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A SUGGESTION FOR EXPERIMENTS ON APPARENT RADIO DIRECTION VARIATIONS*

By

L. W. Austin

(Communication from International Union of Scientific Radio Telegraphy)

The following facts have been observed in regard to the apparent direction shift of long-wave stations at moderate distances (200 to 700 km.).

(1) During the night, as is well known, these stations show large irregular shifts.

(2) During the day, from shortly after surnise, the bearing is generally nearly correct up to about two hours before sunset, tho on a few occasions, notably during some of the cold waves of January, 1924, there were shifts of a number of degrees early in the day.

(3) During the past year daily observations have been taken in Washington, on New Brunswick and Tuckerton, New Jersey, which show a regular shift toward the east beginning about two hours before sunset, reaching a maximum of from 8 to 15 degrees, returning to normal near sunset, after which there is frequently a sharp shift to the west followed by the irregular night shifts. This before-sunset shift is among the most regular phenomena so far observed in transmission in radio telegraphy as it has not failed once during the year. (There were no observations on Sunday and a few other days).

(4) The more distant stations, Rocky Point (415 km.) and Marion (660 km.) seem to show less regular sunset shift than those at about 250 km.

(5) Annapolis (54 km.) shows no definite sunset shift, but frequently shows a short-period (10-15 minutes) continuous shifting for hours at a time at any time of day amounting to three or four degrees.

These apparent direction shifts are generally believed to be connected with reflection from the boundary of a conducting

*Received by the Editor, October 25, 1924.

layer in the upper atmosphere. According to the hypothesis advanced by Eckersley ("Radio Review" II, page 60, 1921), the deviation is caused by a reflected wave which, coming down, strikes the radio compass coil without having previously passed along the surface of the ground. This ungrounded wave will in general not have its magnetic field horizontal, as in the case of a grounded wave, but the field will have a vertical component which cuts the top and bottom of the coil, thus producing an electromotive force which, to produce silence in the telephones, must be compensated by rotating the coil from the position of true minimum.

As Professor Kennelly has pointed out, experiments on direction shift form one of the most promising means of gaining information regarding the Kennelly-Heaviside layer. A determination of the distance at which the variations are a maximum will give an indication of the height of the layer, while observations on possible differences in the effect due to differences in direction, time of day, type of antenna, and so on, may give further useful information. All such information in regard to the upper atmosphere is of the highest importance in developing a complete theory of radio transmission. These observations can easily be made by anyone having a long wave receiving set and a four- to six-foot coil antenna, capable of rotation, with fifty or more turns. If the observer does not wish to work up his results for publication but prefers to send them to this laboratory, he will be given due credit when our work is published.

SUMMARY : The author suggests the systematic investigation of apparent shifts in direction of transmitting stations as indicated on a loop receiver. He describes briefly some of the effects so far discovered.

RECENT INVESTIGATIONS ON THE PROPAGATION OF ELECTROMAGNETIC WAVES*

By

M. Baeumler

(Communication from the National Telegraph Engineering Bureau of Germany (Telegraphentechnische Reichsamt), Berlin)

Our knowledge of the causes of the modifications experienced by electromagnetic waves in their passage thru space has gaps in it. We have observed diurnal and annual variations of intensity of the waves, the magnitudes of which are different at different times, and for which no unimpeachable explanations have yet been found. We have also observed a diminution of field intensity with distance which is not in agreement with the theoretical law connecting these quantities. In addition, we have not yet been able to determine whether the day-time or the night-time value of the received electrical field is the normal value, that is, which of these values is to be regarded as the one which is in accordance with the theory. In order to clear up these questions, which are intimately connected with the propagation of electromagnetic waves, comprehensive measurements have been carried out at the National Telegraph Engineering Bureau of Germany (Telegraphentechnische Reichsamt).

I. Methods of Reception

An objective and quantitative measuring arrangement is required for the investigation of the propagation phenomena, in order that the variations of intensity at the receiving stations may be precisely followed. Quantitative measuring apparatus has been described, among others, by the following investigators: L. W. Austin,[1] J. L. Eckersley,[2] C. W. Pickard,[3] G. Vallauri,[4] M. Guierre,[5] H. J. Round and U. F. C. Lunnon,[6] R. Bown, C. A. Englund, and H. T. Friis,[7] and L. F. Fuller.[8] Some of these investigators have used the telephone as the indicating instrument. In spite of careful calibration of the receiving apparatus,

*Received by the Editor, July 21, 1924. Translated from the German by the Editor. This paper will also be published in German in I, volume 2 of "Elektrischen Nachrichten-technik."

it is not possible to avoid entirely the disadvantages of the telephone, namely the insensitiveness of the ear and the fact that the readings are subjective and therefore, in part, dependent on the observer. The degree of uncertainty which may result from the use of the measuring arrangements depending on the ear is made abundantly clear by the work of A. Klages and O. Demmler[9] and of the writer.[10] In order to avoid these defects, an objective measuring method has been worked out at the National Telegraph Engineering Bureau by G. Anders, which method will soon be fully described.

The following is the basis of this method: The current produced in the receiving antenna by the distant transmitter, after suitable amplification, causes deflections of an electrometer proportional to the received current. The measurement of the antenna current is accomplished by means of an auxiliary transmitter current, which is adjusted accurately to equality with the original antenna current in amplitude and frequency, and which is measured by means of a barreter or a thermo-couple. By the utilization of the principle of the current transformer, it is possible accurately to measure considerably smaller currents than could be measured directly by the available instruments. The measurements can be carried out during the regular operation of the distant transmitting station because the thread element of the electrometer accurately follows the code signals of the station which is under observation. The subjective errors of the observer are avoided in our measuring method, as are also the physiological effects of atmospheric disturbances of reception which tend to spoil the note of the incoming signal and thus to make them seem weaker than they actually are. Our method therefore enables the completely objective measurement of received signals.

II. Mathematical Treatment of the Propagation Phenomena

F. Kiebitz, in his paper "On the Propagation Phenomena and Disturbances of Reception in Radio Telegraphy,"[11] has considered in detail the explanations which have been devised for the physical processes which occur in the propagation of electromagnetic waves. To study the spreading of the electromagnetic wave, we must know the value of the electric field which the distant transmitter produces at the receiving station. The following relations exist, according to Hertz and Barkhausen,[12] between the transmitter current of a continuous wave station, the received current, and the electric field at the receiving station:

$$F = \frac{120 \pi I_1 h_1}{\lambda d} \quad (1)$$

$$I_2 = F \frac{h_2}{r} \quad (2)$$

$$I_2 = \frac{120 \pi I_1 h_1 h_2}{\lambda d r} \quad (3)$$

In the above equations, the symbols have the following significance (using practical engineering units):

F = electrical field at the receiving station in volts per meter
I_1 = transmitting current in amperes
I_2 = received current in amperes
h_1 = effective height of the transmitting antenna in meters
h_2 = effective height of the receiving antenna in meters
r = total resistance of the receiving antenna circuit in ohms
λ = wave length in meters
d = distance from the transmitter to the receiver in meters.

These relations are based on the assumption of a perfectly conducting ground in the form of a plane surface, and hold for wave propagation in a perfectly insulating medium without absorption, reflection, or refraction of the waves by the atmosphere. For wave transmission over a spherical surface, the above equations contain the additional term:

$$\sqrt{\frac{\alpha}{\sin \alpha}}$$

according to H. Poincaré,[13] J. W. Nicholson,[14], H. March,[15] and W. von Rybzinsky,[16] because the distances on a sphere are smaller than those in a plane in the ratio

$$\frac{\sin \alpha}{\alpha}$$

Here α is the angle subtended at the center of the sphere by the arc joining the transmitter and the receiver.

We thus obtain as the value of the electric field at the receiving station, assuming no losses due to absorption, reflection, refraction, or variable conductivity of the earth, the following:

$$F = \frac{120 \pi I_1 h_1}{\lambda d} \sqrt{\frac{\alpha}{\sin \alpha}}. \quad (4)$$

We shall refer to this value hereafter as the "theoretical value." It has been attempted to determine the losses in actual transmission empirically and theoretically. Empirical relations have been worked out by L. W. Austin,[1] L. F. Fuller,[8] and others. In addition to those previously mentioned, ([13-16]), A. Sommerfeld has worked out a theory of the propagation of electromagnetic waves taking account of actual losses.

In general, the effect of these losses is given by a term of the form

$$\varepsilon^{-\frac{Kd}{\lambda^M}}$$

in the equation of the received electric field, where ϵ is the base of the natural system of logarithms, d the distance, λ the wave length. K and M are numerical constants. The above term will be referred to hereafter as the "absorption factor," and takes account of all field reductions in the propagation of electromagnetic waves except those resulting from the theoretical diminution of amplitude with distance.

In practice, the value of the absorption factor found by Austin and Cohen[1] is most generally used. It was determined by daytime measurements on waves traveling oversea over distance up to 3,800 km. and has the value $\epsilon^{-\frac{0.0015\,d}{\sqrt{\lambda}}}$ wherein $K=0.0015$, $M=0.5$, and d and λ are expressed in kilometers.

L. F. Fuller[8] found the value $\epsilon^{-\frac{0.0045\,d}{\lambda^{1.4}}}$ for the absorption factor for measurements between San Francisco and Honolulu (3,800 km.) and Tuckerton to Honolulu (8,000 km.).

III. Experimental Results

(a) Simultaneous Measurements of Transmitted and Received Currents

With the measuring equipment described above, Division II (Research) of the National Telegraph Engineering Bureau in Berlin (Königgrätzstr. 20), and the Radio Research Station at Strelitz have been carrying out a series of measurements on received antenna currents to determine the field strengths of the signals from the American high power stations. The measurements were made on the signals from the stations at Rocky Point, Long Island (call letters WQK and WQL) and Marion, Massachusetts (call letters WSO), all of which are owned by the Radio Corporation of America. Dr. Alfred N. Goldsmith showed most keen interest in our investigations and willingly acceded to all our requests, and Dr. L. W. Austin has also frequently helped us in our work. We cannot refrain from expressing our heartiest thanks to these gentlemen at this time.

During July and August, 1922, the measurements were made by having the antenna currents of both WQK and WQL at Rocky Point recorded at 4 A. M., 9 A. M., and 3 P. M. Central European Time and simultaneously measuring the received currents at Berlin. The results are given in Figures 1 and 2. The

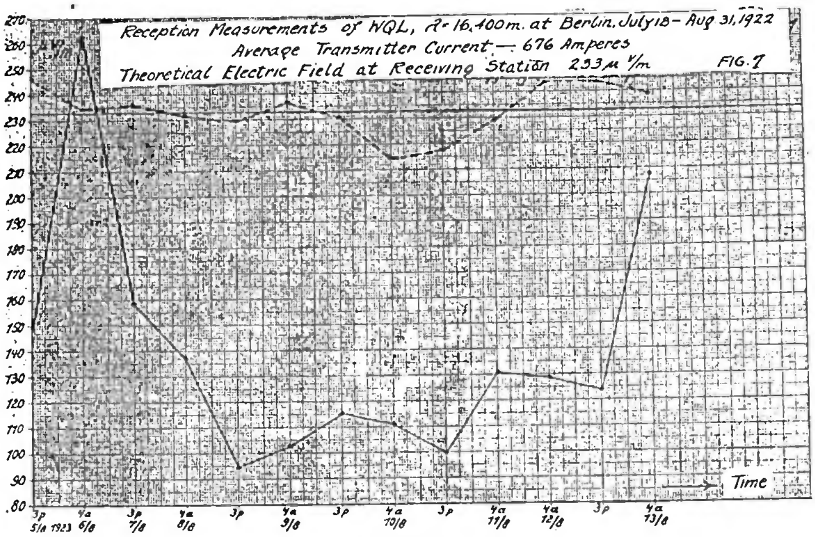

FIGURE 1

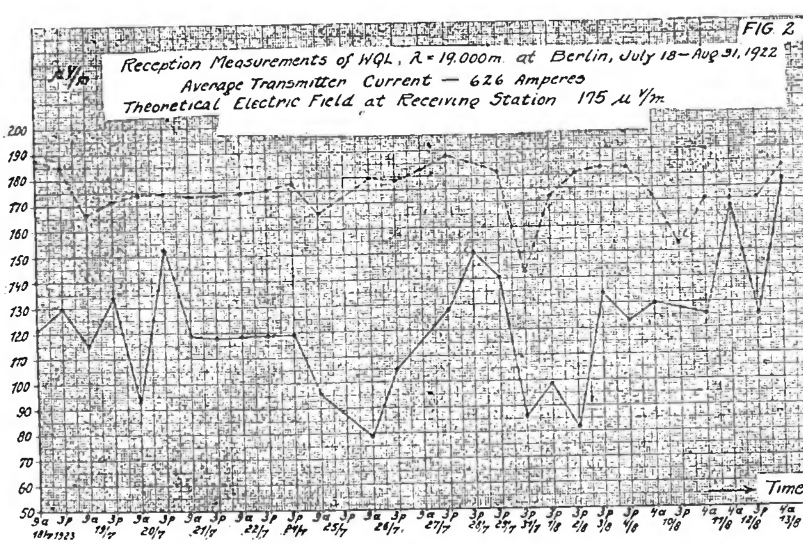

FIGURE 2

full line curve connects the points determined by the measurements, and the dashed line curve the points calculated by equation (4) from the actual transmitter currents; the latter curve is therefore directly dependent on the transmitter currents. It can be seen from the curves that the transmitter current varies only slightly from its average value (at most 20 percent), whereas the field strength at Berlin varies as much as 90 percent. (For passing judgment on the relation between the propagation phenomena and the variations in received intensity, the variations in the transmitter current need not be here considered.) The numerical values of average transmitter currents, effective heights, distances, wave lengths, and resistances necessary for the calculations are given in the following table. The theoretical values of the electric field, on the basis of the average transmitting currents, are found from equation (4) to be 175 μv./m. for WQL and 233 μv./m. for WQK. The actual values obtained by measurements, with the exception of a single night-time signal for WQL, are considerably less.

	Rocky Point			Marion
	WQK	WQL*	WQL	WSO
Wave Length........km.	16.4	19.0	17.5	11.6
Distance............km.	6,400	6,400	6,400	6,100
Average Transmitter Current............amp.	676	626	603	530
Effective Height of Transmitter Antenna.....m.	88	82.5	82.5	60.6
Effective Height of Receiver Antenna at Berlin.................m.	6.7*	6.7*	....	....
m.	5.6	5.6	5.6	5.6
Effective Height of Receiver Antenna at Strelitz................m.	19	19	19	19
Resistance of Antenna Receiving Circuit at Berlin..............ohms.	700*	1,220*	....	....
ohms	170	300	210	83
Resistance of Antenna Receiving Circuit at Strelitz.............ohms	462	....	790	194
Field Strength, Equation (1).............μv./m.	214	160	168	171
$\sqrt{\frac{a}{\sin a}}$	1.09	1.09	1.09	1.08
Field Strength $\times \sqrt{\frac{a}{\sin a}}$ μv/m.	233	175	183	185
Absorption Factor, Austin-Cohen................	0.0933	0.111	0.191	0.0685
Absorption Factor, Fuller.	0.568	0.626	0.59	0.414
Field Strength, Austin-Cohen..........μv./m.	21.7	19.4	16.8	12.7
Field Strength, Fuller μv./m.	133	....	....	76.5
Average Daytime Value μv./m.	150	....	....	60

*For the measurements during July and August, 1922.

(b) Simultaneous Measurements at Two Receiving Stations

No definite conclusions could be drawn from the first series of observations as to the relation between signal variations because there were considerable intervals between the taking of the measurements. It was, therefore, decided to diminish the intervals in question. Accordingly, the station at Strelitz, which was chosen as the second receiving station, was fitted up with apparatus of the same type as that used in Berlin. In November and December, 1922, simultaneous observations were taken at Berlin and Strelitz on the received currents from WQK. Figures 3 to 6 show the measured field intensities for several days. Sunrise and sunset are also shown, as well as the theoretical field strengths. It will be noted that there is a satisfactory agreement

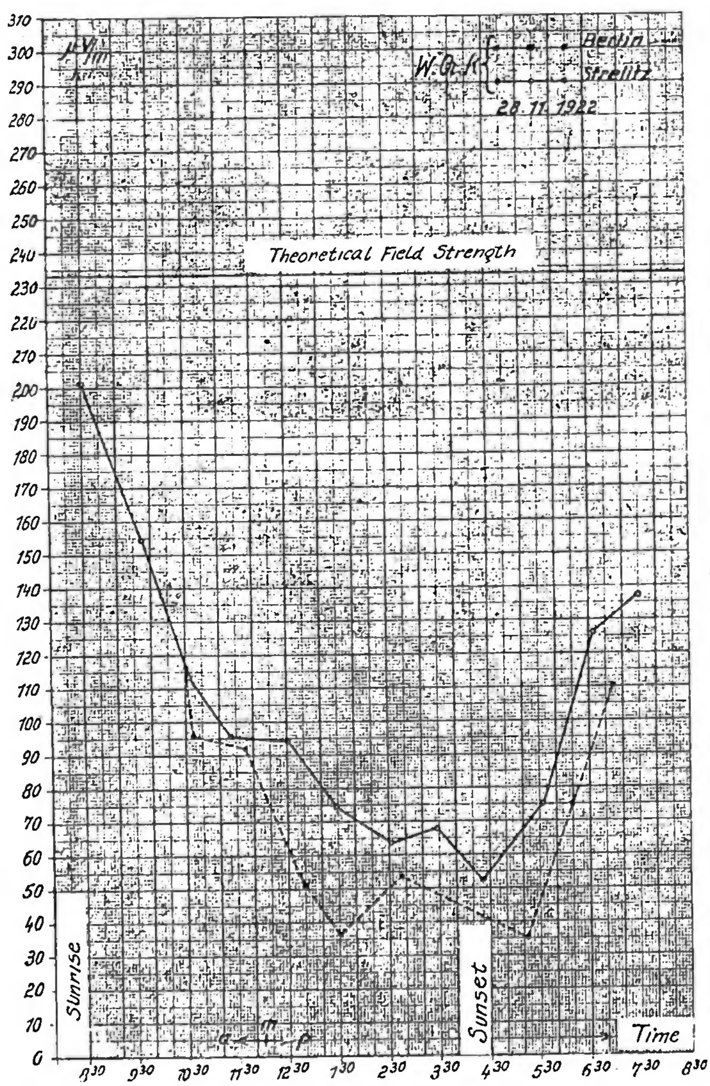

Figure 3

sunrise periods, many observations were made two or three minutes apart. The results of these measurements for the twelve months from February, 1923, to January, 1924, are given in Figures 7 to 18. The distribution of day and night between the transmitting and the receiving stations is shown in these figures. Sunrise and sunset at Berlin and Rocky Point are marked by short vertical lines on the axes of abscissas.

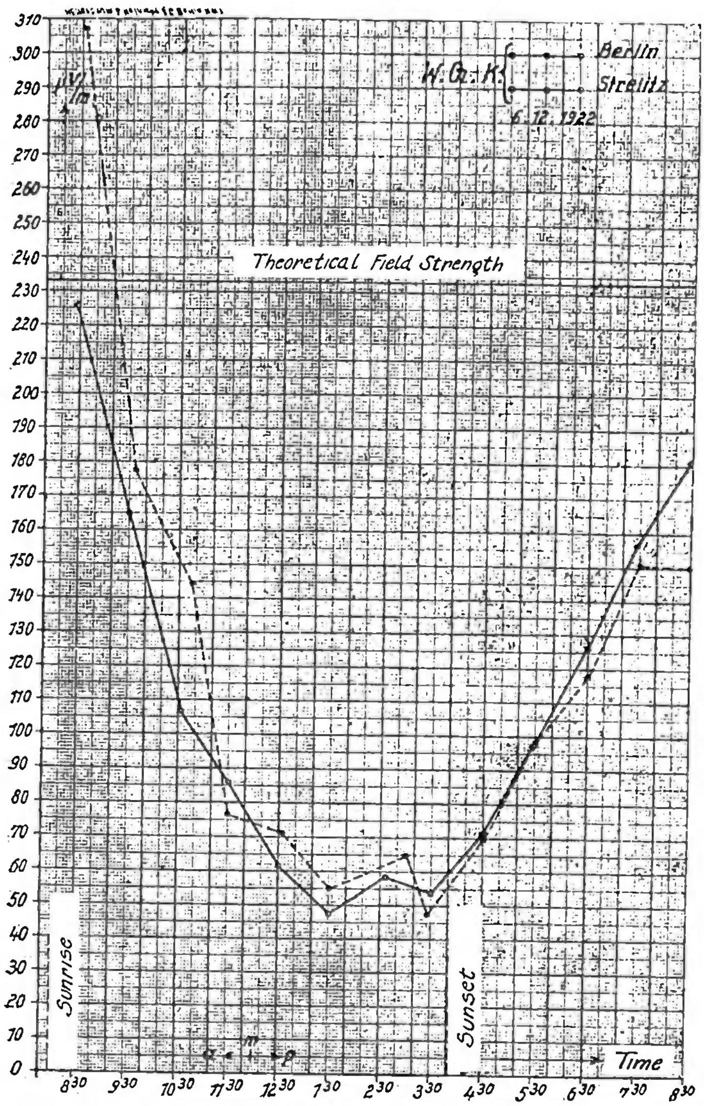

FIGURE 6

The thin horizontal lines indicate the time during which only one of the stations was illuminated by sunlight, and the heavy horizontal lines indicate the time during which the entire path of the waves lay in complete darkness. Times are given in Central European and American Eastern Standard Times. In addition, there are shown on the curves the field intensities calculated according to equation (4) for Berlin and Strelitz on the basis of the average transmitter currents, and hence having the values

233 μv./m. for WQK
185 μv./m. for WSO, and
183 μv./m. for WQL.

