A NEW ANTENNA KIT DESIGN

By

W. L. Carlson and V. D. Landon

RCA Manufacturing Company, Inc., Camden, N. J.

Introduction

This paper deals with the design of a new noise-reducing antenna system of the all-wave type. The antenna proper consists of an inverted L or a vertical structure instead of the conventional dipole or group of dipoles. The polarization of international short-wave signals seems to have a random distribution so that on the average, reception is about equal on the vertical and horizontal components. In the broadcast band, signal strength compares favorably to that of previous designs, while the noise reduction is considerably improved, as will be explained later. Other advantages of the new design are its improved appearance, greater flexibility, and the ease of installation.

The Antenna Proper

The antenna specification calls for a single or multiple-wire antenna of 150-micromicrofarad nominal capacity. The capacity may vary from 75 to 300 micromicrofarads without seriously affecting performance. The first three figures show typical antenna installations. Figure 1 shows an installation in which a single wire constitutes the antenna. The relative lengths of the vertical and horizontal portions may be changed to suit the particular installation. Figure 2 shows a design which requires no horizontal portion. A self-supporting metal pole, insulated from ground by wooden supports, is used for the antenna. In this case the transmission line may be buried if desired. Figure 3 shows the type of antenna which is recommended where the highest obtainable signal strength on short waves is desired. The lower *L-C* ratio of this antenna gives somewhat better signal strength at some points in the short-wave band.

Design of the Transformer System

The circuit of the antenna system is given in Figure 4. The upper section of each transformer is for high frequencies and the lower section is for the broadcast band. Because of the great flexibility of the antenna specification, the impedance of the antenna for high frequencies is a variable quantity. For this reason this part of the antenna transformer was designed while using a resistance for a dummy antenna.

In the line-to-set transformer, the high-frequency section is designed to match the 100-ohm transmission line to a 200-ohm receiver.

In designing the broadcast portion of the kit a capacitive dummy antenna was used. The design of the broadcast sections of the transformers is rather novel. No attempt was made to match the surge impedance of the line for this frequency band. Instead, the line is treated as a capacity. This capacity is used to resonate the windings to which it is connected.

