that an input of more than about 1.7 volts will throw it off scale, and the grid of the tube will begin to take current. With many transformers, this situation does occur. This is remedied by cutting in an additional adjustable bias at the point X with a switch, permitting the reading of amplification up to 10,

without any grid current being taken, even though the voltage may become quite high.

IMPEDANCE CHECKING

Impedance or resistance couplings are checked in a similar manner but with slight circuit changes.

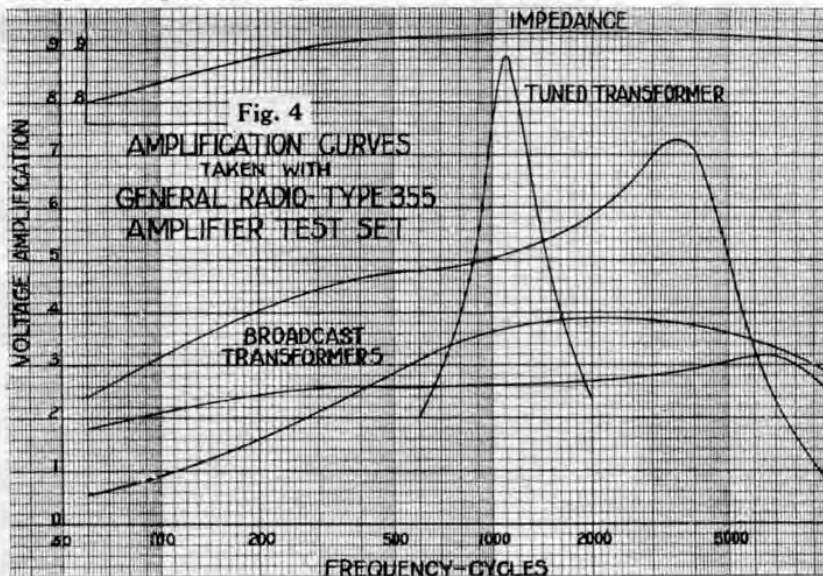
A switch changes the input resistance connections as shown in fig. 3. Since the potentiometer is calibrated 0 to 10, the readings are now one-tenth of former indications and a one-volt input is obtained with the potentiometer scale reading 10. The procedure is now the same as before.

If desired, direct current may be used in the transformer or impedance to determine its effect on the resultant performance curve. Likewise, a tube may be connected across the secondary to determine the effect of capacity.

Attention should be called to the fact that the vacuum tube voltmeter is used only as a transfer instrument, so that changes in the tube characteristics, or the running down of batteries have no effect on the accuracy of measurement. These things will affect the calibration of the 1 volt point, but even large percentage changes of input voltage have little effect on the resulting curve.

The Test Set finds its greatest use in design work, either to determine the proper coupling device to use under certain conditions, or to develop the coupling unit itself. The rapidity with which points may be taken, makes it easy to plot many curves with only a small consumption of time.

Figure 4 shows curves on various transformer and impedances, taken with the Test Set





Coil Calculations

By C. T. BURKE, Engineering Department

The experimenter has frequent occasion to design air core tuning inductances. As few have means of measuring the inductance of such coils after they are built, it is rather important to be able to predict the inductance of a specific coil, and conversely, to design a coil to have a given inductance.

The calculation of inductance for iron cored coils is impossible unless the permeability of the iron is known under the conditions existing when the coil is used. The design of air core coils, however, is relatively simple. Three variables are involved, the diameter of the winding, the length of the winding, and the number of turns. The generally accepted formula for the calculation of air core single layer solenoids is as follows:

$$L = 0.0251 \frac{d^2 n^2}{b} \text{ K microhenries}$$

L = inductance in microhenries
 d = diameter of the coil (in inches)
 b = length of the coil (in inches)
 n = number of turns
 K = a constant depending on the ratio of the diameter to the length of the coil.

Inspection of the formula shows that the inductance is inversely proportional to coil length, that is, the longer the coil, for a given number of turns, the less the inductance. This is due to the fact that in a long coil, much of the flux surrounding wires at one end of the coil does not link turns at the other end. If inductance were the only consideration, coils should be bunched in the shortest possible length, but the requirements for low coil resistance forbids this. The inductance is proportional to the squares of both the diameter and turns, that is, doubling either turns or diameter multiplies the inductance by four. Other things remaining equal, a change in coil diameter may be compensated for by a proportionate change in the number of turns.