The value for WQL being in practical agreement with that for WSO, it is not specially marked on the measurement curves of January, 1924. Inasmuch as the observation station at Strelitz had to be shut down at the end of December, 1923, all later observations could be taken only at Berlin.

(d) General Discussion of the Results of the Measurements

The four curves which appear in the Figures 7 to 18 have the same general shape and roughly maintain their relative amplitude ratios thruout. In general, the field strength of WSO is less than that of WQK, which is also true for the corresponding values of the field strengths calculated from equation (4). The superiority or greater consistency of the longer waves is evidenced by the closer approach to the theoretical values of the signals from WQK as compared to those from WSO. If we consider individual readings, it is found that the values for WQK and WSO frequently are different, altho there is good general agreement. These differences are to be ascribed to the limits of accuracy of the measuring equipment. Anyone who has watched radio telegraphic reception with a galvanometer or an electrometer is well aware that the moving element of the instrument is usually in rapid motion because of the incoming code signals and the atmospheric disturbances. This is particularly the case for received signals which are at the lower limit of measurement or are of the same order of magnitude as the atmospheric disturbances, which has frequently been the case during the measurements on the American high power stations. Readings of the electrometer in such cases were made only on dashes during which no strays occurred, and in such cases the deflection of the electrometer thread at the end of the dash was sharply defined. In addition to the above uncertainties in the readings, there were variations due to changes in the transmitter energy and in its frequency, interference from other transmitters, uncertainty in the value of the effective antenna heights and resistances and variations therein, and differences in the individual measuring equipments, all of which limit the accuracy of measurement. We cannot, therefore, assume too extreme an accuracy for the result. We have taken for our results an accuracy of 30 percent, which embraces a range such that the differences of the Berlin and Strelitz signal measurements will be included within it in about 5,000 cases. Differences between these measurements up to 70 percent occur in only about 100 cases (or 2 percent of the whole), and for weak field strengths accompanied by powerful atmospheric disturbances. They thus constitute instances in which the observation or measurement limit had been reached.

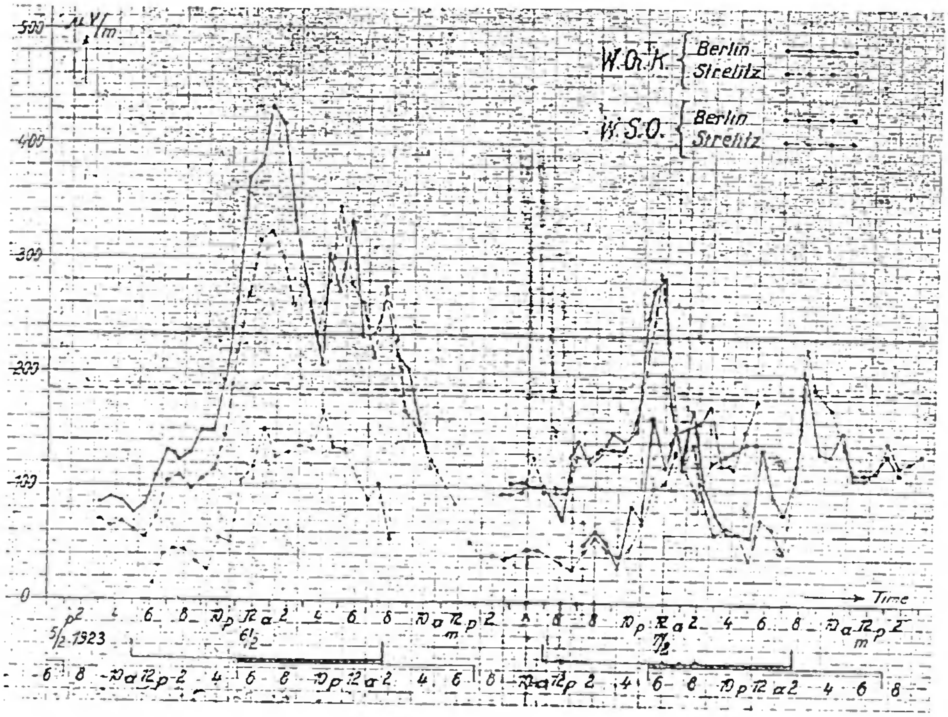

FIGURE 7

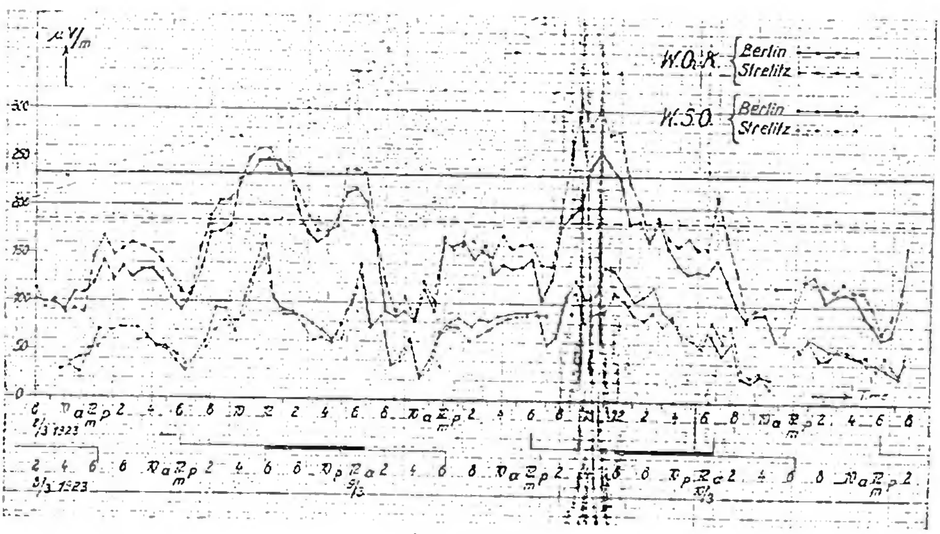

FIGURE 8

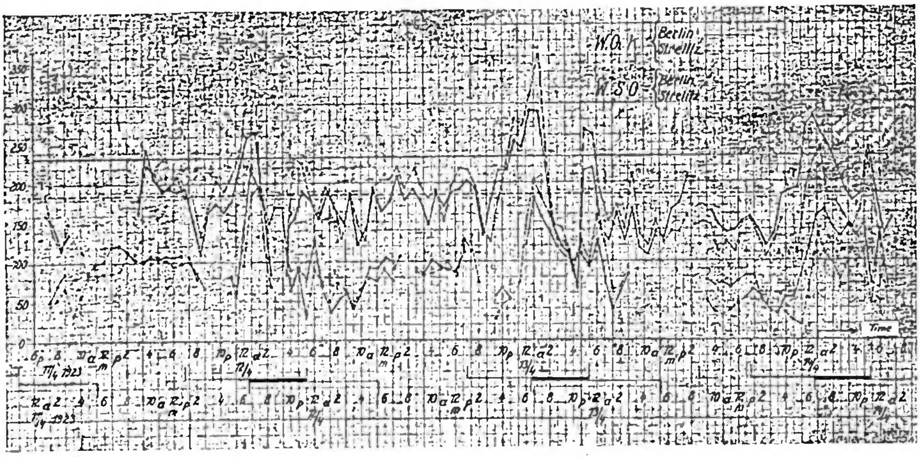

FIGURE 9

If we attempt to pass judgment on the accuracy of the measurements, we reach the conclusion that a probable accuracy of 30 percent in dealing with the very rapidly altering effects which must be followed by the measuring instruments represents a step forward in the field of radio telegraphic measurements. In connection with the measurement of the field strengths of the American high power stations, we carried out special tests to determine the reliability of our apparatus. Thru the courtesy of the Transradio Company for Overseas Radio Communication (Transradio A. G. für drahtlosen Übersee-Verkehr), arrangements were made to excite the large antennas at Nauen (at distances of 76 km. from Strelitz and 36 km. from Berlin) with such currents that the received currents at our observations were of the same order of magnitude as those produced by the American high power stations. These currents and the corresponding field strengths were in agreement with the theoretically calculated values, and larger currents also gave equally close agreement.

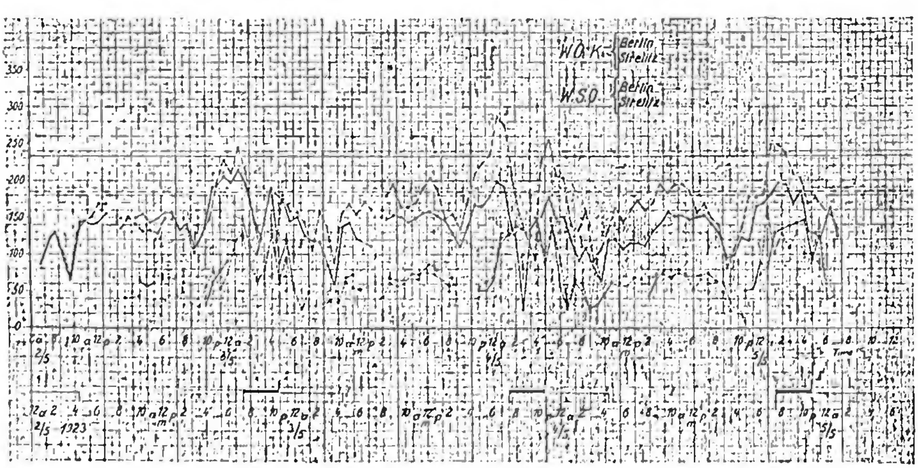

FIGURE 10

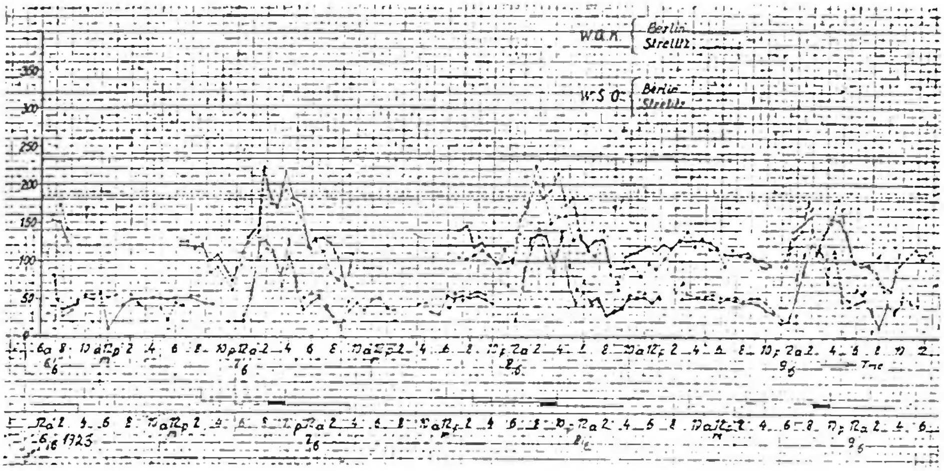

FIGURE 11

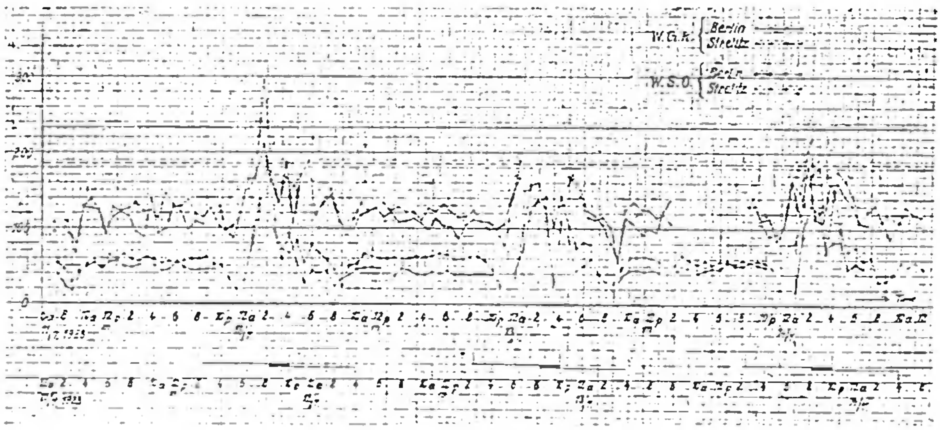

FIGURE 12

If we examine the curves more carefully with reference to diurnal and annual variations, we observe very clearly, as previously stated, the high values of the field strengths at night and the low values during the day. The increase in strength occurs after sunset at the receiving station, and the decrease at sunrise. The highest values are obtained when the entire span between the stations is in darkness. The night values are several times the day values, the ratio being approximately four-to-one in the winter and two-to-one in the summer. The differences, therefore, are not pronounced and are much less than the numerical values for these ratios previously given by other observers using, in some cases, subjective methods of measurement.

The differences between day and night values depend on the time of year. The night values are higher in the winter than in the summer. The least values have been measured at sunset at the receiving station and at sunrise at the transmitting station.

Between these two minima, there are found two maxima, namely, a marked one during the night and a relatively broad maximum during the day. During the winter the minima approach each other since sunset and sunrise occur relatively closely together at opposite terminals of the span between the stations during that season. The difference between the field strength by day in the summer and that in the winter is therefore chiefly a result of the approach of sunset and sunrise on paths between the transmitter and receiver of such lengths as we are here considering.

There are large and rapid variations in field intensity during the night in the winter and spring which are particularly remarkable. Instances of these occurred on February 6, 1923 at 2. A. M. and on May 4th at 1. A. M. The drop in signal strength, and

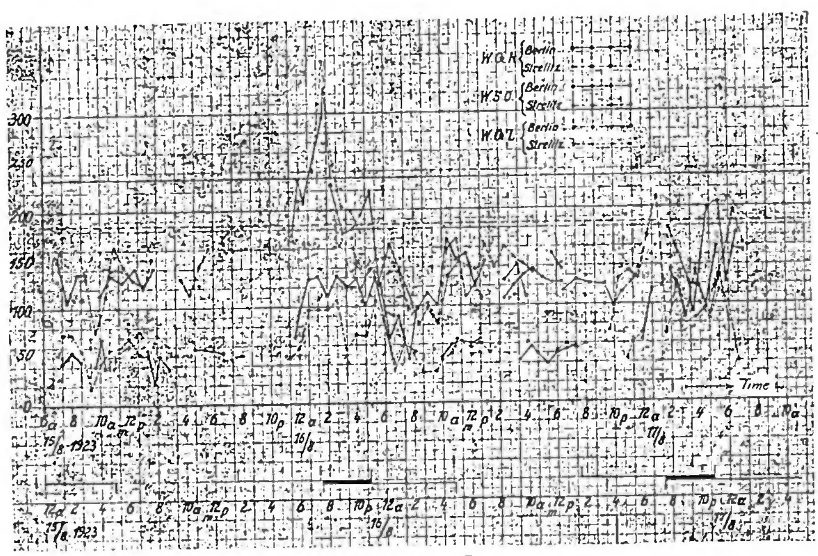

FIGURE 13

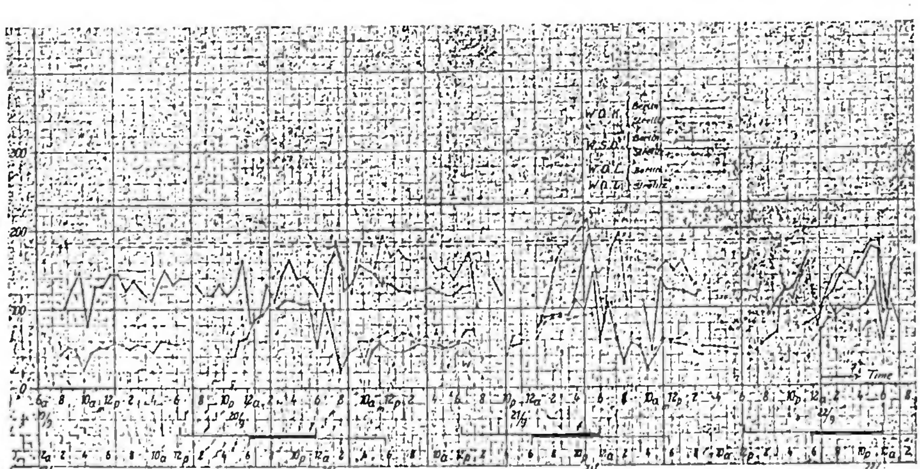

FIGURE 14

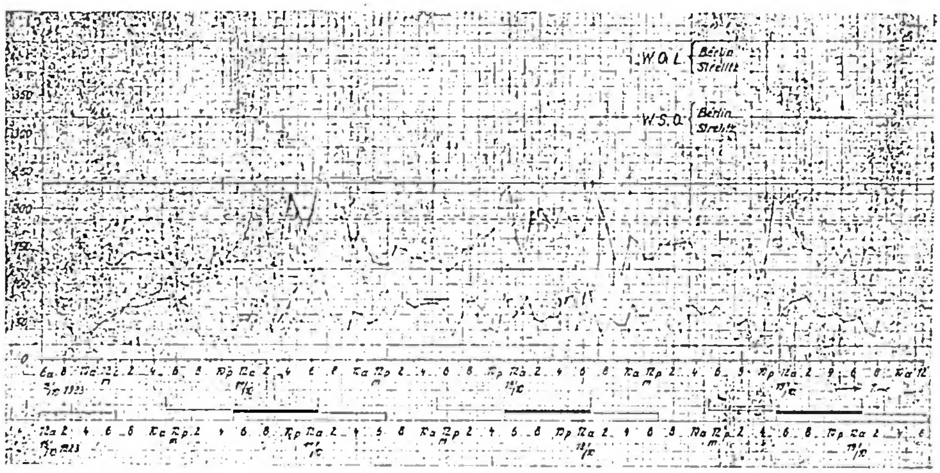

FIGURE 15

sometimes to a lower value than the weakest daylight signal, takes place in a short time, and is often accompanied, as we have noticed, by interruptions in the service. It first seemed correct to ascribe such signal changes to the transmitting station and due, for example, to a diminution in the transmitter current, alterations of frequency, or partial breakdown of the insulation of the transmitting antenna by rainfall. Questions addressed to Dr. Alfred N. Goldsmith showed these assumptions to be incorrect. The transmitter current was held almost perfectly constant during the measurement days, and it was easy to observe that at other times the transmitter currents and frequencies of the two stations were held extremely constant. No abnormal atmospheric conditions could be detected at the transmitting stations. Consequently the cause of the peculiar signal drop can only be found in the intervening medium.