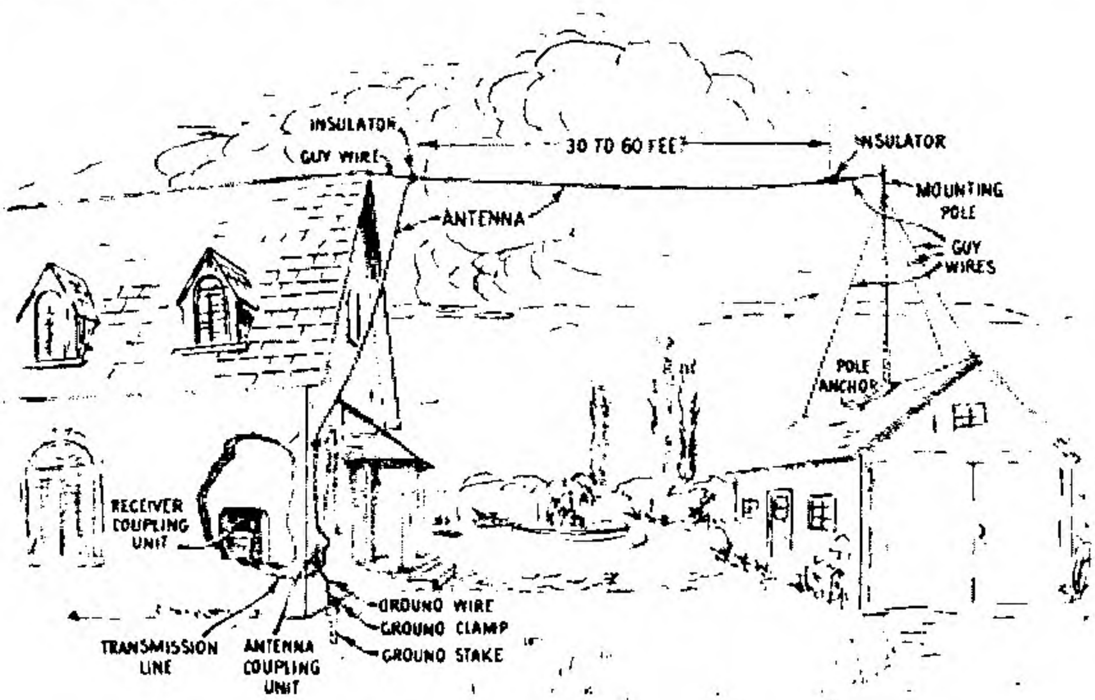

Fig. 1—Single-wire antenna installation.

The antenna circuit, the line circuit, and the set circuit are each resonant to the middle of the broadcast band. Tight coupling is used to broaden the response and the result is a three-peak response curve covering the broadcast band nicely. It is well known that when three identical circuits are coupled and used as a band-pass filter, the response curve has a typical head and shoulder shape. It is impossible with identical circuits to get the shoulders of the curve as high as the central portion. However, when the damping is largely concentrated at one end of the network, a relatively flat response may be obtained. This is true in the present case since the input impedance of the receiver constitutes a major portion of the damping of the network. This system results in an economy since it eliminates the need for the large capacitor which would otherwise be required to resonate each line winding in the broadcast band.

Due to the resonant condition of the line, the performance curve is changed somewhat by a change in line length. However, the effect is surprisingly small. A satisfactory curve is still obtained after changing the line length over wide limits. The line may be placed underground if desired with only a slight increase in the attenuation.

The performance data on the overall kit from dummy antenna to resistance load is given in Figure 5. For the broadcast band a resistance of 2000 ohms was used to represent the input resistance of a radio receiver. This is a common value of the input resistance at the frequency of resonance. Nevertheless, this curve is somewhat mis-

Fig. 2—Vertical antenna installation.

leading because this resistance is present as a load on the antenna system only at the frequency to which the receiver is tuned. At frequencies removed from resonance the impedance of the receiver is much higher. Thus the antenna system may resonate at frequencies differing from the frequency of reception, and reduce the apparent selectivity of the receiver. To reduce this effect a small amount of resistance is inserted in the antenna circuit. This resistance was not made as large as required by conventional filter theory as this would result in too great a sacrifice in signal strength. This resistance is obtained by using resistance wire in the primary winding of the broadcast section of the antenna transformer. The high-frequency performance is not affected.

Factors Affecting the Signal-to-Noise Ratio

The most important electrical characteristic of a receiving antenna is the ratio of signal to noise which is obtained from it. Thus a low noise level is just as important as a high signal level. The principle of operation of noise-reducing antennas is as follows:

The antenna proper is located in a comparatively noise-free area. Signals are transmitted from the antenna through the antenna transformer, the transmission line and the line-to-set transformer to the receiver. In most systems, including the one under discussion, the