The effect of changes in coil diameter and coil length are considerably modified by the constant K , which depends on the ratio of coil diameter to coil length. K is an empirical constant, i.e., is not a function of the coil dimensions, but has been determined by experiment. Since the value of K increases, as the ratio of diameter to length decreases, the constant tends to lessen the reduction of inductance as the coil is lengthened.

For accurate calculations, a table of the values of K is required. Such a table is contained in Circular 74 of the Bureau of Standards.* This book contains a great deal of valuable information and formulae, and is worth many times the price to anyone interested in radio laboratory work. Formulae are given for many types of coils other than the single layer solenoid.

The coil formula can be greatly simplified by choosing coil dimensions. If both length and diameter of the coil are always the same, the formula reduces to a very simple form, depending only on the number of turns.

For the standard General Radio Type 277 form, wound full length, the formula reduces to:

$$L \text{ (in microhenries)} = n^2 \times 0.000059$$

In order for this formula to apply, the coil must be wound the full length of the form, spaced if necessary.

It is often convenient or necessary to use a coil length different from the 277 form. A chart (Page 4) has been prepared, giving the solution of the formula for the case where diameter = 2.75 inches. This chart will be found sufficiently accurate for most purposes. As it is nearly always desired to design a coil to tune to a certain wave length with a given capacity, a chart for computing the required inductance has been combined with the inductance chart.

The inductance chart consists of curves of inductance against turns for various coil lengths. The inductance scale runs to 600 microhenries and 100 turns. The right hand scale, running to 30 turns, may be used for lower inductances. The inductance scale is divided by 10 when using the 1 to 30 scale of turns, that is, 64 turns on a 2-inch coil would give 240 microhenries, while 21 turns on the same length coil would give 24 microhenries inductance.

The use of the charts is simple and obvious. The inductance chart may be used either to determine the inductance of a coil already built, or to give the number of turns required to obtain a desired inductance. In the former case, the number of turns and the length of the winding are learned. Project horizontally along

the line corresponding to the number of turns until the curve for the proper coil length is reached, then project vertically to the scale of inductance. Thus, 40 turns, on a winding 1 1/2 inches long, gives an inductance of 115 microhenries. For smaller coils, use the right hand scale of turns. When using this scale of turns, inductance values read on the scale must be divided by ten. Thus, 5 turns on a winding 1/4-inch in length gives 4 microhenries inductance.

In designing a coil, the desired inductance and the length of the winding must be known. The procedure is then similar to that for the determination of inductance. The table of wire data accompanying this article will be found of use in calculating the coil length from the wire size.

SIZE B. & S.	TURNS PER INCH				
	Enamel	Single Silk	Double Silk	Single Cotton	Double Cotton
20	29	27	25	27	25
21	32	30	27	30	27
22	36	34	30.5	34	30
23	40	38	34	37	32
24	45	43	38	41	35
25	50	47	41	45	38
26	57	52	45	50	41
27	64	58	50	55	45
28	71	64	53	60	48
29	81	71	58	65	51
30	88	80	66	71	55