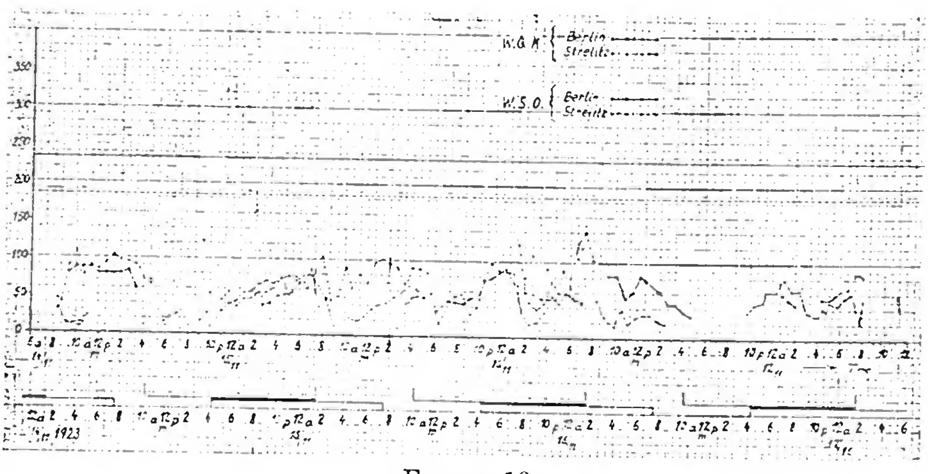

FIGURE 16

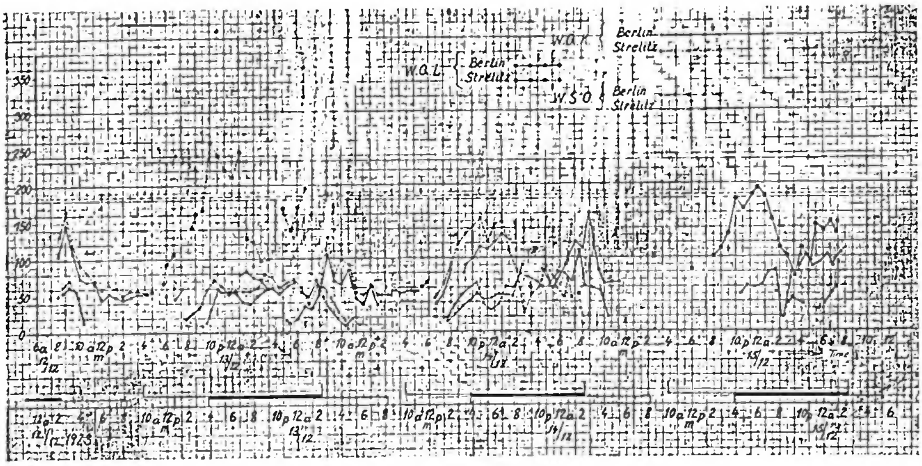

FIGURE 17

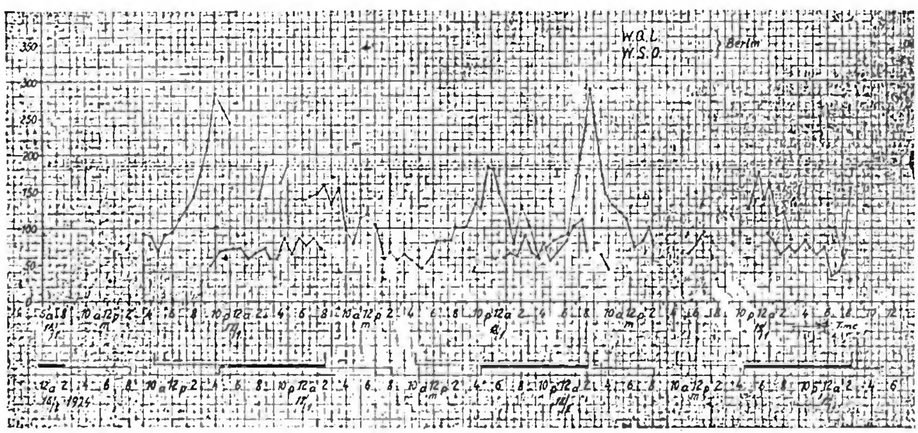

FIGURE 18

III. CONCLUSIONS

(a) THE NORMAL FIELD STRENGTH

In making assumptions as to the relationship between the day and night signals, one can either regard the day value as a diminution of the night value or the night value as an increase of the day value, and one can therefore be led to regard either the day value or the night value of the field strength as the normal one. The previous material enables us to give a decisive answer to the question of which value of the field amplitude is to be taken as normal. Using the law connecting field amplitude and distance, we should expect from equation (4) that, neglecting losses due to absorption, the following would be the electric field values at Berlin or Strelitz for the corresponding stations:

for WQK, an electric field of 233 μv./m., and
for WSO, an electric field of 185 μv./m.

If we compare these values with those actually measured, we find that they are exceeded only in a few instances in winter and spring during the night, and that the measured values during the summer lie below the theoretical values. The peak values at night during the winter and spring differ from the theoretical values by an amount less than the probable error of the measurements except for a few values in February, 1923 (for WQK), in August, 1923 (for WQL), and in January, 1924 (for WQL). Furthermore, the most recent measurements taken from February to June, 1924 (which are not given here), show that the night values of the measured field are of the same magnitude as the theoretical values.

In addition to the measurements of the American high power stations, the European high power stations at Lyons, Rome, Carnarvon, and Stavanger were measured at Strelitz. Stavanger shows a particularly marked difference between the day and night values—sometimes as much as eight-fold. A description of these observations will be given by S. Wiedenhoff[18]. If we carry out the same calculations for the Stavanger signals as we did in the case of the American stations, equation (4) gives a value of the electric field of 800 μv./m. Measurements at Strelitz gave actual night field strengths of from 200 to 1,100 μv./m., whereas the day value was only 130 μv./m. So that we find a good agreement between the theoretical value and the actual night field even for the comparatively short distance of 800 km. between Stavanger and Strelitz.

Since, as we have already seen, the field intensities calculated theoretically and the actually measured night field strengths are always comparable, we must regard the night values and the night transmission phenomena as normal, whereas the day values and the day transmission effects must be looked upon as abnormal or disturbed. This point of view has already been given by F. Kiebitz[19] in his paper on the refraction of electromagnetic waves in the atmosphere, and it is now confirmed by measurement.

Previously developed theories of transmission can be regarded as of possible validity only if they are based on assumptions similar to the above. For example, we might more readily regard the point of view of Fleming[20] as correct, which assumes energy losses during the day, than the theory of Eccles[21] in which the day transmission is regarded as normal and the night values are considered as due to an increase of field strength arising from a good conducting layer of ionized gas in the upper regions of the atmosphere—the so-called Heaviside layer. Our measurements, by establishing such close agreement between the values of field strength calculated theoretically and the actually measured night values, make the assumption of the reflection of the waves by such a layer unnecessary.

(b) The Reason for Variation in Field Strength

As a result of the proof that we must regard the night field strength as normal, it follows that the day values are to be considered as a weakening of the night values. We therefore face the problem of the cause of this weakening and, more broadly, of field variations. As we have stated in III (d) of this paper, there is a unique correspondence between the daily changes in the field strength and successive positions of the sun and also the changes in illumination at both the transmitting and the receiving station influence the field strength. This typical daily variation in field strength has been noted in commercial service and also by other observers using subjective methods, the first of whom was G. Marconi. The material given in this paper verifies the earlier observations quantitatively by objective measurements, and has the great advantage that the actual magnitudes of the field strength variations are definitely determined, as previously described. It is therefore established that electromagnetic waves are enfeebled by day transmission. Whether this occurs directly or indirectly, and whether electrical or meteorological causes produce this effect is beyond our present knowledge.

Attention may, however, be directed to the following group of phenomena. The heating of the earth by the radiation of the sun brings about various stratifications of the atmosphere. At night, the air has been uniformly cooled and may be regarded as a homogenous layer. By day, the air becomes disturbed, and therefore, non-homogenous, by the irregular passage of heated air to the higher regions and the downward flow of the cooler air. Bodies of air of different densities lie side by side. The medium thru which the waves pass thus becomes "electrically turbid," and has a disturbing influence on the propagation of the waves since the waves are refracted, absorbed, or diffused at the boundary surfaces of air volumes of different densities, as was previously pointed out by F. Kiebitz.[19] After sunset the vertical motion of the air gradually ceases. The atmosphere slowly becomes uniform, and the causes of the disturbance of a perfectly free wave transmission are decreased. So that we may regard the night atmosphere as a meteorologically homogenous medium which interferes little or not at all with the passage of the waves.

The assumption that the waves at night pass thru a medium which does not absorb, diffuse, or reflect them is quite plausible and is supported by our measurement establishing the agreement between the theoretical and the actual field strengths.

In accordance with optical laws, the waves can be refracted only by masses of air of different densities if these masses have sufficiently large dimensions. Consequently field strength variations must be more common on the shorter waves because the formation of small masses of rarefied or compressed air can occur more readily and therefore more frequently than the formation of larger masses. As a matter of fact, more rapid and extreme variations of signal strength are observed on the short waves than on the long waves.

In part III (d) of this paper attention was directed to the fact that the measured night values of the field strength were greater in winter than in summer. This annual variation of the field strength fits readily into the above theory of the causes of field strength variations. During the winter the difference between the night and day values of ground and air temperature is small and therefore the "turbidity" of the atmosphere is small, so that a good homogenous intervening medium between the transmitting and the receiving station can readily be formed at night. In summertime, because of the marked heating of the ground and the short duration of darkness, the formation of such a homogenous atmosphere can occur only to a small extent, and thus the atmosphere remains non-homogenous and weakens the waves in their path even at night.

In addition to these causes of variable transmission, we have changes in the pressure of the atmosphere, the formation of clouds, precipitation of moisture, and accompanying phenomena. It was not possible to determine the extent to which these various meteorelogical conditions affect variations of field strength since comprehensive data relative thereto, particularly over the Atlantic Ocean, could not be obtained. The marked variations of the night field strengths occurring during the winter months cannot be explained by the above theory; their explanation must, therefore, be sought elsewhere.

(c) Field Strengths in Large Cities and in Flat Open Country

We are often told that the field strength produced by a station in a large city is less than that in open country because the layer of fog or smoke over the city weakens or diverts the waves.

If we consider our observations, we find this statement is not confirmed for the observed wave lengths of 16,400 and 11,600 m. Considering WQK and WSO, we find that the field strengths are sometimes higher in Berlin and sometimes in Strelitz, as can be seen directly from the curves.

(d) The Absorption Factor

The difference between the theoretical and measured values of field strengths is described as due to the sum total of all losses caused by absorption. Even a brief examination of the experimental curves shows the extraordinary difficulty which is necessarily experienced in attempting to express them by any equation. Such an equation would have to contain the distance, the wave length, the time of day and year, the weather, and even the nature of the intervening ground (because of the different velocities of electromagnetic waves over land and sea). It requires no further consideration to see that it is impossible at this time to produce such a universally applicable formula. The problem of the propagation of electromagnetic waves requires much further clarification thru numerous objective measurements before we can expect to derive such a formula.

If we do not agree to abandon entirely the development of an equation of this sort, we are forced to restrict it to some special case, for example for the transmission of the waves oversea by day. We shall examine the Austin-Cohen and Fuller formulas, using these limitations.

Applying it to our transmission measurements, the Austin-Cohen formula gives the following electric field strength values:

for WQK, a field of 21.7 μv./m. and
for WSO, a field of 12.7 μv./m.

Our measured field strengths are several times greater than these values. The daytime field strengths as measured for WQK are six times the value given by the Austin-Cohen formula, and for WSO they are five times the value. On the other hand, the absorption factor given by L. F. Fuller gives values in better agreement with our measurements, namely the following electric field strengths:

for WQK, a field of 133 μv./m. and
for WSO, a field of 76 μv./m.,

which are of the same magnitude as the actual measured values.

In measuring the field strength of Annapolis in the neighborhood of Rome, Vallauri found values which were thirteen times as large as those calculated, using the Austin-Cohen absorption factor. Dr. Austin, who is carrying on regular measurements on the European high power stations at Nauen and Lafayette (Bordeaux), found field strengths during the day which were about twice as great as values calculated, using his absorption factor. Similar conclusions have been reached by G. W. Pickard, J. L. Eckersley, and C. R. Englund.[22]

We have seen that the results of measurements are to some extent in disagreement. The explanation for these differences remains to be found. We shall accordingly carry forward our measurement work.

SUMMARY: Since the summer of 1922, quantitative measurements have been carried out on the signal strengths of the American high power stations WQK and WSO, using an objective measuring method. The object of these measurements is to study the propagation of electromagnetic waves. It has been shown that these phenomena can be studied only by continued measurements.

Curves are presented showing the field strengths on three successive days and nights once each month for the year February, 1923-January, 1924. In view of the agreement of the calculated values of field strength and the values actually found at night, it is concluded that the night value is to be regarded as the normal one and the day value as the abnormal or disturbed one. An explanation of the diminution of field intensity is given by assuming that the atmosphere is "electrically turbid" by day in consequence of the heating of the earth and the resulting vertical motion of masses of heated air. The waves are refracted, absorbed or reflected (and hence weakened) at the boundary surfaces of air masses of different densities. Diurnal and annual variations of field intensity can be readily explained by this theory. It was not possible to establish any difference between field intensity in a large city and in nearby open country.

The derivation of a universally applicable formula giving the field strength, while taking account of all absorption losses, is regarded as impossible at present. The empirically determined absorption factor of the Austin-Cohen formula does not give results in agreement with measurement, but yields markedly smaller values of field intensity; on the other hand, the absorption factor found by L. F. Fuller gives values in good agreement with the results of measurement.

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THE MARCONI MARINE RADIO DIRECTION FINDER*

By

H. de A. Donisthorpe

(American Representative, The Marconi International Marine Communication Company, Limited)

Introduction

Radio direction finding is daily becoming an essential feature of mobile radio stations and today there exist a large number of steamers fitted with this extremely useful adjunct to navigation.

The introduction of the thermionic tube to the radio art may be said to have been mainly responsible for the practicability of the modern direction finder, as hitherto the range of these instruments was extremely limited, owing to the poor receptive quality of the loops necessarily employed when used in conjunction with the detectors available in pre-war days.

The erection of a large number of radio fog stations has given a large impetus to the fitting of direction finders on steamers, and the United States of America have shown great partiality towards these beacon stations, a large number of these radio beacons having been installed on lighthouses and light vessels by the Bureau of Lighthouses.

Historical

It is not the intention of this paper to go deeply into the theoretical side of the directional properties of antennas, but rather to describe the practical side of the modern marine radio direction finder. Bearing this in mind it will perhaps not be out of place to briefly trace the modern day apparatus from the early day experiments of radio directional effects.

Marconi in his early investigation noticed a marked directional effect associated with certain types of antennas and adopted such forms of antennas in his first trans-Atlantic work.

Prior to this, Hertz himself, had shown how electromagnetic waves of small length could be directed by reflection using parabolic mirrors. This fact is mentioned merely "*en passant*" in

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view of the interest which is being shown today with the radio beams, which, however, employ a different method to obtain directional reception than is to be described herein.

The well known inverted "L" antenna, such as is employed largely on board ship, has a very marked directional effect towards the heel of the "L," and in 1906 Marconi took out a patent embodying a series of these inverted "L" antennas, erected with the horizontal limbs equally spaced radially about the actual receiving apparatus.

However, progress in direction finding was given a practical start when certain investigators examined the properties of two spaced antennas, and of the receptive qualities of loops.

Time does not permit in this historical survey to discuss all the various types of apparatus, but it is perhaps necessary to mention that Messrs. Brown and Stone discovered that two open vertical antennas joined together and spaced half a wave length apart had marked directional effects, and it was proposed to rotate this system as a practical direction finder.

A scheme for overcoming the difficulty of rotating such an antenna system was introduced in 1907 by Bellini-Tosi, and their method forms the basis of the direction finders now utilized by the British Marconi Companies.

This system has many advantages over the rotating loop for the direction finder, as a loop, particularly of large dimensions, does not offer a very good mechanical proposition as regards rotation, whilst a small loop introduces electrical errors.

The Bellini-Tosi Direction Finder

Description of Basic System

The Bellini-Tosi Direction Finder consists substantially of three essential parts namely—

1—The special oriented antenna system.	Active portion of system.
2—The radiogoniometer. 3—The amplifying and detector unit.	Screened portion of system.

The original method consisted in erecting two directional loops or frame antennas of equal dimensions insulated from each other and at right angles. The leading-in wires from these were brought thru some form of tuned buzzer device and connected to the radiogoniometer.

The radiogoniometer consisted of two antenna coils wound on a common frame and which were of equal electrical dimensions, wound at right angles to each other. Within this former, carrying these two antenna coils, a rotatable coil, known as the search coil, was fitted.

The actual antennas and the respective coils of the radiogoniometer were connected in series with a variable condenser to allow of each antenna system being carefully tuned to the wave length of the station it was desired to receive.

One of these condensers had connected across it a small variable "billi" or tubular condenser to allow of fine tuning in order to produce perfect balance between the two antennas. The search coil was also shunted by means of a further condenser to permit of that circuit also being tuned to the incoming waves, and this search coil circuit was then connected to some form of tube receiver and amplifier.

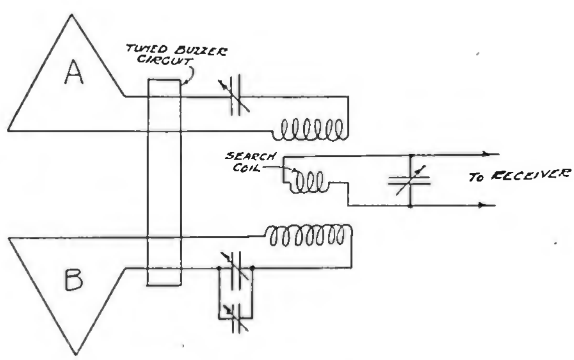


FIGURE 1

METHOD OF TUNING SYSTEM

The tuning buzzer was set so as to produce a wave corresponding to that it was desired to receive. Then having first tuned the search coil circuit and receiver to that wave, each loop was tuned separately without the second loop being in circuit.

Following on, the two loop circuits were then brought into action with the tuning buzzer still operating, and the radiogoniometer search coil was varied until a position was arrived at where the two antenna radiogoniometer coils produced no energy in the search coil and consequently no signals were heard in the receiver. This state of balance was not always effected immediately, and it was sometimes necessary to vary the final adjustment condenser shown across the tuning condenser of antenna *B*.

Altho it will be seen there are quite a large number of tuning adjustments to be made irrespective of the actual detecting and amplifying device, it was found that telegraphists readily became capable of accurately tuning the whole system very rapidly, within a short specified time. However, the method of tuning this whole system is somewhat laborious and is not practical for everyday marine direction finding work.

The description of this early apparatus forms, however, a useful basis to work on in the developing of the modern day apparatus.

Theory of the System

Assuming the circuits all to be in resonance and regarding merely the oriented antenna system and radiogoniometer, now consider the effect of an electromagnetic wave incident on this system. (See Figure 2.)

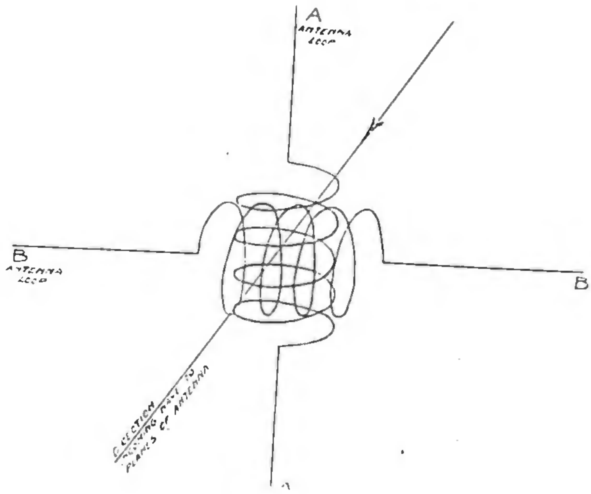


Figure 2

Suppose the wave is arriving in the plane of the antenna loop A, then following the usual electrical laws, no current will be induced in the antenna loop B which is at 90° to A, and consequently at 90° to the direction of the path of incoming waves.

But antenna A is so disposed as to be able to obtain the maximum effect of the incoming wave and will have a current induced in it producing a magnetic field along the cylindrical axis of the A antenna coil. The search coil rotating within the two antenna coils will have to be rotated to such a position as to be under the maximum coupling effect in order to produce a maximum current in its winding.

Similarly, if the incoming wave is exactly incident with the plane of the antenna "B," a magnetic field will only be produced along the axis of the antenna coil "B."

Now take the case of a wave arriving in a direction somewhere between the planes of the two antennas, then both antennas and their respective coils will have currents induced in them, the relative strengths of each being dependent upon which of the antennas most closely coincides in direction with that of the incident wave.

It will be easily seen from this that the resultant field produced by the antenna coils bears exactly the same space relationship to the axis of these antenna coils as the direction of the received wave does to the planes of the antenna loops.

In order to obtain a maximum current in the search coil, it follows that the same must be rotated within the antenna coils until the cylindrical axis of the winding of this coil lies along the direction of the resultant electrical field produced by the two antenna coils. It follows, therefore, that at a position of 90° to this maximum position, a minimum or zero current point is obtained.

It is usual for the zero position of the search coil to be used for practical working as it is easier for the human ear to determine the minimum signal strength than to observe a maximum.

As the search coil is rotated thru 360°, it will be found that the signals heard in the telephones alternate maximum and minimum signals 90° apart;—in other words two maximum and two minimum points are given at 180° apart.

A pointer is fixed to this search coil which moves round a scale fixed to the radiogoniometer marked off in degrees, so that the direction of the resultant field can be obtained, and therefore the direction of the incident wave relative to the antennas is shown.

In ship work, of course, the relative directions of the antennas to the incident wave are continually varying and consequently the course of the ship has to be noted at the time when readings on the system are being observed.

Description of the Modern-Day Marine Direction Finder

It has already been pointed out that the tuned direction finder system offers rather a laborious manipulation if rapid and reliable working is required, and consequently a very much simplified apparatus embodying the direction finder and amplifier has been evolved (Figure 3).

Two antenna loops are erected and insulated from each other, one of which is rigged accurately fore and aft along the centre line of the vessel, and is known as the fore and aft loop, whilst the second is erected thwartships and is termed the thwartship loop.

These loops should be constructed to be as large as available space permits, having due regard to the local conditions and should be erected as far as possible from ventilators, skylights, and other metal obstructions.

It is very essential that no portion of the loops come nearer than 6 feet to such obstructions, otherwise their presence will become known by the introduction of errors. Earthed metal constructions, if not symmetrically disposed under the loops, are also likely to cause errors if within twelve feet.