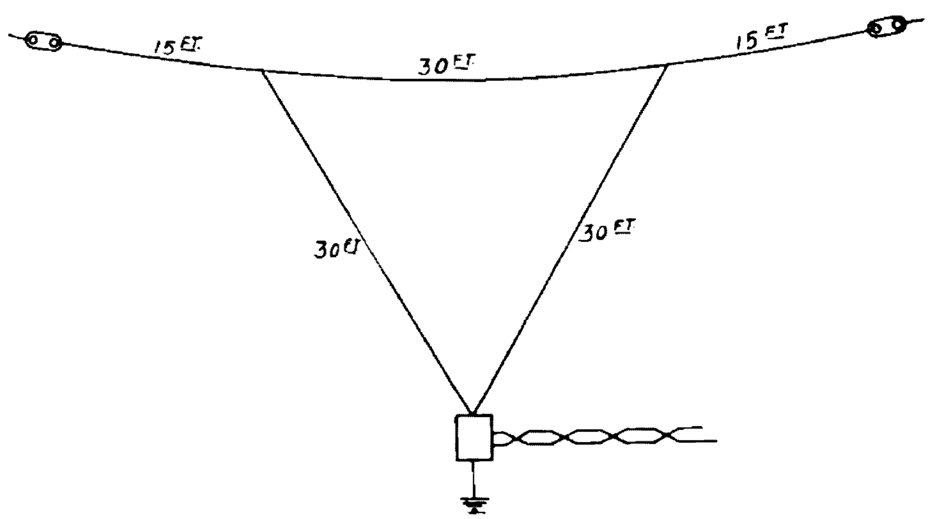

Fig. 3—Vertical "V" antenna.

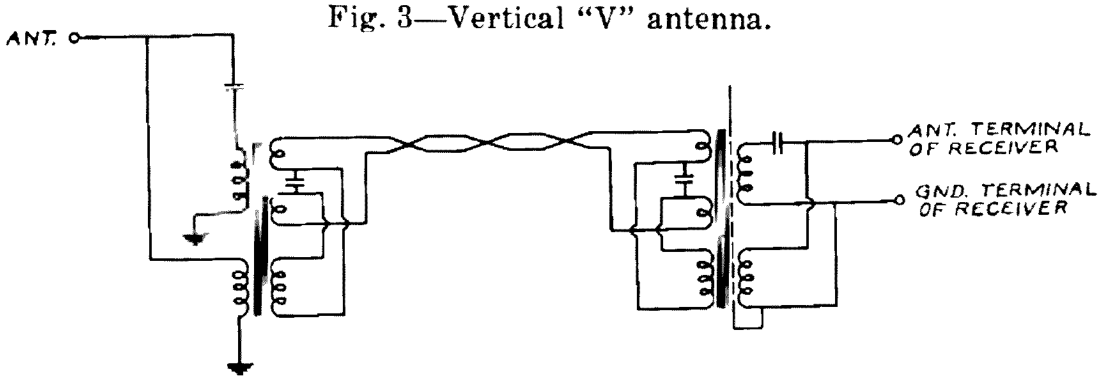

Fig. 4—Circuit diagram of the new antenna design.

transmission line is balanced to ground. The useful signals produce currents in the two sides of the line which are equal in amplitude and opposite in direction.

The noise, which is to be reduced or eliminated, arrives chiefly by way of the power cord of the receiver, though some noise is transferred from the power line or directly from the noise source to the transmission line by inductive or capacitive coupling. The noise coming in on the power cord puts a radio-frequency noise voltage on the chassis. In most locations it is difficult to reduce this voltage materially by grounding the chassis because the ground lead cannot be made short enough to have a low impedance.

The fact that the noise voltage appears on the chassis of the receiver does not necessarily mean that the voltage reaches the input terminal of the receiver providing the line-to-set transformer is properly shielded. If this transformer is well designed, then the only way of exciting the receiver is by means of a current in the primary. When the transmission line is balanced to ground, no primary current is produced by either a voltage on the chassis or a voltage induced on the transmission line. In each case equal currents flow on the two sides of the line, but these currents cancel each other in the primary.

In a practical set-up it is difficult to obtain complete-elimination of such disturbances. In general, the noise is attenuated a certain