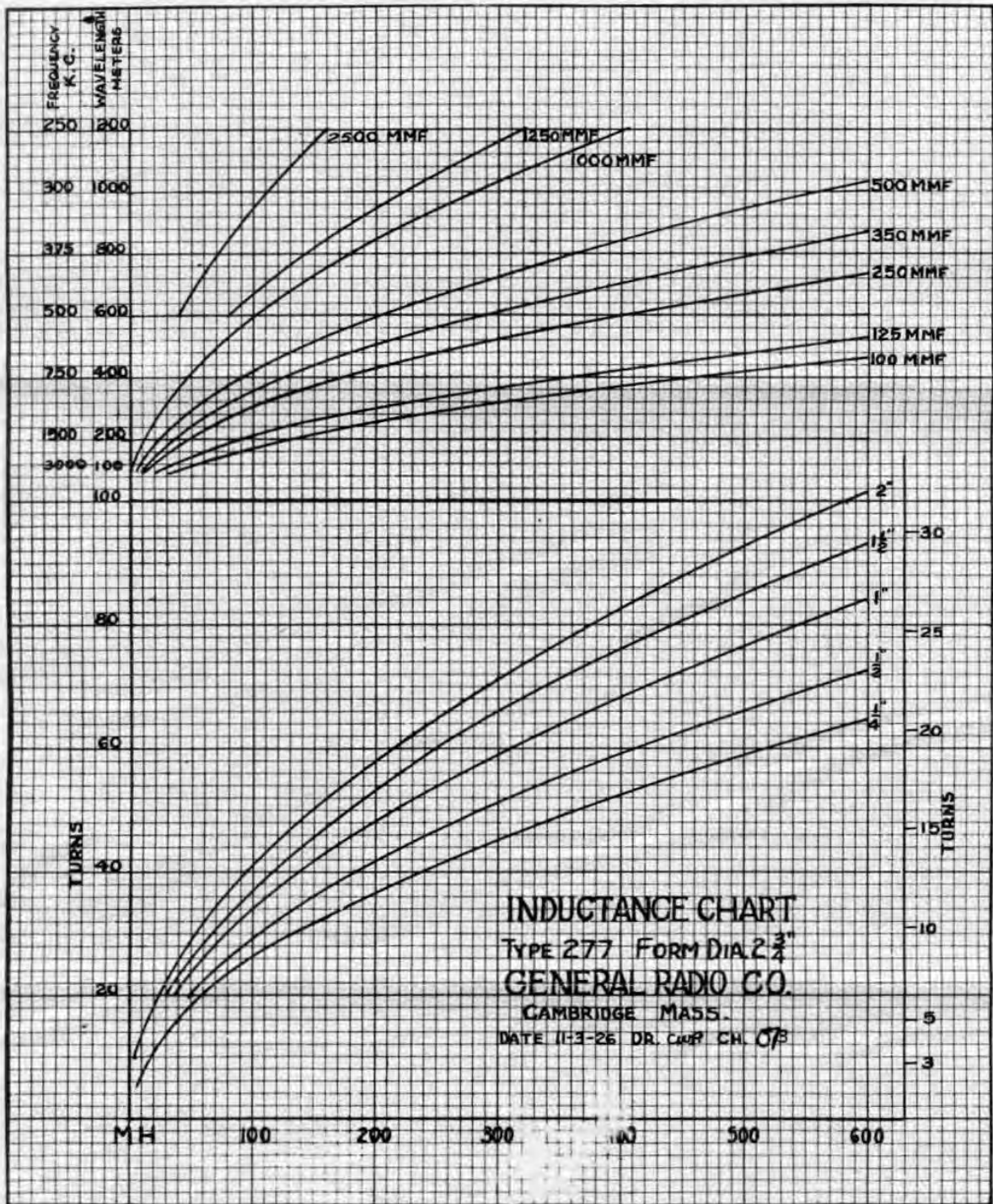
Considerable variation from the figures in the table may be expected, depending on the tension under which the coil is wound. If it is desired to wind a coil to tune to a certain wavelength with a given condenser, the upper part of the chart

*Obtainable from the Superintendent of Documents, Government Printing Office, Washington, D. C. Price \$.60.





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is used. A scale of frequency is shown beside the wavelength scale for convenience.

Suppose it is desired to tune to 500 meters with a 350 MMF condenser. Project horizontally from the 500 meter mark on the diagram to the curve for 350 MMF. Project down from the point of intersection into the inductance chart, and find that the turns required ranges from 45 with a 1/4-inch winding length to 72 with a winding length of 2 inches.

It should be possible to determine the winding length within a quarter of an inch from the wire data, and the coil is thus approximated within a turn or two.

The range of the chart may be extended by dividing the scales. Remembering that wavelength is proportional to the square root of the product of inductance and capacitance, it is obvious that the wavelength scale can be reduced to read to 120 meters by dividing the capa-

city and inductance scales also by 10. The right hand scale of turns is then used.

To find the turns required for tuning to 60 meters, project horizontally along the 600 meter line to the 2500 MMF curve and down to the inductance scale (e.g., 2 inches winding length). Projecting horizontally from the intersection to the **Right Hand** scale of turns, and find nine turns required.