It has been noticed that the turning of a ventilator within the 12-foot limit has produced a very noticeable error varying with the position of the aperture of the ventilator.

The thwartship loop as a rule runs nearly the full beam of the ship, and less than 40 feet in this connection is not regarded as satisfactory. The fore and aft loop should be constructed so that

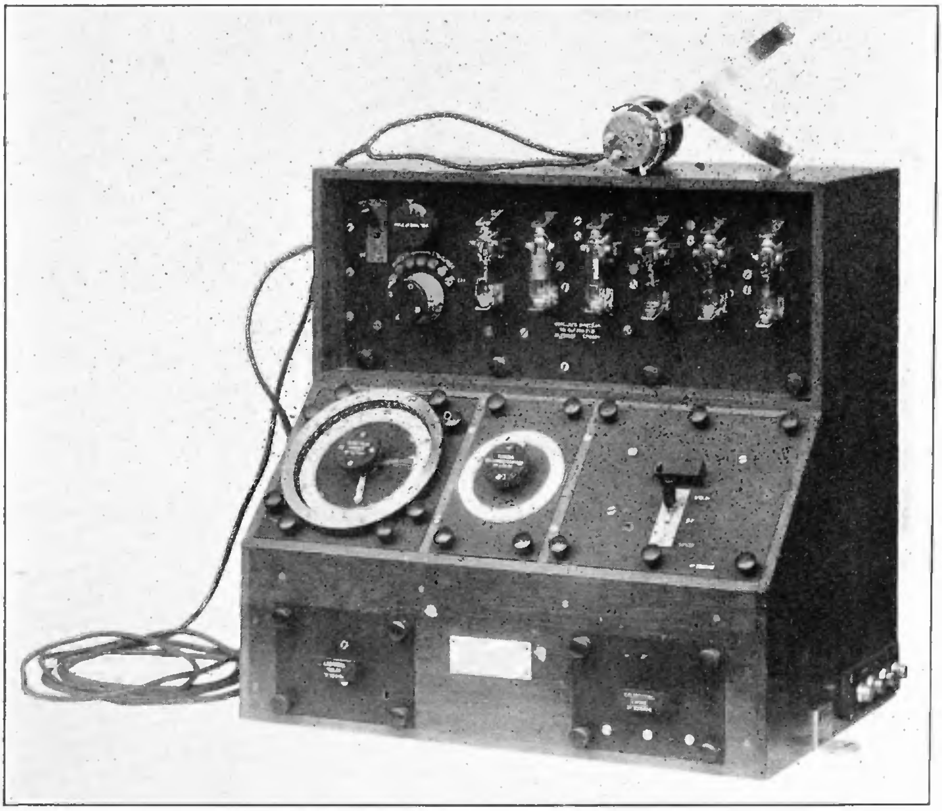


FIGURE 3—The Marconi Marine Direction Finder Type 11-B

its area is about three-quarters that of the thwartship loop, for reasons which will be discussed later. It is not necessary for both loops to be identical with regard to shape, neither is it essential that they should intersect each other altho this latter condition is generally desirable when viewed from a practical erection point of view.

At the time of erection the fore and aft loop is generally not made a permanent fixture as it is with this antenna that calibration alterations are made. Some typical types of direction finder antenna systems for shipboard use are shown in Figures 4 and 5.

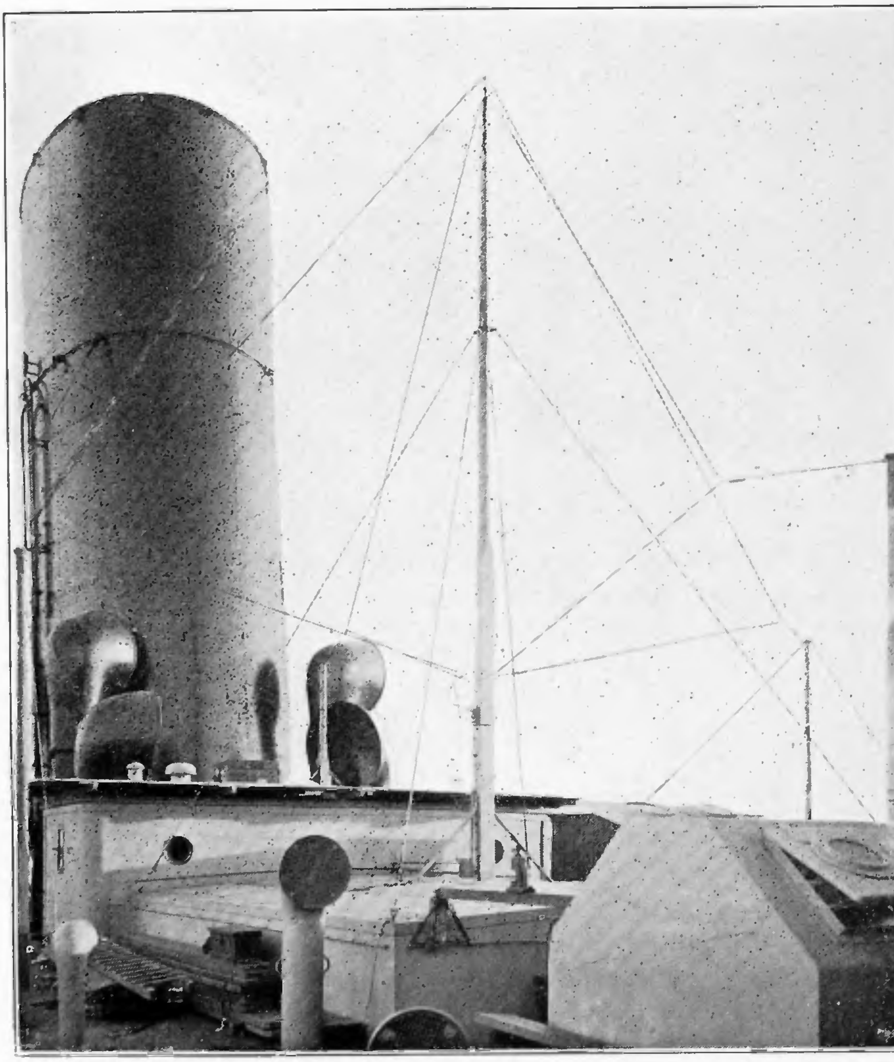


FIGURE 4

As a general rule, the leads from these loops are taken to four swan-neck insulators which are erected on a wooden spar fitted directly under the apex of the whole antenna. The leads from these insulators are taken to an outside junction box, each loop having its own box. These general external connection arrangements can be seen in the illustrations referred to above.

From these outside junction boxes the antennas or active system of the direction finder are connected by means of a special

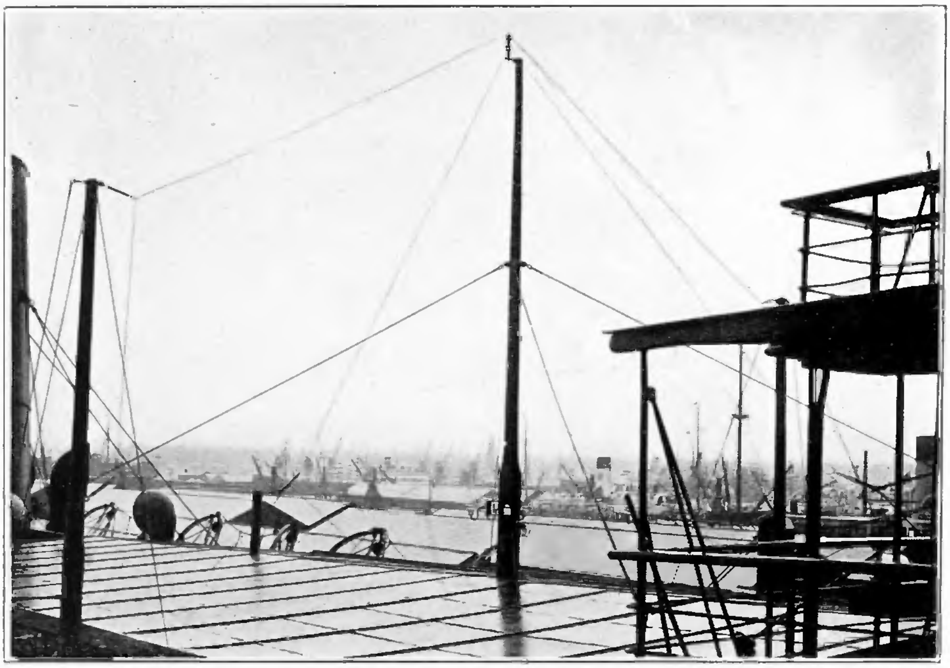


FIGURE 5

pair of cables to two further junction boxes located inside the radio room from which direct connection is made to the actual radiogoniometer (Figure 6). The cable effecting this junction

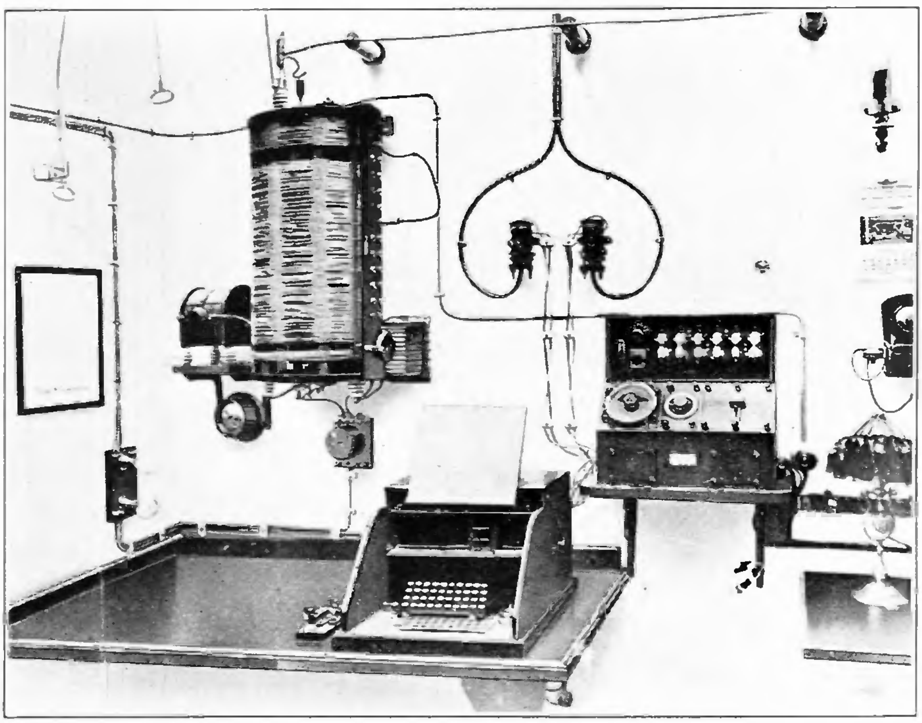


FIGURE 6—Connections of Radiogonimeter. (Inside Wireless Room).

is of a special design and is lead-covered and contains two wires insulated from each other by means of paper insulation which reduces the electrical capacity between the two contained wires of the cable to an absolute minimum. The actual capacity of this cable between the wires for every 100 feet is only 0.0008 mfds.

The reason for employing such a cable is to insure that the natural wave length of the complete antenna circuits is always shorter than the shortest wave it is desired that the radiogoniometer will have to receive.

In order to reduce the actual tuning adjustments to a minimum, these shipboard antennas are used in conjunction with a very tightly coupled radiogoniometer (Figure 7).

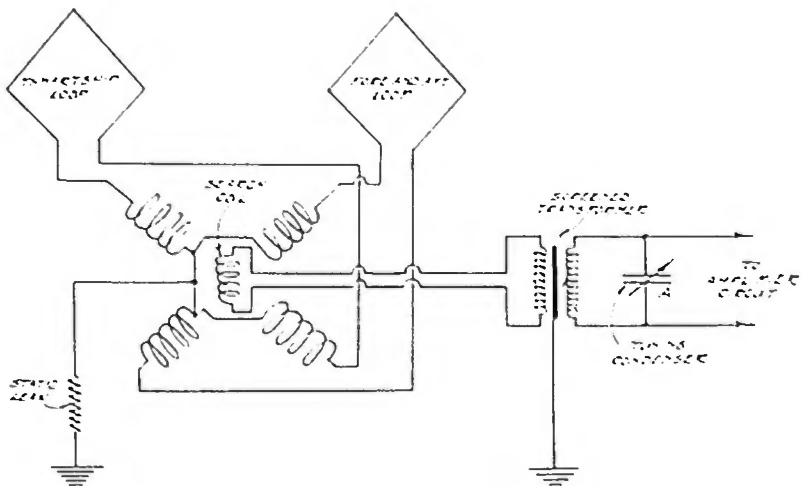


Figure 7

This action permits of the two loops being of an untuned or practically aperiodic order which are tunable by one condenser A, located in the coupled search coil. The actual coupling between this circuit and the two loops is somewhere of the order of 80 percent.

The goniometer itself consists of the two usual identical antenna coils disposed at right angles, the mid-points of which are earthed thru a static leak to insure of the antennas being protected from static discharges.

The introduction of a long cable connection between the active and screened portions of the direction finding system, such as is mentioned above, is likely to produce an undesirable electrical component which would be exaggerated if the loops were grounded directly at the mid-points of the antenna coils, and consequently a static leak of considerable impedance is inserted.

The search coil itself is in turn also duly coupled to the amplifying system by means of a screened transformer. The screen of this transformer is grounded and eliminates the possibility of an out-of-balance electrostatic coupling, which is one of the causes of the insidious vertical component referred to above. This vertical component produces errors in the readings given and is due to the loops themselves tending to act as plain aerials instead of as directional frames.

Figure 7 shows the actual connection of the radiogoniometer and screened transformer and readily illustrates the manner in which the screen effectively insures that the amplifying system responds only to the currents flowing in the search coil circuit.

Amplifying Circuit

The amplifying device of this Marconi Bellini-Tosi direction finder consists of five stages of radio frequency amplification, a detector, and one-stage of audio-frequency amplification. The tubes employed in the radio and audio amplifications are the well-known Marconi V-24 type, whilst the detector is of the QX variety. The working current of the tubes is about 0.7 ampere each.

There is nothing of particular interest in this form of amplifier which embodies the usual radio frequency air core transformer wound on cylindrical ebonite formers.

"Sense" Finding

Plotting a polar curve for the current received by a rotating frame or the search coil of a Bellini-Tosi for every direction of the incident wave to such systems results in a "figure of eight," or bi-directional diagram. (Figure 8.)

It can be seen from this diagram that in the direction in which signals are at a maximum the receiving power of the antennas undergoes a very small change over a considerable angle, whereas the same change in angle in the direction in which the signals are a minimum gives a very large change in the signal strength, illustrating graphically the reason for the reading of minimum points when taking bearings.

This diagram, however, produces two minima and therefore is only useful for indicating the bearing of the incident wave from the system and does not denote its actual direction of origin.

To produce this actual direction a uni-directional or cardioid diagram is necessary and this can be obtained by combining the effects of a vertical antenna which is equally sensitive to signals from all directions, with those of a loop.

Suppose a loop and a vertical antenna be both coupled to a common circuit in such a manner that the current induced in this circuit by the incident wave on the vertical antenna is exactly equal to that induced in the loop when the plane of that loop lies along the direction of propagation and is, therefore, at its optimum portion of reception. It will be seen that the electromotive force induced in the vertical antenna is either in phase or 180 degrees out of phase with the electromotive force induced in the frame according to the actual direction and consequently the two currents will either add or subtract giving one maximum and minimum for the whole 360 degrees. This addition and subtraction of currents for the whole rotation gives the cardioid diagram shown.

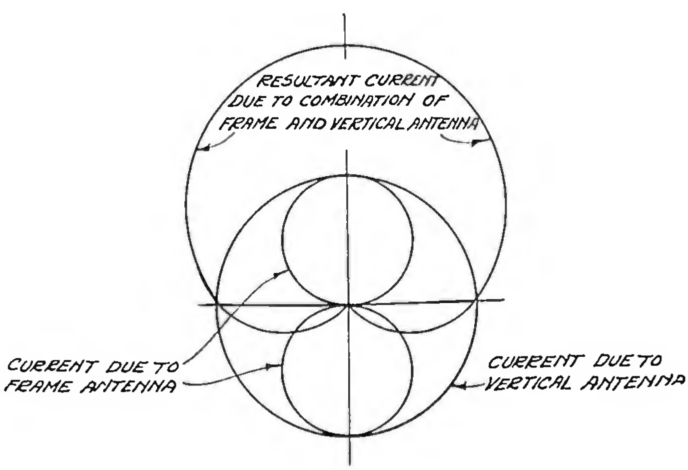


FIGURE 8

In the actual marine direction finder under discussion the tow loops are themselves made to function also as a vertical antenna as well as individual loops. This is accomplished by connecting the mid-points of the two loops thru a resistance to a tertiary winding of the afore-mentioned screened transformer. The resistance mentioned performs the double function of adjusting the phase and also the amplitude of the current. The value of this resistance is so chosen as to give the best minimum possible over the whole band of wave lengths covered by the transformer and its tuning condenser. Actually there is only one wave-length where perfect zero balance is obtained. Figure 9 shows the connections when the apparatus is functioning under this "sense-finding" arrangement.

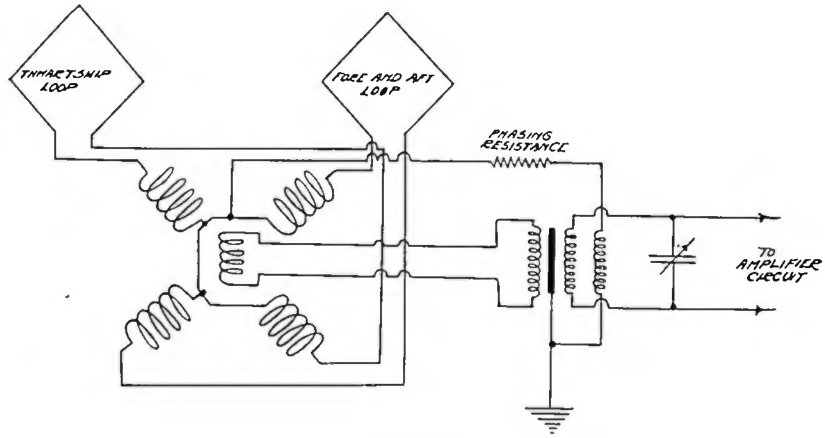


FIGURE 9

The sense minimum is never utilized alone in marine working as it is not usually sufficiently defined to guarantee accurate working and it is therefore used in conjunction with the more pronounced minima of the bi-directional diagram.

The actual apparatus (see Figure 10) is equipped with a switch which enables the operator to use the instrument in either the bi- or uni-directional functions which are known as the "DF" or "Sense" positions, respectively. There is a third position of this switch, known as the "Stand-bi" position, when the whole system functions purely as a simple receiving circuit and is used in searching for signals.

The complete circuit of this direction finder is shown in Figure 10.

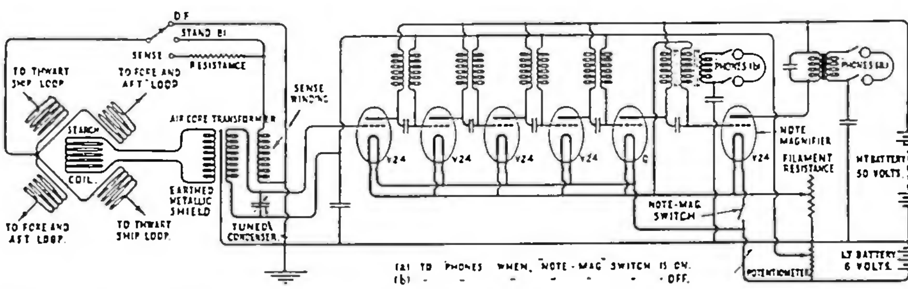


FIGURE 10—Two Small Variable Calibrating Chokers Are Omitted for Sake of Clearness. (These Are Actually Connected in Each Side of Fore and Aft Loop Circuit)

ERRORS

The errors that are likely to be encountered with the Marconi Bellini-Tosi marine direction finder can be divided into four classes.

Firstly, those errors associated with the antennas and the local external ships' rigging.

Secondly, inherent errors in the radiogoniometer instrument.

Thirdly, errors due to atmospherical conditions, which include the well-known sunrise sunset and night effect, and,

Lastly, errors due to coastal refraction.

The former two are governable by mechanical or electrical corrections whilst the latter two present a much more difficult problem, necessitating the taking of observations under special conditions.

Antenna Errors

Calibration Error

In equipping a radio direction finder antenna system on board ship, it is not possible to follow the process adopted in the case of the basic apparatus described, that is to say, two identical oriented receiving loops cannot be utilized.