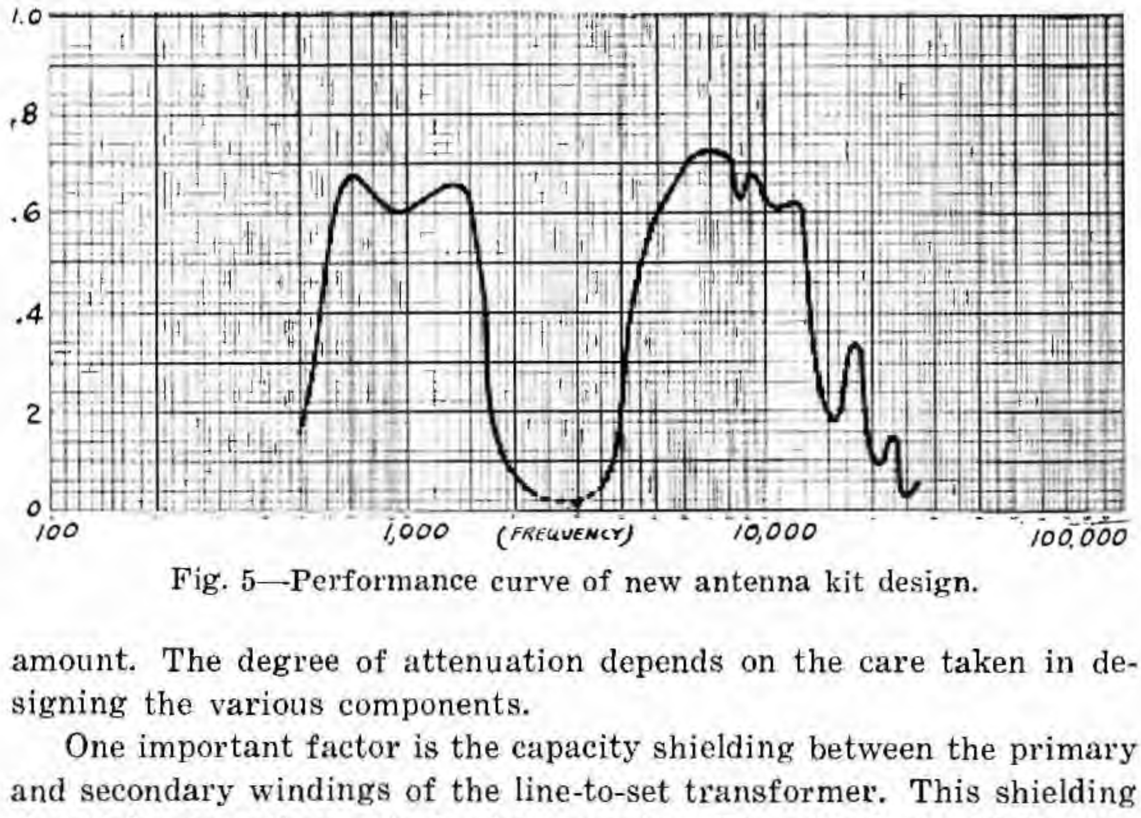

Fig. 5—Performance curve of new antenna kit design.

amount. The degree of attenuation depends on the care taken in designing the various components.

One important factor is the capacity shielding between the primary and secondary windings of the line-to-set transformer. This shielding should be very thorough for best results. The shield should be connected to the receiver chassis. If a separate ground were employed, line noise would not be eliminated due to the impedance in the ground wire.

Another important factor is the symmetry of the line winding. When a series condenser is used in the short-wave section, it should be placed in the center of the winding as shown. Otherwise the inequality of the capacities to ground throws the line out of balance. At best a certain residual unbalance will always exist. The effect of this unbalance is that the currents in the two sides of the line are not equal. A current equal to the difference between these two currents, flows in the primary winding inducing noise into the receiver. The effect of this residual capacity unbalance can be further minimized by a reduction in the capacity between the primary windings and the shield of the line-to-set transformer. This lowers the value of the noise currents in both sides of the line and hence lowers their difference. The magnetic balance is also improved by spacing the primary and secondary windings apart.

Figure 6 illustrates how these principles are utilized in the present design. This sketch is a cross section of the set-to-line transformer. The shield consists of a sort of fabric woven with wires running in one direction and threads at right angles. The wires are soldered together at one end and grounded to the chassis. This cloth is wrapped around the coil form outside of the primary windings. All primary connections go to the terminal board to the left. The secondary coils are outside the shield and all connections go to the terminal board to the right. Each of the primary coils is separated from the shield by

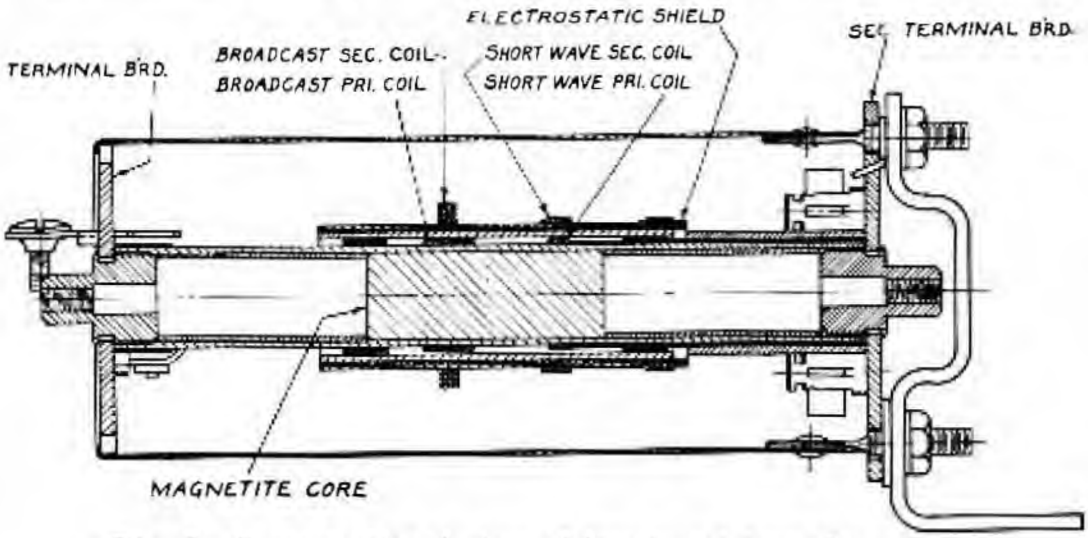

Fig. 6—Cross-sectional view of line-to-set transformer.

a considerable air space. This results in a low capacity to the shield and minimizes the leakage capacity through the shield. This leakage capacity would be quite appreciable if the windings were placed very close to the shield. The magnetic core is used to maintain tight couplings in spite of the comparatively large spacing between the windings.

It is also necessary to use care in designing the antenna transformer if good noise reduction is to be obtained. The line winding should be kept symmetrical in its capacity to ground. Otherwise, equal noise currents flowing up the two sides of the line are reflected unequally and the difference component is passed into the receiver.

The broadcast primary is a universal coil and is placed outside the secondary winding spaced 1/16 inch from it. The start of the primary coil is grounded and hence the first few turns act as a capacity shield for the rest of the winding. The use of a Faraday screen between windings was found to do more harm than good in this transformer, because of the voltage drop across the impedance of the ground lead. Noise disturbances traveling up the transmission line cause a current to flow in the ground lead because of the capacity from the secondary windings to the shield. This current results in a voltage drop in the ground lead if the impedance of this lead is appreciable. The disturbance is then passed on to the line and to the receiver in the same manner as the desired signal. The methods of reducing this effect are to shorten the ground lead and to reduce the capacity between primary and secondary circuits. The ground lead is shortened by placing the transformer only a foot or two above the ground.

The capacity between windings has been reduced by employing small-diameter coils on a magnetite core and by spacing the coils from each other. A magnetite core is used to hold up the magnetic coupling. These features play a large part in accounting for the improved noise reduction obtained, particularly in the broadcast band.