The reason for this is due to the fact that the ship itself, being of metal construction with all its rigging, can be considered as an auxiliary receiving loop, lying in a vertical plane parallel to the keel of the vessel. This introduces an artificial loop parallel to the fore and aft loop, and therefore electrically coupled to it with the resulting mutual induction effect. This effect tends to improve the reception qualities of the tangible fore and aft loop. Naturally it is impossible to erect the loop outside the electrical coupling of this fictitious loop furnished by the ship's keel, and to overcome this difficulty the thwartship loop has to be made considerably larger than that of the fore and aft loop. This latter loop has in its electrical circuit two chokes, so that a final calibration adjustment can be made to render the reception qualities of the two loops equal.

Loop Tuning Error

The possibility of a loop tuning error is brought about by the fact that the two loops must necessarily be of slightly different sizes for reasons mentioned just above, so that the frequency of the two circuits regarded as two loops will be different. If one loop happens to be in tune with the wave being received and the other not, a very large error may result as the current induced in the loop that is in tune with that of the incident wave will be very much too strong.

This error, however, will not be present unless the frequency of the loops is quite close to that of the received wave. In order to overcome this difficulty, the wave lengths of the loops are kept well below 450 meters and it is for this reason that the use of the special low capacity cable mentioned above is imperative.

Lack-of-Symmetry Error

The lack-of-symmetry error is caused by the electrical constants of the two halves of one loop measured from the apex to the mid-point being unequal. If this error is present it will result in the antenna coil, which should be giving say a zero current, producing a current which in turn will induce energy in the search coil and so introduce an error or tend to make the minima ill-defined.

The causes of this lack of symmetry are two-fold; the first of which is that due to unequal distribution of any electrical dimensions between the two sides of the loop, which result in unequal impedance in the two halves measured from the apex to the midpoint. This can be corrected by reconstructing the loops.

The second cause is that due to re-radiation from conducting portions of the structure and rigging of the ship which may have unequal effects upon the two halves of the loop. This is a difficult fault to discover and also to eliminate, and requires a careful planning of the antenna loops at the time of fitting.

In fitting a vessel it is essential that both the loops have a very pronounced apex so as to eliminate the alteration of the apex due to the pitching and rolling of the vessel which would otherwise result in the symmetry of the system being destroyed.

Instrument Errors

Vertical Component Error

One of the chief errors with regard to the instrument to be combatted is that known as the vertical component error. This error is brought about by superimposing the stray capacity coupling between the antenna coils and the search coils on the magnetic coupling. The effect of this stray capacity coupling is to distort both positions of zero result of coupling so that the two zero readings are not exactly 180 degrees apart, altho the line bisecting the angle between the observed zero is at right angles to the proper zero due to the magnetic coupling only. The presence of this error, however, is detrimental to rapid and accurate work and can easily be eliminated by the introduction of an earth shield between the windings of the transformer connecting the search coil with the tuning condenser, such as is described heretofore.

Quadrantal Error

This second instrument error is due to the fact that the coupling of the search coil and the antenna coil as a whole is not perfectly constant for all positions of the search coil relative to the antenna coils. By employing a search coil with a specially disposed winding, we can overcome the varying coupling effect so that errors due to this effect are no longer experienced in practice.

Errors Due to Atmospherical Conditions

(Sunrise, Sunset and Night Effect)

The taking of bearings by a radiogoniometer during sunrise and sunset is not desirable as it is during these periods that the well-known Heaviside layer effect is very prominent, with the result that electromagnetic waves are polarized to a certain extent and are tilted to such an angle as to produce a false directional effect in the whole system. This effect is also noted sometimes during the night, and whilst antennas of certain construction have been designed to overcome this difficulty it has not been possible at the moment to instal them on board ships, owing to the very poor receptive qualities of such antennas.

The usual manner of combating this difficulty is to take "large swing" readings during the night period, observing two points on the scale of equal sound intensity rather than to work to a fine minimum.

Night effect can be artificially produced by the transmitting of signals from an aeroplane carrying a trailing antenna, the electromagnetic waves so produced being of a polarized nature

Coast Line Refraction Error

It has been found by experience that radio bearings are distorted or thrown out of line if the line joining the transmitting station and the receiving direction-finding station cut a coast line at an angle of 15 degrees or less or if high land intervenes either close to the transmitting or receiving station.

The refraction of the electromagnetic waves may produce an error of as great as five degrees and is nor always constant in direction, altho for one particular locality this error for a given direction is found not to vary; this error will also alter considerably for very small changes of position.

In order to overcome this difficulty, navigators are warned to study the contour of the land surrounding the transmitting station, the bearings of which it is his desire to observe.

Special sketch charts are being slowly compiled of localities where such errors are noticed, giving the arcs of good bearings observed of the known coast stations; a typical example of such a chart is shown in Figure 11.

Conclusion

In conclusion, it perhaps will not be out of place to detail one or two instances showing the use of the marine direction finder.

The S. S. "Stavangerfjord," proceeding on her first voyage from Christiania, after being fitted with a Marconi direction finder, received distress signals from the S. S. "Otta," which was drifting helplessly with her rudder-stock broken. From the position sent out by the "Otta," and accepted without question, it appeared she was 275 miles away, and the "Stavangerfjord" steered toward the position given. On arriving there, however, no trace of the "Otta" could be found, and observations with the direction finder indicated that she was sixty miles away. The course was altered accordingly, and the information given by the direction finder was found to be correct. Meanwhile the salvage steamer "Jason" had been sent out from Bergen to assist the "Otta," and the "Stavengerfjord" stood by. It soon appeared

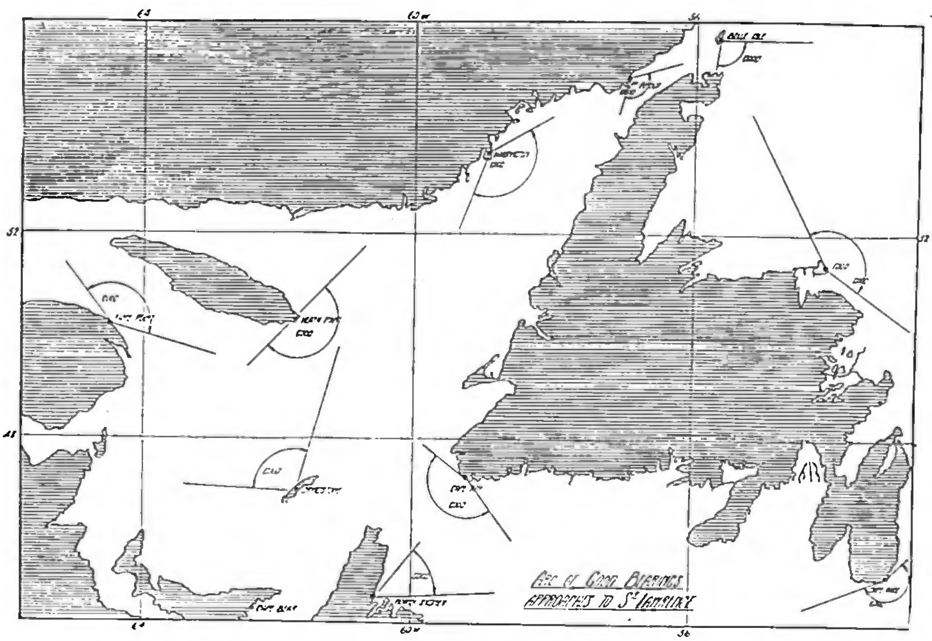


Figure 11

that the "Jason" was steering a wrong course, owing to her inability to take observations by the sun, and the "Stavangerfjord" piloted her to the right place by repeated directional observations.

During somewhat heavy storms in the North Atlantic the Norwegian steamer "Mod" was so badly damaged that she became practically a wreck, and for thirty-six hours the crew were huddled on deck without food. The captain sent out an "SOS" message, giving what he believed to be his position, but which proved erroneous. At least six vessels diverted their courses in an endeavor to render help, but no trace of the "Mod" could be found. For some time the British vessel "Melmore Head" was too far away to be of any assistance, but the captain kept in touch with what was happening, and when he found the "Mod's" signals getting stronger, he directed the radio operator to ascertain her position by means of his direction-finding apparatus. According to the reading thus obtained, the "Mod" was seventy-eight miles away from the position she herself had sent out, and in an entirely different direction. The captain of the "Melmore Head" placed his reliance on the direction finder and found it to be correct, arriving at the foundering vessel just in time to save twenty-three members of the crew before the "Mod" sank.

The rescue of the crew of the Norwegian steamer "Ontaneda" constituted another triumph for this latest development of radio science. A heavy gale had left the "Ontaneda" drifting helplessly with broken-down engines and listing at an angle of 50 degrees in a heavy sea. Her captain sent out the "SOS" signal for help, but in the thick weather he could get no observations of sun or stars, and had to estimate his position by dead reckoning. His calculations proved to be ninety miles out. Several vessels went to his assistance and steamed about near the position given without finding a trace of the "Ontaneda," but the S. S. "Fanad Head," by means of her direction-finding apparatus, discovered the true position of the vessel. She was nearer to the "Fanad Head" than to the ships which had originally steamed to her assistance, and the captain of the "Fanad Head" proceeded to the spot where he calculated the "Ontaneda" to be. Thus the radio direction proved to be the correct one, and the distressed sailors were rescued just in time.

An instance of the utility of the direction finding apparatus installed on board the White Star Liner "Megantic," is forthcoming in the case of the great assistance afforded to that vessel in locating the position of the U. S. S. "Charlot," after the latter struck an iceberg in dense fog and requested the "Megantic's" help. The commander relied implicity on the bearings taken, and the "Megantic" was only some ten miles distant when the "Charlot" advised that help was no longer required.

The master of the S. S. "Rosalind" reports that on his way to help the distressed steamer "Thyra," which was drifting rapidly before a strong breeze, he ran down to the position given by her, but could not find her anywhere. He then tested the direction-finding apparatus, called up the "Thyra" and got a bearing, ran straight on it, and proved the utility of this piece of apparatus. On the day following this incident, in a blizzard, the captain of the "Rosalind" directed the S. S. "Eastern Course" to his ship by means of the direction finder.

The salvage of the Norwegian ore-carrying steamer "Capto" was probably due entirely to the fact that its true position was plotted by the Marconi direction finder on board the S. S. "Montclare," when other vessels failed to locate its position from the directions sent out by the "Capto" itself. The "Capto's" wireless distress call, reporting the loss of a rudder and asking for assistance, was picked up by "Sachem" when the vessels were about 100 miles apart; and the "Sachem" immediately steered in the direction given. A heavy gale was raging, and altho the "Sachem" searched thoroughly, she could not locate the disabled ship until the Canadian Pacific liner "Montclare" determined the exact position of the two ships by means of its direction finder, and communicated the information to the "Sachem," which then came up with the "Capto." A tow of 750 miles to St. John's, Newfoundland, followed, ten days being taken to weather the conditions and reach harbor.

When on her first voyage with a Marconi radio direction finder on board, the Canadian Pacific Steamer "Metagama" ran into a dense fog off Belle Isle and was navigated by the aid of bearings obtained with the direction finder.

A case of another kind was that in which the transfer of a sick man from one ship to another was materially assisted by the use of a Marconi Wireless Direction Finder. On January 10th, when 1,700 miles west of the Franch coast, there was an accident on board the American steamship "Eastern King" and one of the seaman was injured internally. There was no doctor on board, and a message was sent out asking for a ship, with a doctor, bound for New York. This was answered by the Italian steamship "Conti Rosso," which was 300 miles away. Steaming directly towards each other, the two ships were due to meet at midnight, but owing to the heavy sea running, the captains mutually decided that it was unsafe to transfer the injured man at that time, and it was arranged that the ships should meet at 7 A. M. In the morning there was a dense fog, but the "Conti Rosso" was equipped with a Marconi direction finder, and by its use the ships were able to find each other without delay. They met at 6.45 A. M., and the sick man was transferred to the doctor's care and eventually landed at New York.

SUMMARY: A description of the circuits, construction, installation, and use of the Marconi Bellini-Tosi marine radio direction finder is given. The method of determining "sense" as well as "line of direction" of a distant station is explained.

The various forms of errors in reading and the methods of reducing or eliminating these are discussed.

The paper concludes with a description of a number of cases where the Marconi direction finder has contributed to the safety of life at sea in stormy weather.

RECENT DEVELOPMENTS IN VACUUM TUBE TRANSMITTERS*

By

B. R. Cummings

(Radio Engineering Department, General Electric Company, Schenectady, New York)

The present paper may be considered as a continuation of the one presented before the Institute on April 4, 1923, by Mr. W. R. G. Baker.

Near the end of Mr. Baker's paper, reference was made to a 20-kilowatt transmitter which was then under development. I shall begin, therefore, with a description of this transmitter, a number of which have been built and installed, going into its circuit and design rather in detail, because it is felt that they indicate most clearly the present accomplishments in medium power vacuum tube transmitters.

Before discussing this, and other transmitters, however, I would call attention to several standard practices which were adopted with their development.

It will be recalled that the majority of tube transmitters built prior to 1923 were essentially "antenna oscillators," that is, no intermediate circuit was used. The wave length was established by the antenna circuit, and change in wave length by a change in the antenna loading with suitable changes in plate and grid coupling.

Such transmitters have been found to be unsuited to some classes of service, due to one or the other of the following reasons:

(a) As the efficiency of tube transmitter circuits increased, thru subsequent development, and the tube efficiency carried well above 50 percent, resulting in an approximation to a square wave plate current, it has been found necessary to utilize a circuit which would suppress the radiation of harmonics from the antenna.

(b) When used on antennas which are not rigidly secured in place, a swaying of the antenna is accompanied by a

*Presented before The Institute of Radio Engineers, New York, April 2, 1924. Received by the Editor, April 3, 1924.

change in the transmitted wave length. This effect is aggravated appreciably at the receiving station by the low decrement of the continuous wave signals.

A satisfactory solution to the suppression of harmonic radiation from the antenna has been found in the "Intermediate Circuit" transmitter which, in its elements, is shown in Figure 1.

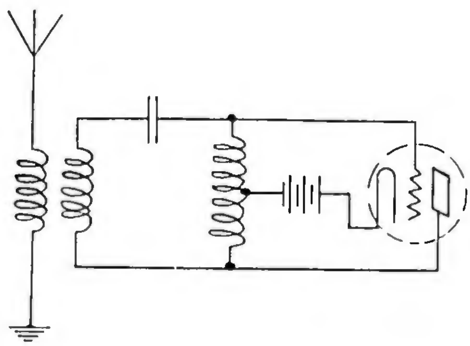


FIGURE 1

The intermediate, or "tank" circuit, as it is commonly called, is designed to have a circulating KVA. (kilowatt-amperage) many times that of the KW. (kilowatts) in the antenna circuit, usually in the order of from 12 to 15 times. It has been found that the suppression of harmonics is proportional to some degree on the ratio of intermediate circuit KVA. to antenna KW.

This circuit, when applied, brings us at once to the difficulties introduced by the so-called "drag-loop" effect encountered in intermediate circuit tube transmitters. Considerably more has been published abroad than in this country on this phenomenon. I will only include here a statement of the conditions under which the "drag-loop" is encountered.

If, for test purposes, the intermediate circuit transmitter is set up as shown in Figure 2, and an attempt is made to bring the secondary circuit into resonance with the primary by increasing the capacitance of C_2, it will be found that the frequency of the transmitter will slightly decrease as resonance is approached, and that in the neighborhood of resonance the frequency will suddenly change to an appreciably higher value, the extent depending, among other things, upon the degree of coupling between the circuits. Further increase in the capacitance of C_2 will cause a gradual decrease in frequency, which becomes constant at a value slightly higher than the original frequency.

This effect is illustrated clearly in Figure 3.

If C_2 is now gradually decreased, the sudden change in frequency will again be noted, except that this time the change will occur at a smaller value of C_2. The resulting loop is the "drag-loop."

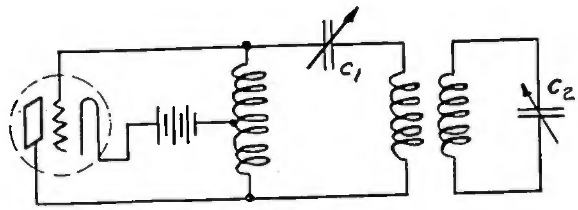


FIGURE 2

It is apparent that at values of C_2 lying between A and B, the circuit will oscillate at either of two frequencies and that operation is unstable. It has been found, in attempting to key a circuit of this kind, that the frequency set up would be either the higher or the lower one.

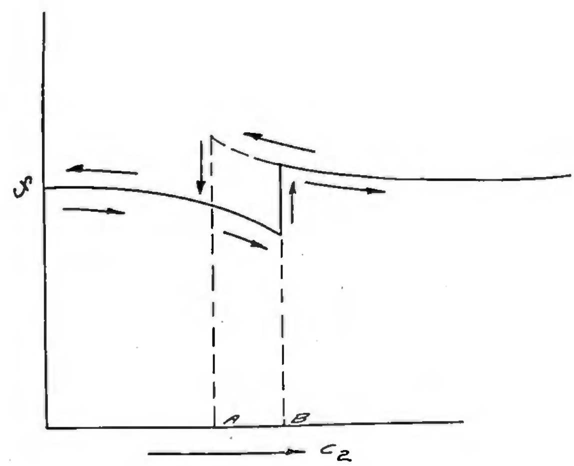


FIGURE 3

The cause of this phenomenon lies in the familiar laws of coupled circuits. It is encountered in spark transmitters when coupling is too tight, or when the gap does not quench properly, and all are familiar with the double hump in the frequency curve of such a transmitter. The lower frequency is established when the current in the intermediate and secondary circuits are in phase, the higher, when they are out of phase. These frequencies are lower and higher, respectively, than the natural period of the intermediate circuit.

In the vacuum tube transmitter there is no parallel to the quenching in a spark transmitter, so that the elimination of the drag-loop must depend on other considerations.

It has been found that the drag-loop may be eliminated in any of the three following ways:

(a) By having a very high circulating KVA. in the intermediate circuit. This solution is not economically practical.

(b) By secondary grid coupling, that is, coupling the grid to the secondary instead of the intermediate circuit.

(c) The use of a separately excited oscillator.

The third method has been adopted in transmitters in which an intermediate circuit is used. This has been done, primarily, because the separately excited oscillator also is of service in overcoming objection (b) to antenna oscillators, that is, the change in frequency with changes in antenna constants.

The separately excited oscillator, or the "master-oscillator" circuit, as it is more commonly called, has been adopted to hold constant output frequency and to facilitate the keying of the intermediate circuit transmitter, the intermediate circuit being provided, primarily, to suppress harmonic radiation from the antenna.

20-Kilowatt Transmitters

Outstanding among the transmitters which have been developed and built during the past year, are the 20-KW. vacuum tube transmitters built for the United Fruit Company for installation at a number of Central American locations for carrying the traffic of the United Fruit Company and the Tropical Radio Company.

Figure 4 shows the location of a number of these stations. It will be seen that they form a comprehensive communication system. The first three of these equipments have been installed and are in operation at Tegucigalpa, Honduras, at New Orleans, Lousiana and at Puerto Barrios, Guatemala. The installation of the remaining sets is now under way. Installations will also be made at Porto Barrios, Managua, and at Almirante.

The specifications laid out for the performance of these transmitters made it necessary to include positive means for the suppression of harmonics, and for maintaining constant frequency of output.

A schematic diagram of the rectifier of this transmitter is shown in Figure 5. It has an output of 2 amperes at 15,000 volts d. c. A 110- or 220-volt, 3-phase power supply supplies the primary of the plate transformer. The secondary is connected

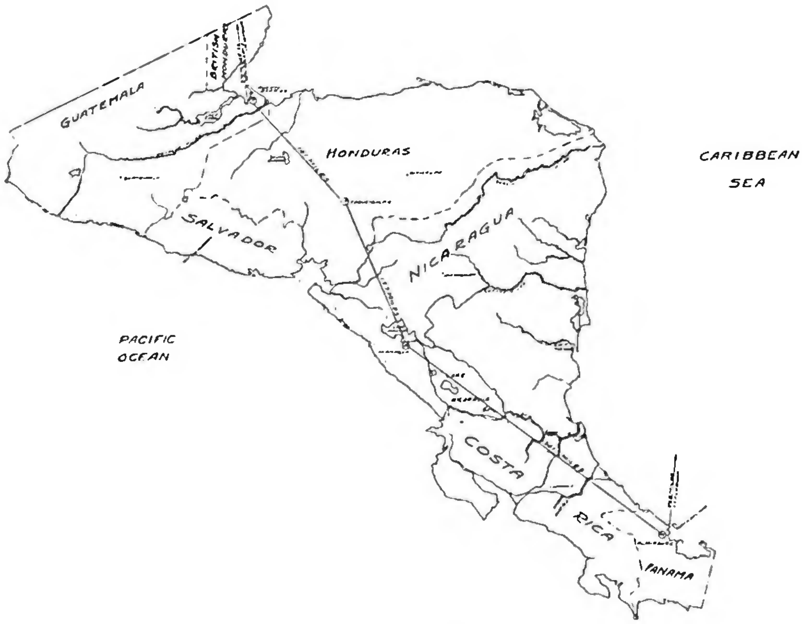


FIGURE 4

double Y with an interphase reactor between the common points of the Y's. A model UV-219 kenotron is connected in each leg of each secondary winding. The filaments are connected in parallel, and the load is taken from a mid point on the filament transformer, and a mid point on the interphase reactor. Smoothing condensers are placed across the output to decrease the ripple. These condensers are shunted by resistors, which are used to equalize the potential distribution across the condensers.