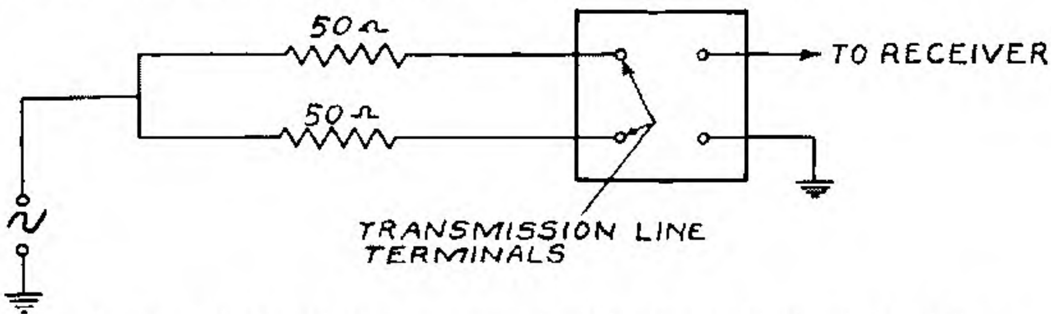

Fig. 7—Circuit for testing noise reduction in set-to-line transformer.

Testing for Noise Reduction

The final test of the antenna system should be a test of its ability to reduce noise under operating conditions. It is convenient, however, to be able to evaluate the noise-reducing performance of the component parts and of the entire kit by laboratory tests. The relative efficiency of various designs may then be compared. A series of such tests have been devised.

In testing line-to-set transformers for noise reduction, the circuit of Figure 7 is used. A voltage is applied to the two sides of the primary in parallel. A receiver is used to pick up and measure the weak signal which leaks through. The attenuation of this voltage is a measure of the noise-reducing efficiency of the transformer. Figure 8 is a curve obtained by this method. In the curve the attenuation applied to in-phase line voltages is plotted as a function of frequency. This test has several defects, but has been found quite useful nevertheless. The defects of the test are as follows:

First it is necessary to balance the two resistors very accurately to obtain valid results. Second the impedance of the line is not accurately represented. In spite of these defects the test has been found very useful in comparing transformers. A similar test has been used on antenna transformers. In this case voltage is fed in on the two sides of the line as before and the leakage voltage is measured across the dummy antenna.

Tests have also been devised for evaluating the overall noise reduction under operating conditions. In one test a bifilar choke is placed in series with the power cord and a radio-frequency signal voltage is applied across the choke with a signal generator. The sensitivity of the receiver to this signal is measured. The ratio of this sensitivity to the normal sensitivity gives the noise-attenuation ratio.

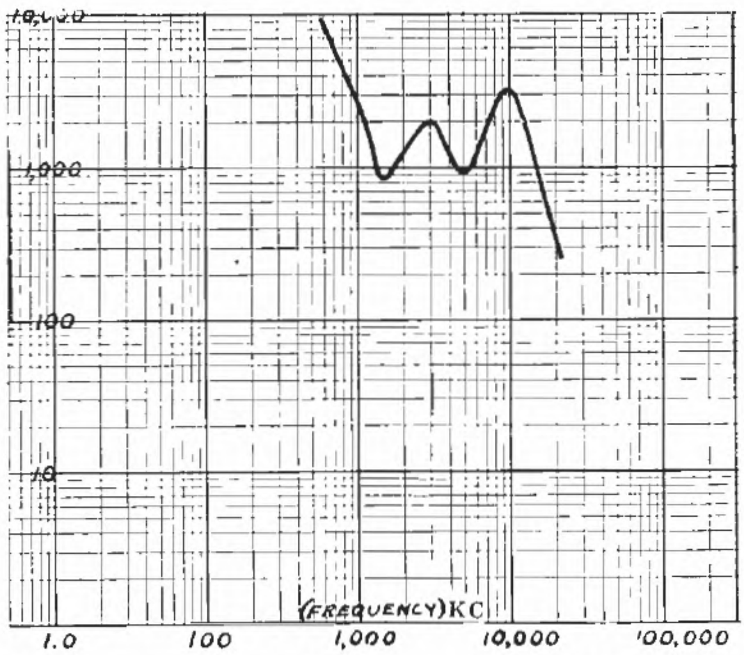

Fig. 8—Noise reducing performance of set-to-line transformer.