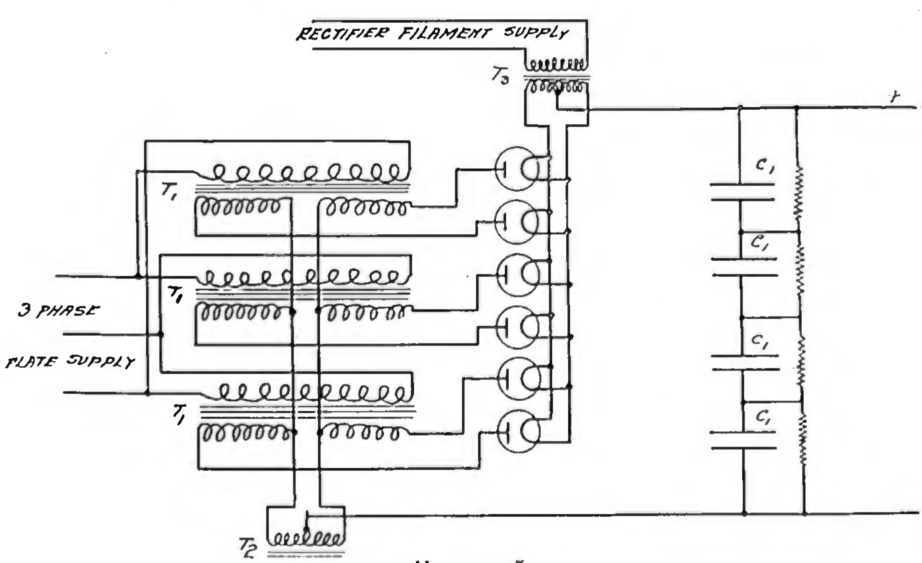


FIGURE 5

A schematic diagram of the complete transmitter is shown in Figure 6. The output of the rectifier is used to supply both the master oscillator and power amplifier, the plates of each of these tubes being operated at 15,000 volts, and the supply to them being thru suitable radio frequency choke coils L_1 and L_2.

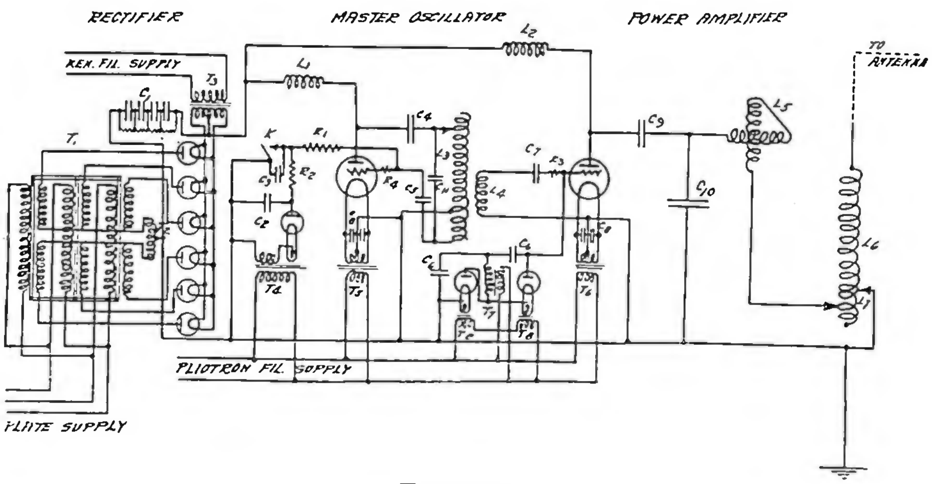


FIGURE 6

The master oscillator operates in a standard Hartley circuit, the output of which is fed to an intermediate circuit, the condenser of which is shown at C_{11}.

Grid biasing is accomplished by means of a kenotron rectifier, the circuit of which will be discussed in more detail later.

The grid of the power amplifier tube is coupled inductively to the coil system of the master oscillator, and is also biased by two kenotron rectifiers.

This method of biasing is of interest, and is shown more clearly in Figure 7.

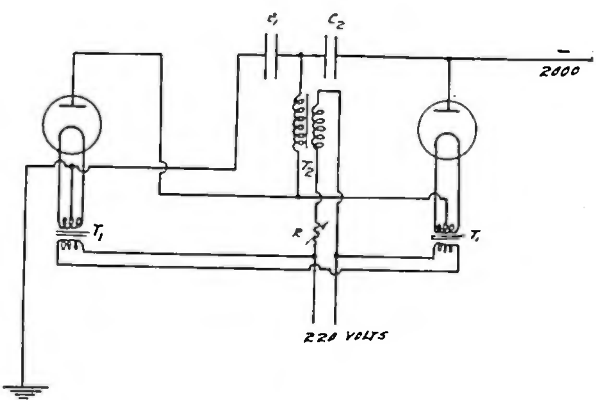


FIGURE 7

In this circuit, condensers C_1 and C_2 are alternately charged thru the kenotron in series with them, and the two condensers are in series with respect to the grid. The functioning of the circuit may best be understood by considering the rectifiers as functioning to keep the condensers C_1 and C_2 charged.

Referring again to Figure 6, the power amplifier operates into an intermediate circuit having a capacity C_{10}, and a variometer L_5 for tuning purposes. This circuit is coupled directly to the first down-lead of the multiple tuned antenna.

Keying is accomplished in the grid circuit of the master oscillator by opening and closing a circuit shunting the biasing rectifier. When the key is closed, the bias on the grid is controlled by grid leak R_1, but when the key is opened, a bias of approximately 2,000 volts is placed on the grid of the master oscillator.

All the equipment, except the outdoor tuning coils and their associated switching mechanisms, is installed indoors. The transmitters are built to cover a wave length range of from 2,500 to 4,500 meters. This range has been divided into two bands of from 2,500 to 3,300 and from 3,300 to 4,500. It will be noticed that in each case the wave length ratio is 1.3:1. Wave lengths within either of these bands are obtained by adjustments of the master oscillator tank variometer, the power amplifier, grid variocoupler, and the power amplifier tank variometer (4). The capacity values are not changed.

When changing from one wave length band to another, switches are thrown manually which change the capacitance of the master oscillator and power amplifier tank condensers, and change the coupling to the antenna tuning coil. During the tests of this equipment, it was found that the set gave stable operation over the required wave length range with a satisfactory safety factor in each direction.

The equipment, as built, is divided into the following mechanically independent units:

- Control switchboard.
- Kenotron rectifier.
- Master oscillator panel.
- Power amplifier tube unit.
- Power amplifier tank circuit variometer.
- Power amplifier tank circuit condensers.
- Outdoor wave change and coupling change switches.
- Outdoor tuning coils.

The power and control equipment consists of the following, assuming that the main power supply is not generated at the station.

Starter and rectifier panel.
Filament motor generator set.
Operator's control switches.
Bias voltage control panel.

The filament motor generator is supplied primarily as part of the filament voltage regulator equipment, and provides means whereby a voltage regulator can effectively maintain constant voltage.

The voltage regulator has been included on a panel with the filament generator starting contactors, as illustrated in Figure 8. The voltage regulator shown in the glass cabinet to the right is of the vibrating type and maintains constant voltage by means of a vibrating contact which is actuated by a coil placed across the a. c. output of the generator. The vibrating contacts

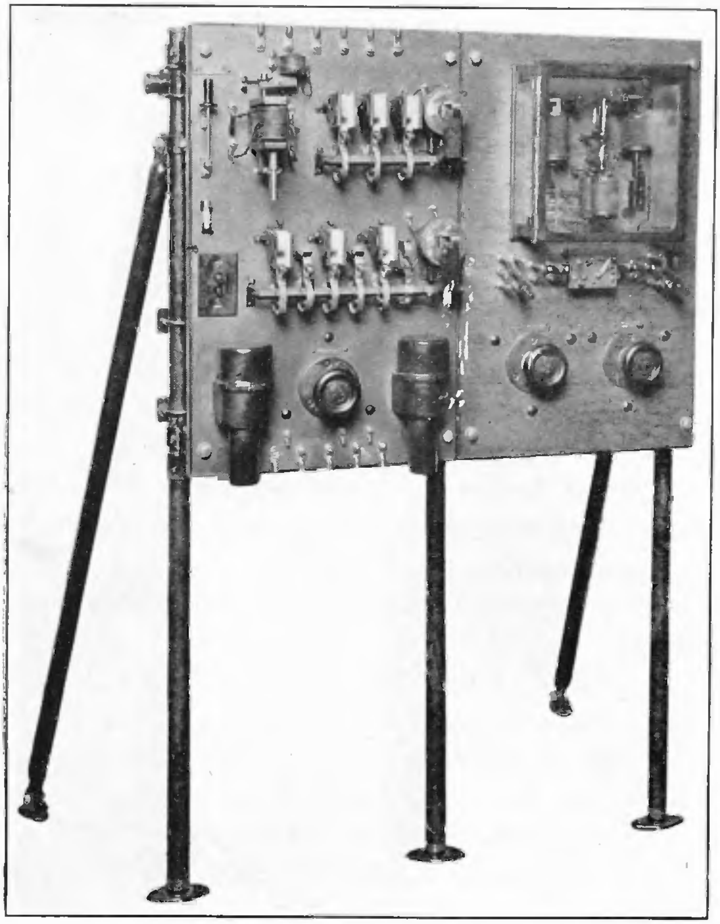


FIGURE 8—Starting and Regulating Panel for Use with Filament Lighting Motor Generator Set (A. C. Motor Driven) for 20 KW. Transmitting Equipments

act intermittently on the excitation of the filament generator. This regulator will maintain constant filament voltage over variations in supply voltage of from 95 to 115 volts, or its equivalent.

The control board is shown in Figure 9 and consists of the necessary instruments, controls, rheostats, and switches for the control of the set. Instruments are provided for reading total plate current, total power taken from the line, and the voltage impressed upon the kenotron, master oscillator, and power amplifier tube filaments. Two plate overload relays are mounted below the instruments, which, in the event of plate overload, open the holding coil circuit of the main line contactor, removing power from the set.

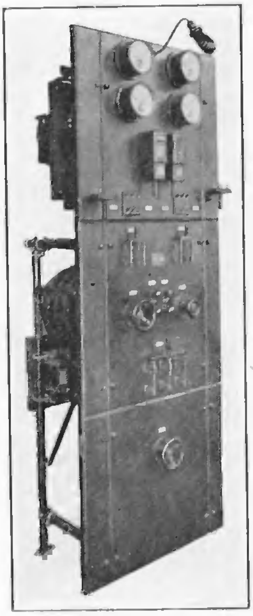


FIGURE 9—Service Panel for Use with 20-KW. Transmitting Equipment. Front View

The switches control the filament supply to the kenotron and power amplifier tubes, and rheostats are provided for filament voltage control and for plate voltage control. The latter rheostat is in series with the field of the power generator in those stations which generate their own power. For other stations, power change is accomplished by means of a switch, in the primary of the plate transformer which has three positions for each phase This switch is located in the same housing as the plate transformer and is oil immersed.

Figures 10 and 11 show more detailed views of the kenotron rectifier and its associated equipment. This rectifier is three-phase, double Y connected, and utilizes six UV-219 kenotrons. At full load the rectifier has an output of 2 amperes at 15,000 volts, with a ripple of 0.8 percent. At full load the rectifier efficiency is 92.7 percent, while the over-all efficiency, including filament consumption, is 83.6 percent. Other than the filaments, the losses in this unit are as follows:

Plate transformer	1,125 watts
Interphase transformer	100 watts
Protective resistances	313 watts
Space charge	790 watts

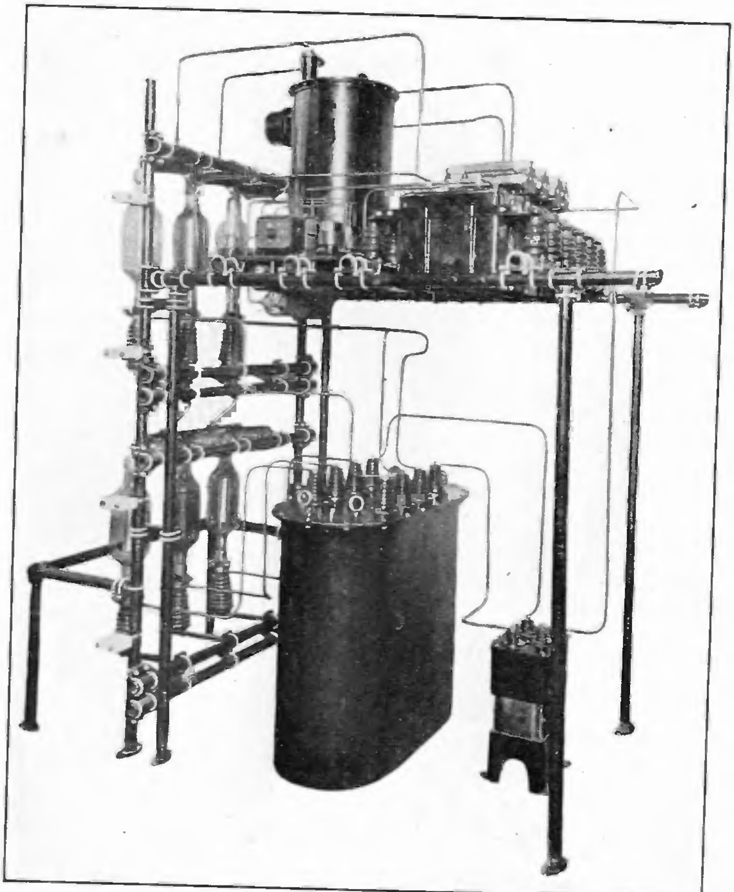


FIGURE 10—Kenotron Rectifier Unit for Use with 20-KW. Transmitting Equipment, Side View

This rectifier was given, among other tests, a heat run at full load for 12½ hours continuous operation, after which the maximum temperature rise in any of its parts was 48° C.

Referring to Figures 10 and 11, the plate transformer is shown at the bottom of the rectifier, and in the rear of it the filament transformer for the kenotron tubes.

The large tank on the superstructure is the interphase transformer. In the rear of the interphase transformer on the superstructure are mounted the smoothing condensers and protective resistors. No controls are provided in this assembly, all of them being located on the service panel. On the superstructure (Figure 10), can be seen the small plate transformer, filament transformers, and model UV-217 rectifiers used for biasing the power amplifier grid.

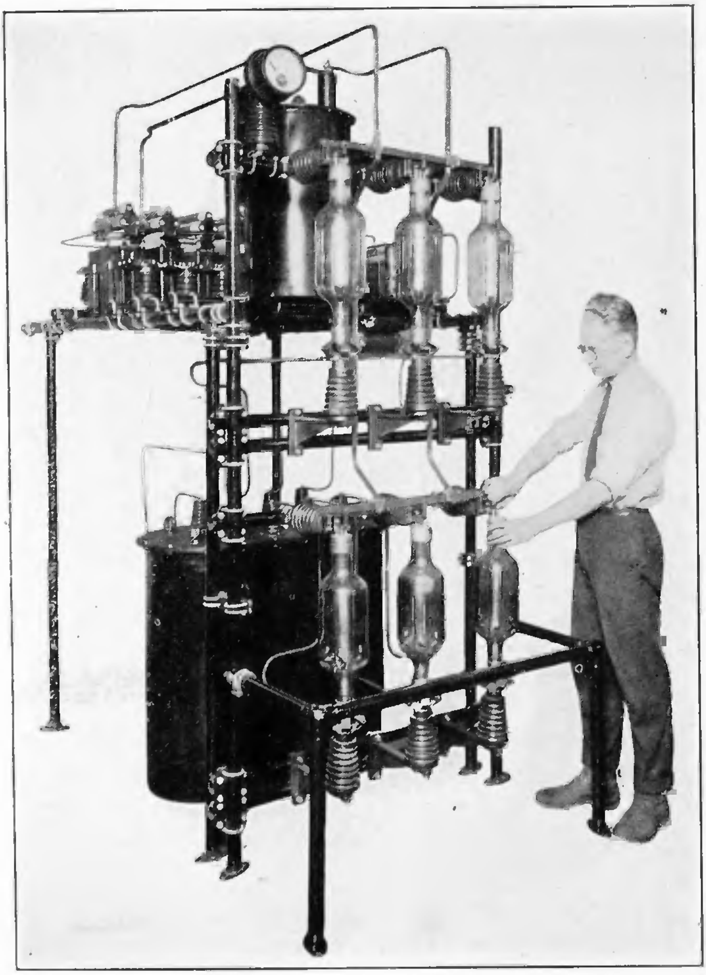


FIGURE 11—Kenotron Rectifier Unit (20-KW. Transmitting Equipment)

The resistances mounted across the smoothing contactors serve three purposes:

(a) As protective resistors to equalize the potential drop across the smoothing condensers.

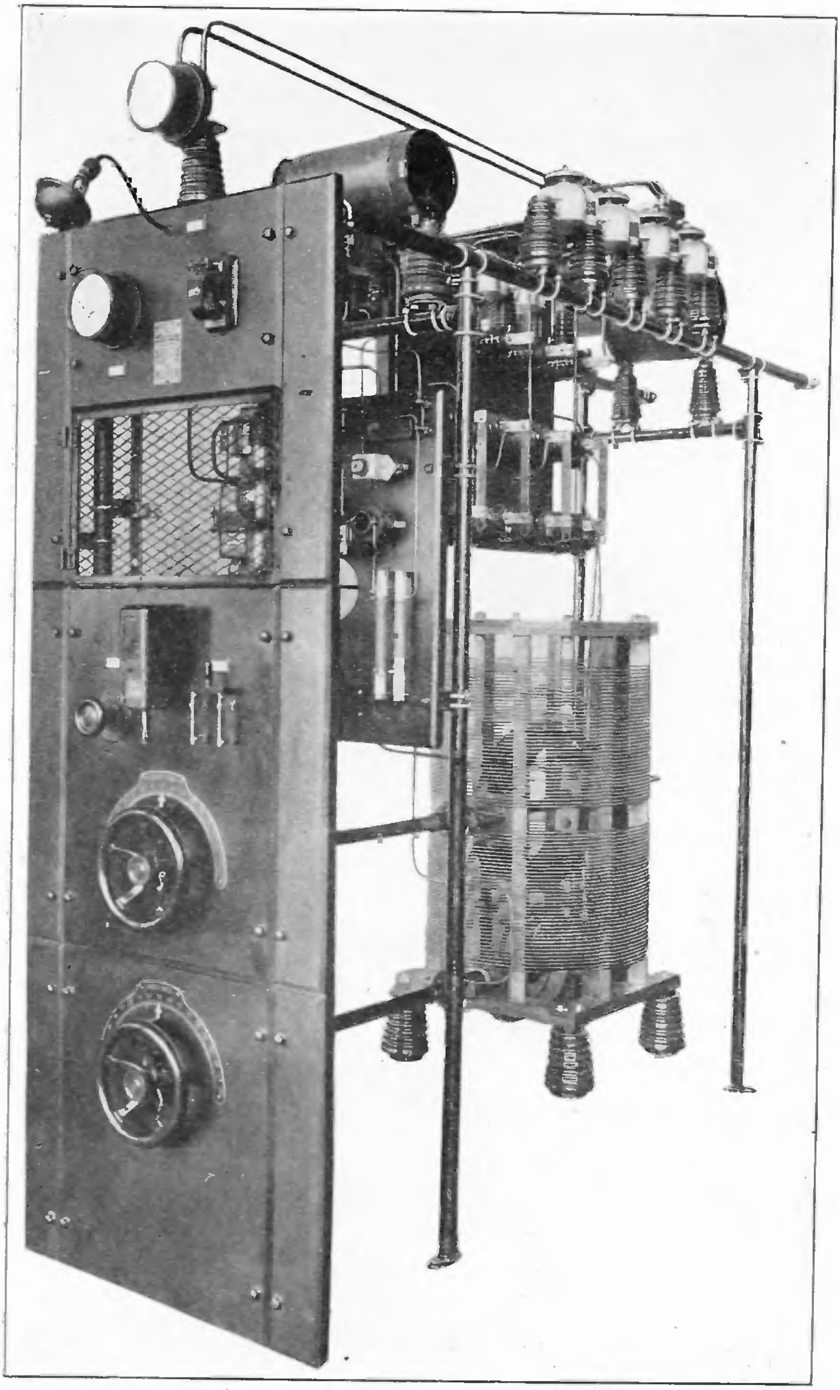


FIGURE 12—Master Oscillator for Use with 20-KW. Transmitting Equipment, Front View

(b) As a "dummy load" on the rectifier to improve its regulation.

(c) As a voltmeter multiplier.

The plate voltmeter is mounted on the insulator as shown on the top of Figure 11, and is in reality an ammeter connected in series with the protective resistors, calibrated in volts.

Figures 12 and 13 indicate two views of the master oscillator assembly. The 1-kilowatt tube may be seen in Figure 13 mounted in the rear of the main panel protected by a mesh screen.

In the rear of the main panel is located the coil system of the master oscillator. The two rotors in this structure are provided for adjusting the wave length of the master oscillator, and adjusting the coupling between the master oscillator and the grid of the power amplifier.

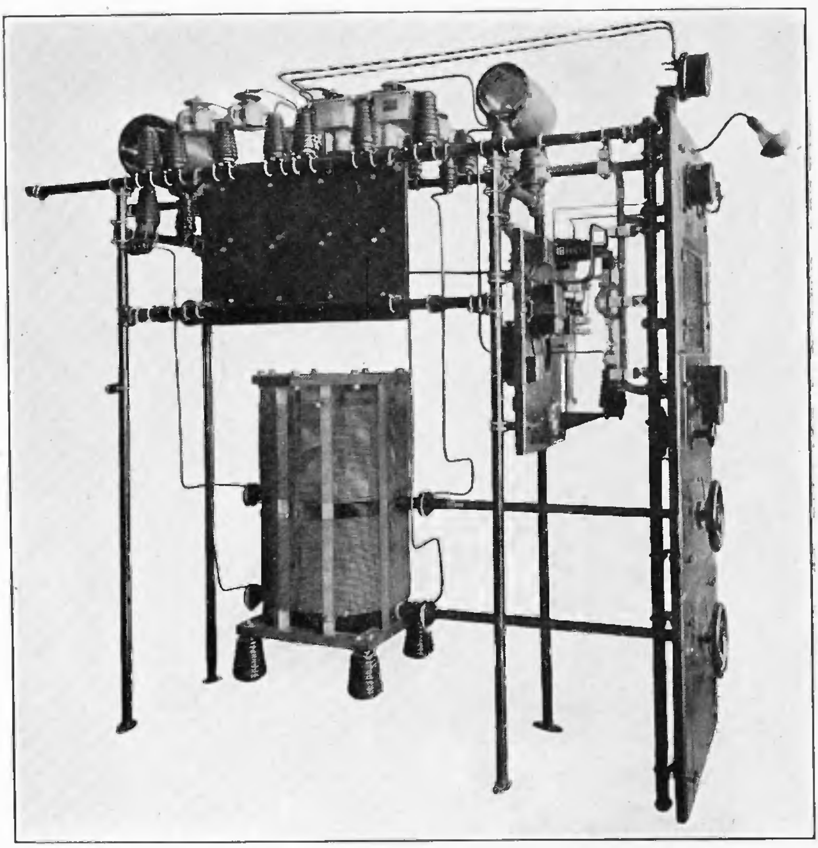


FIGURE 13—Master Oscillator for Use with 20-KW. Transmitting Equipment, Side View

The switches shown on the superstructure are provided for wave length change, and are used when throwing from one wave length band to the other.

In the upper right hand corner of the panel is mounted the keying relay, which is operated by a Morse key on the operator's table. The superstructure also contains the master oscillator tank condensers and plate choke coils.

The ammeter mounted above the panel on a porcelain insulator indicates the radio frequency current of the tank circuit of the master oscillator. The voltmeter on the panel indicates the voltage impressed on the master tube filament.

The contactors of the relay in the middle panel are connected in the ground lead to the filament transformer, in which position they protect the master oscillator tube from overload by opening the holding coil circuit of the main line contactor. The model UV-216 kenotron, which is used for providing bias for the master oscillator tube, can be seen on the sub-panel of Figure 13, together with its associated transformer.

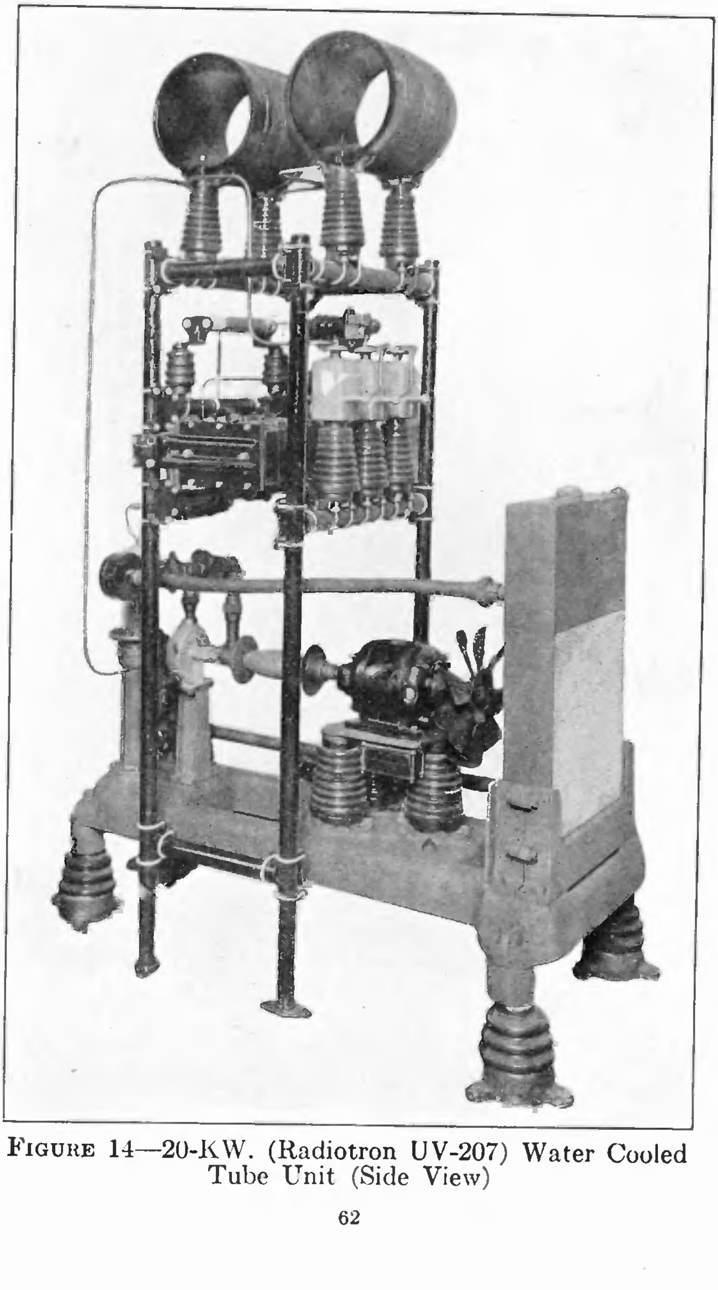


FIGURE 14—20-KW. (Radiotron UV-207) Water Cooled Tube Unit (Side View)

Figures 14 and 15 show front and rear views of the power amplifier tube and its associated cooling system and equipment. Figure 15 shows one of these tubes being lowered into the water jacket which forms part of the water cooling system.

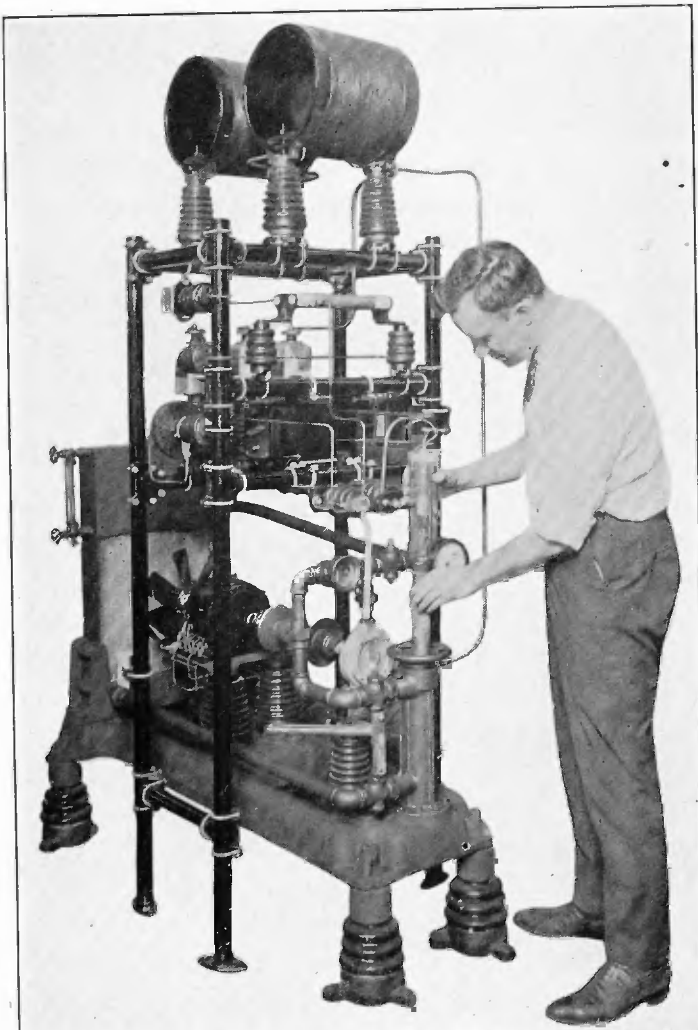


FIGURE 15—20-KW. (Radiotron UV-207) Water Cooled Tube Unit

This unit has been standardized upon for use with sets utilizing 20-kilowatt pliotrons, and has been supplied with various equipments other than those under discussion.

Since the anode of the pliotron is at a potential of 15,000 volts d. c. above ground in addition to the a. c. plate voltage, it is necessary to insulate the entire cooling system from ground for this voltage. For this reason the bed plate is substantially insulated from ground as shown in Figures 14 and 15. The circulating system consists of a motor-driven pump, the water jacket of the tube, a radiator for cooling purposes, and necessary pipe work. Associated with the system is a flow indicator, a dial thermometer and a sight gauge on the radiator. The pump motor is also used to drive a cooling fan in the rear of the radiator. The motor and its associated circuit is insulated from the potential of the remainder of the cooling system by porcelain insulators shown in these figures, and by an insulating coupling between the motor and pump, which can be most clearly seen in Figure 14.

When removing a tube from its water jacket, the lever shown slightly above the coupling in Figure 15 is thrown which closes the inlet and outlet of the water system to the cooling jacket and also operates an auxiliary contact removing power from the set.

The cooling system as designed will dissipate 16 kilowatts, with a temperature rise of 15 degrees. It is imperative that the cooling water be not allowed to approach the boiling point, under which conditions the anode of the tube would not be completely in contact with the cooling water and hot spots would develop.

The system is also laid out so that it can be operated on the thermo-syphon principle, at reduced power. This provision was made to provide against any possible failure of the artificial cooling system. A by-pass is provided for the pump when so operated.

The superstructure shown in these figures contains the power amplifier, filament transformer, the plate-blocking condenser, grid leaks, and by-pass condensers.

High potential tests on the cooling unit show that it is capable of withstanding a potential of approximately 60,000 volts without flash-over.

The tank condensers for the power amplifier are shown in Figure 16. These condensers have capacitances, respectively, of 0.0021 and 0.0032 microfarads, and a power factor of approximately 0.03 percent. They will withstand a potential of 22,000 volts without flash-over. Their design is a flexible one and it is possible to build up condensers of this type with any number of plates, depending upon the requirements of the circuit.

Figure 17 shows one of the tuning coils built for outdoor installation. The concrete base on which these coils are mounted is built by the customer at the time of installation. These coils are wound with litzendraht conductor on porcelain forms.

Metal supports are provided at the base of the coil structure, which are broken by insulators to minimize losses. No terminals or taps are provided on these coils when built, the location of such taps being experimentally determined when the sets are installed, at which time connections are made by suitably connecting taps for the various wave lengths.

Figure 18 shows the solenoid-operated high voltage disconnecting switch, six of which are used in each installation. Four are located at the first outdoor tuning coil, two for wave change and two for coupling change. Two are located at the second tuning coil for wave change. These switches are not in themselves suitable for outdoor mounting, but are mounted inside of protective housings erected at the tuning coils.

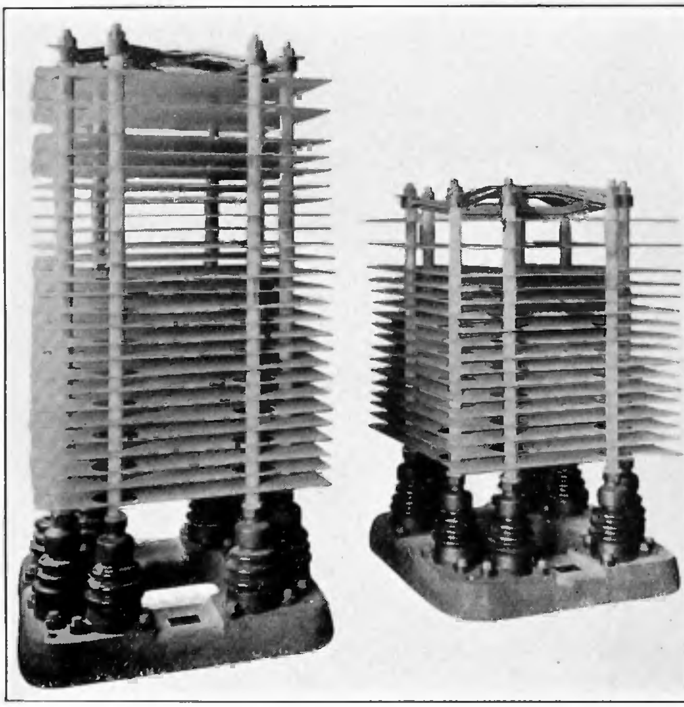


FIGURE 16—High Voltage Air Condensers

Figure 19 indicates the power amplifier tank circuit variometer. On this panel are mounted an ammeter indicating the current in the amplifier tank circuit, and a radio frequency ammeter indicating the current in the first down-lead. The latter instrument is operated from a thermo-couple located in the secondary of a radio frequency transformer, the primary of which is in the ground connection.

The switches in the lower right hand corner of this panel are provided for operating the outdoor switches of the tuning coils for wave length change. Two signal lamps are included, one above and one below these switches, to indicate the position of the outdoor contactors. The outdoor switches have asso-

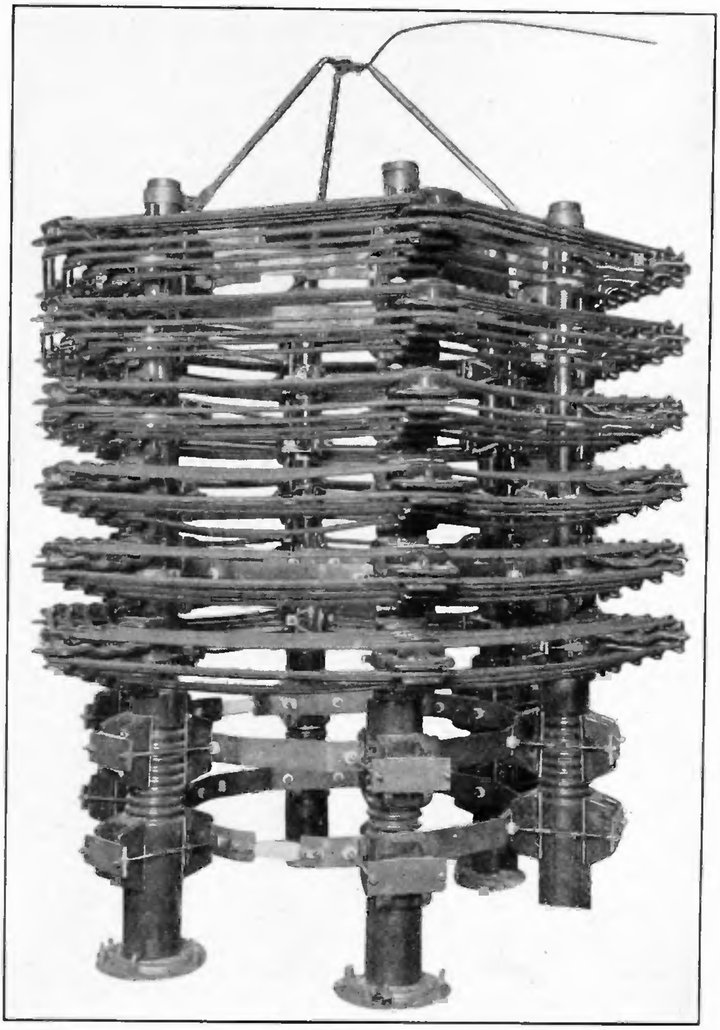


FIGURE 17—Tuning Coil for United Fruit Company, Radio Equipment

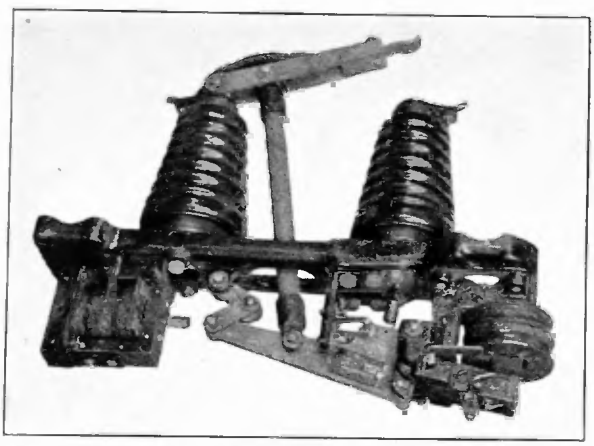


FIGURE 18—High Voltage Disconnecting Switch (Solenoid Operated), 25,000 Volts

ciated with them an auxiliary contact, which closes when the switch is in the closed position. Each of the signal lamps on this panel is in series with these auxiliary contacts on the outdoor switches so that positive indication is given in the station that all the outdoor switches have properly functioned when wave length is changed.

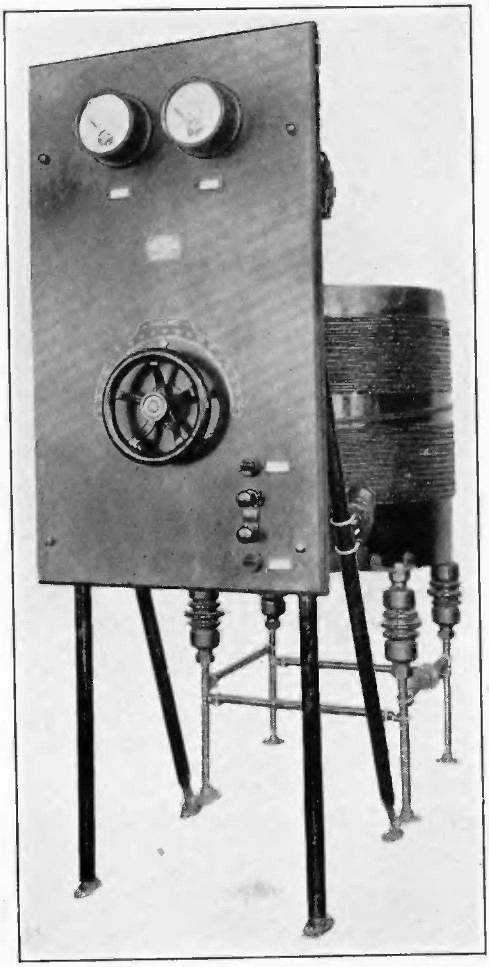


FIGURE 19—Intermediate Circuit Variometer, Front View

Figure 20 shows the operator's control panel, which is mounted on the operator's table and which includes all controls necessary for the normal operation of the set. The controls are operated in the sequence shown; power supply is connected by means of the plate contactor; the filament circuits are closed by the second contactor and the filament motor-generator set is started with the third contactor. The signal light at the top of this panel gives positive indication that the set is functioning.

Figure 21 illustrates the installation of one of these transmitters at New Orleans. This photograph illustrates the complete equipment, except for the filament motor-generator set and the outdoor coils and switches. The power amplifier tube unit is, unfortunately, not clearly visible in this picture.

Figure 21-A illustrates the installation of one of the outdoor tuning coils. The switches for wave change and coupling change are mounted in the housing shown to the right.