The ratio obtained in this manner will vary considerably from one installation to another because of variations in the impedance of the power line and ground leads. However, the ratios obtained for the broadcast band are in the order of 300.

In another test, the test voltage is applied to the two sides of the transmission line in a manner similar to that used for testing the transformers alone. The attenuation ratios obtained by this method are about three to one less than those obtained by applying the test voltage on the power cord. This shows the effectiveness of keeping the capacity small between the primary and the shield in the line-to-set transformer.

Chassis Ground Connection

The use of a ground connection on the chassis is of doubtful value with this antenan system. Noise reduction is sometimes better with the ground, but just as frequently it is better without. The signal strength is not affected.

Receiver Power-Line Filter

In designing receivers, it is generally accepted as good practice either to use a shield between windings of the power transformer or to by-pass both sides of the power line to the chassis. This desirable practice should not be discontinued because of the availability of noise-reducing antenna kits. In fact a line filter of some sort is more necessary than ever when using a noise-reducing antenna. The function of such a filter is to prevent the noise from entering the radio circuits by way of the "B" supply. The importance of this function is increased when the noise is also prevented from entering through the antenna circuit.

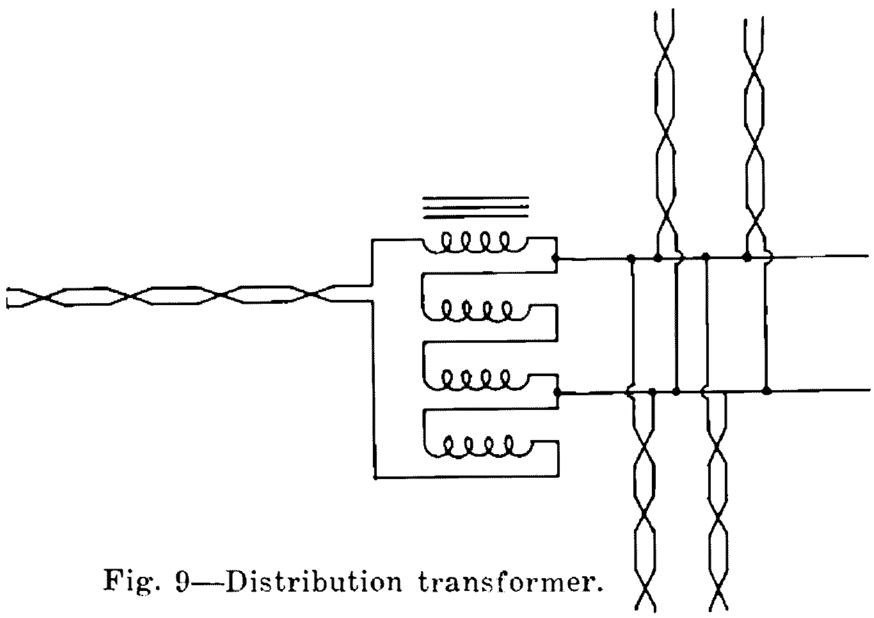

Fig. 9—Distribution transformer.

Distribution Transformer

There is a large demand for an antenna kit capable of feeding several receivers simultaneously. To accomplish this, a special distribution transformer has been designed. The circuit is given in Figure 9. The four coils shown are wound simultaneously turn for turn. This is accomplished by using a special four-strand litz wire. The four strands are connected in series as shown. A magnetite core is used to reduce the leakage reactance still further. The result is a balanced two-to-one, step-down transformer having extremely low leakage reactance. This transformer passes both broadcast band and short-wave signals with high efficiency. Having a two-to-one ratio, the transformer operates most efficiently into four outlets. Of course, each of the four branch lines may be split up into four outlets again, making a total of sixteen. Signal strength is down a little more than two-to-one with four outlets and four-to-one with sixteen outlets. Since the transformer is balanced, the noise reduction is not affected by its use.