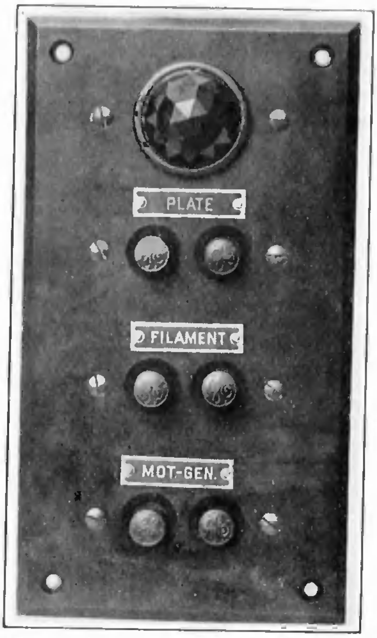


FIGURE 20—Operators' Control for Use with 20-KW. Transmitting Equipment

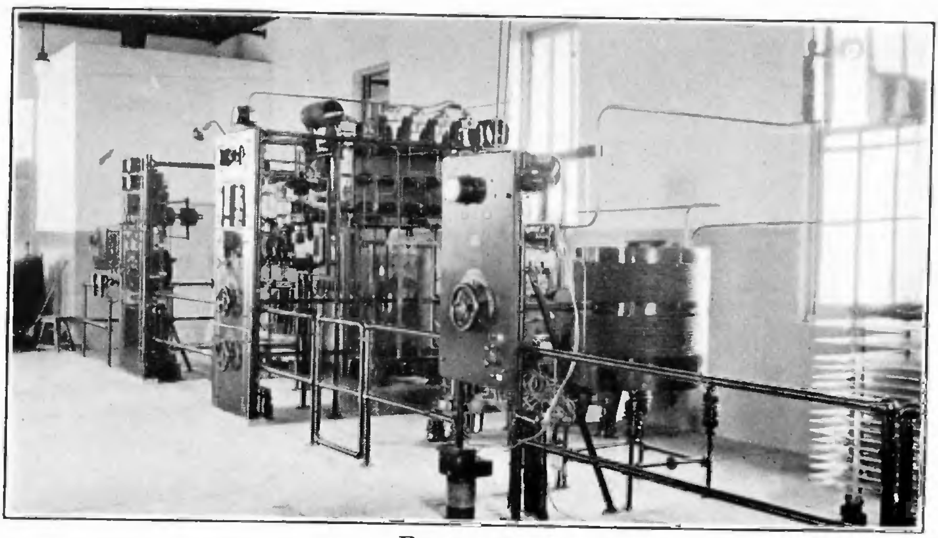


FIGURE 21

Complete reports are not available on the distances covered by thsee sets, altho the following results, obtained during preliminary tests, are of interest.

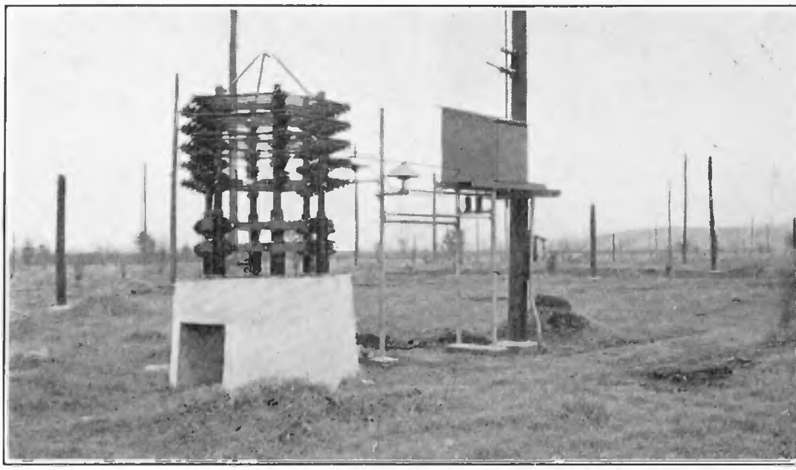


FIGURE 21-A

With the set at Tegucigalpa operating at medium power, and putting approximately 10 kilowatts into the antenna, average signals at New Orleans, a distance of 1,100 miles (1,780 km.), has an audibility of 400, daylight, and 700 night. At New York, a distance of 2,000 miles (3,200 km.), the average audibilities were 200 day and 600 night.

With 20-kilowatt input into the antenna at New Orleans, audibilities at Boston, Massachusetts, were reported in excess of 10,000.

10-Kilowatt Signal Corps Transmitter

A 10-kilowatt telegraph transmitter has been built for the United States Signal Corps, which, while resembling the 20-kilowatt sets in many respects, has sufficient points of difference to warrant discussion. This transmitter is now installed in service at Fort Douglas, Utah. The circuit is substantially the same as that of the 20-kilowatt transmitters, altho the set differs fundamentally from the 20-kilowatt in the following points:

(a) The wave length range is 1,500 to 3,500 meters.

(b) Group wave change switches are provided.

(c) The characteristics of the power supply were such that no automatic filament voltage regulation was required.

(d) The set is designed to operate on a single tuned antenna.

The difference in the rating of these transmitters is mostly noticeable in the output of the rectifier. The rectifier for the 10-kilowatt transmitters, which is illustrated in Figure 22, gives an output of 21.6 kilowatts at 15,000 volts d. c., with a ripple of approximately 1 percent. It utilizes six model UV-218 kenotrons in a 3-phase, double Y rectifier, with an interphase transformer. the over-all efficiency of the rectifier, including filament consumption, is 81.2 percent. Power change is accomplished by taps on a switch in the plate transformer, giving plate voltage of 6,900, 10,700, and 15,000, respectively. The handle of this switch can be seen in the rear of the cover of the plate transformer, in Figure 22.

The master oscillator of this transmitter, shown in Figures 23 and 24, duplicates that of the 20-kilowatt transmitters, except that the coil system has been located externally, and its

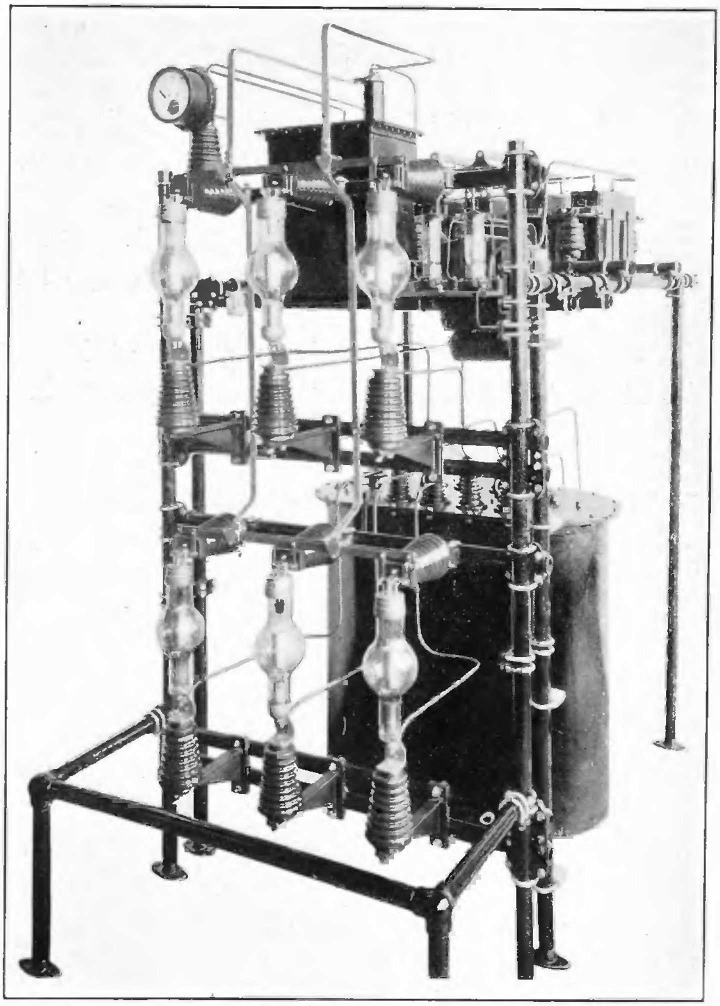


FIGURE 22—Kenotron Rectifier Unit (Signal Corps) Type RA-6

place taken by a three-bank wave change switch of novel construction.

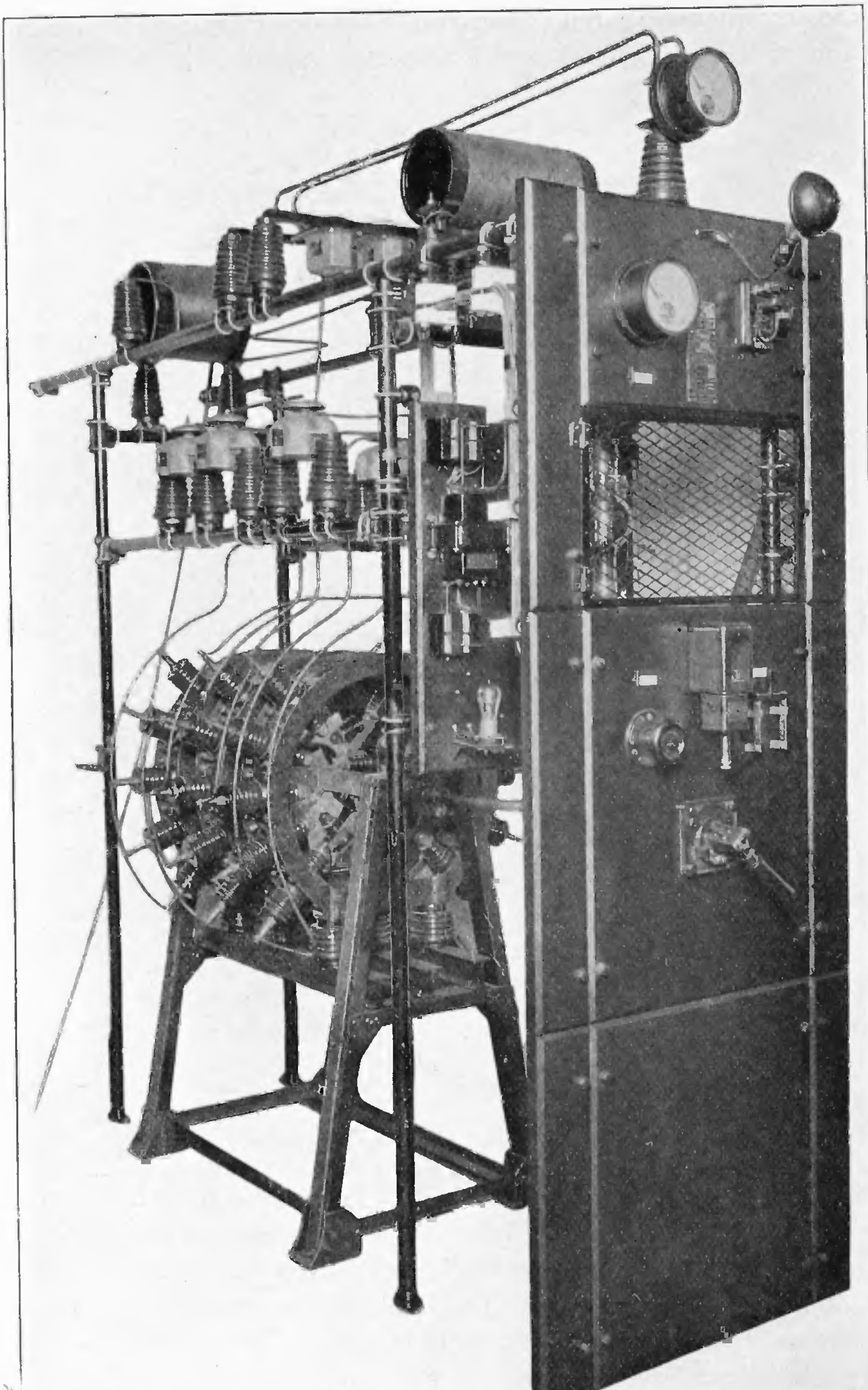


FIGURE 23—Master Oscillator Unit (Signal Corps) Type VO-2 (Front View)

Figure 25 shows the master oscillator coil system as an independent unit; the upper variometer varying the inductance of the intermediate circuit, and the lower one varying the excitation of the grid of the power amplifier.

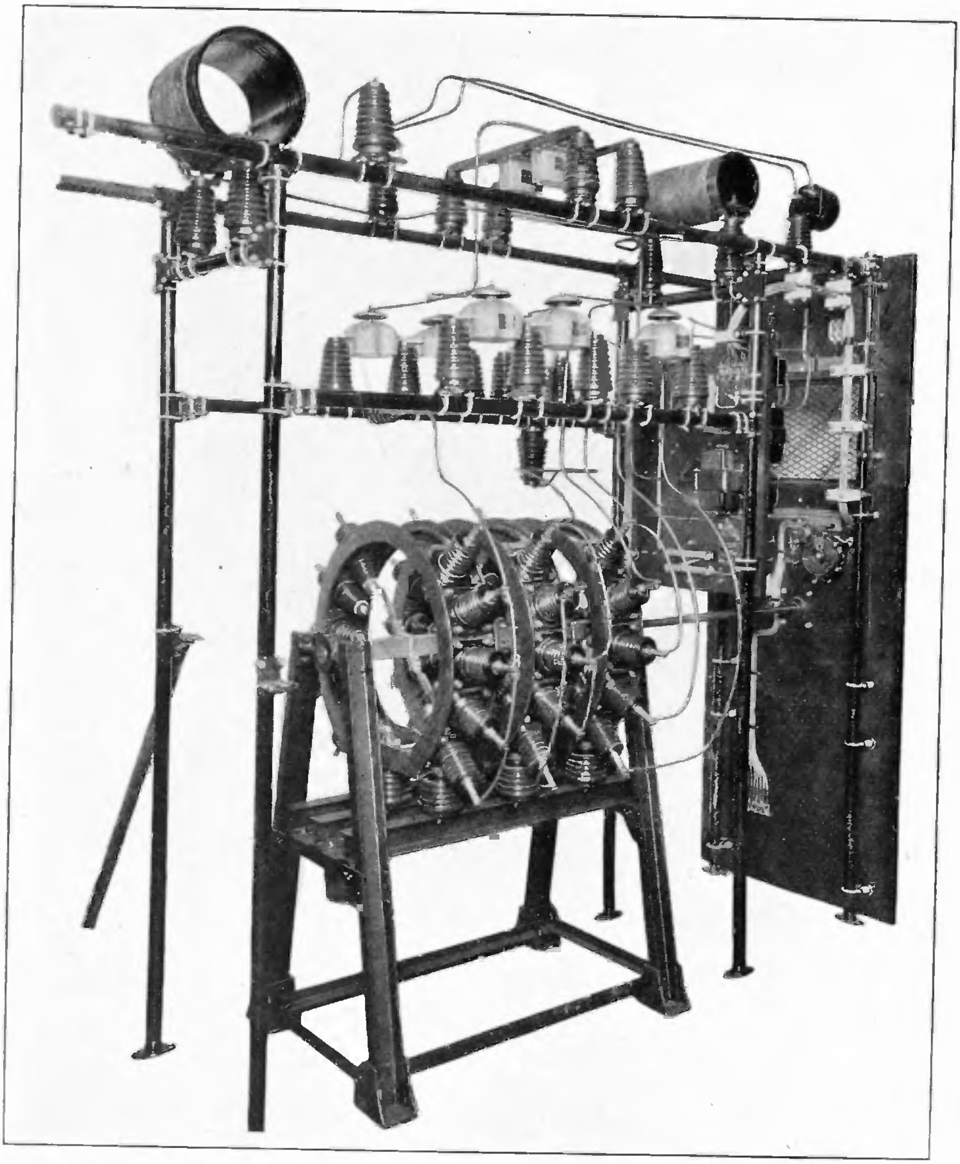


FIGURE 24—Master Oscillator Unit (Signal Corps) Type ID-9 (Rear View)

Figure 26 shows the wave change switch for the power amplifier and antenna, the largest bank in the rear of the switch being used to change the antenna loading. These wave change switches have been found to be extremely substantial mechanically, and are of a type which will probably be used in future sets requiring quick change in wave length.

Figure 27 shows the front of the same switch. The operating handle is so constructed that, when depressed, the switch is locked in position at the desired wave length. This panel also includes meters indicating antenna current and the intermediate circuit current of the power amplifier.

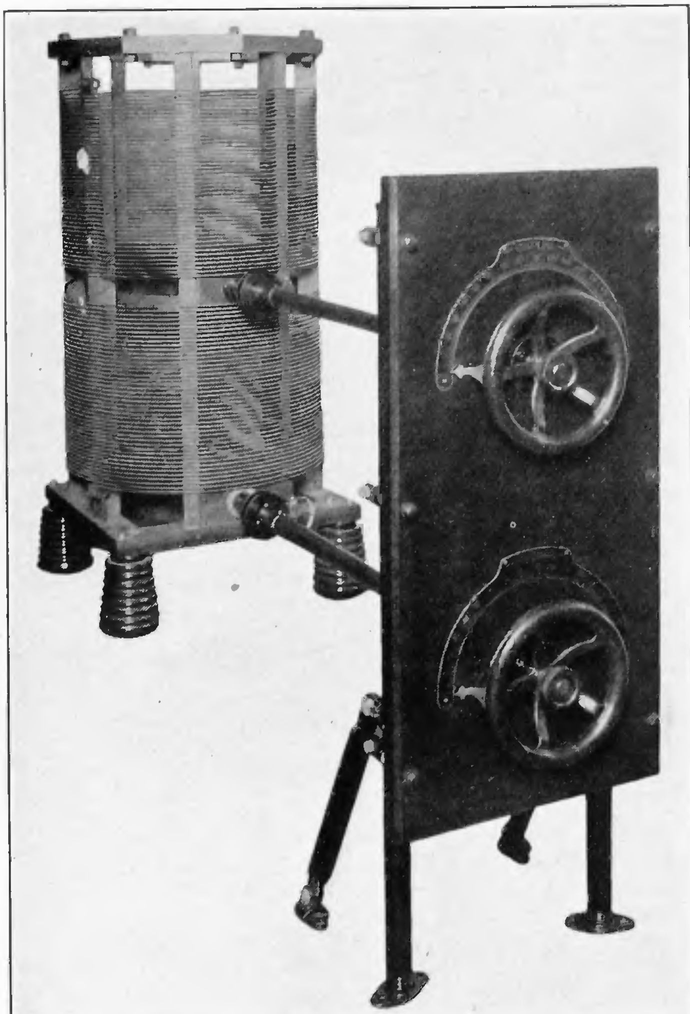


FIGURE 25—Master Oscillator Inductance (Signal Corps) Type ID-9

The loading coils for the antenna are shown in Figure 28. They are wound on treated wood supports to minimize losses.

Figure 29 shows the power amplifier intermediate circuit condenser, of the same type as those used in the 20-kilowatt transmitters, altho differing in the assembly. This condenser is rated at 22,000 volts. The three sections have capacitances, respect tively, of 0.0005, 0.0008, and 0.0012 microfarads. With these three values of capacitance, combinations can be used for the five wave lengths as follows:

Wave change number 1	0.0012 microfarads
Wave change number 2	0.0013 microfarads
Wave change number 3	0.0017 microfarads
Wave change number 4	0.0020 microfarads
Wave change number 5	0.0025 microfarads

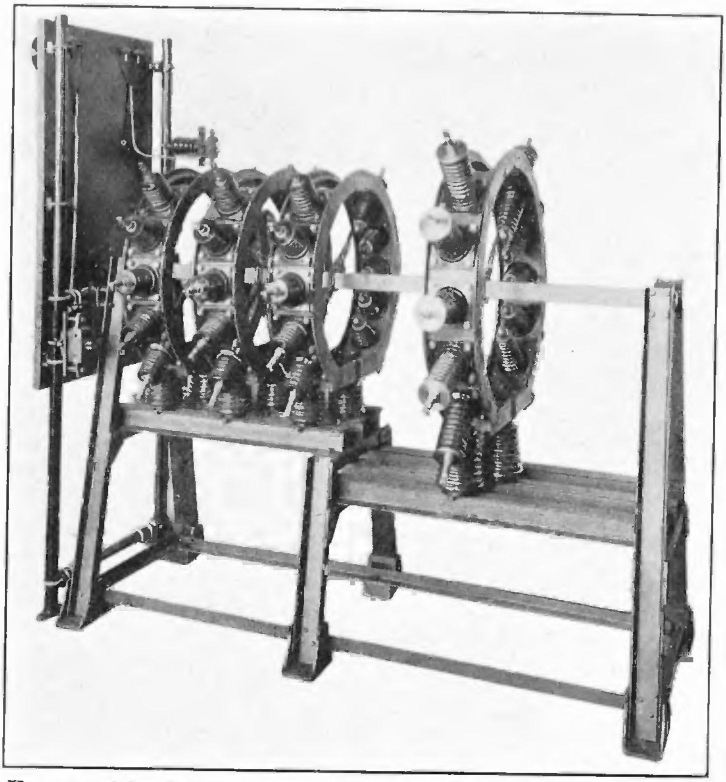


FIGURE 26—Wave Change Switch (Signal Corps) Type SW-83 (Side View)

The changes in connections to accomplish these capacitance steps are made by the power amplifier wave change switch.

The efficiency of this complete transmitter, based on the input from the line and the input in the antenna, including all filament consumption, is 56.5 percent at 1,700 meters.

Figure 30 is shown as a matter of interest to indicate the wiring on the service panel of one of the medium power transmitters. All wiring on these panels is of lead-covered conductor, to provide adequate shielding. The Radio Department has adopted the practice of photographing the first panel to be wired, and then using such photographs in the wiring of duplicate equipments. This procedure has been found much more efficient than the previous practice of making actual drawings of the wiring.

Figure 31 is another photograph taken primarily for wiring purposes.

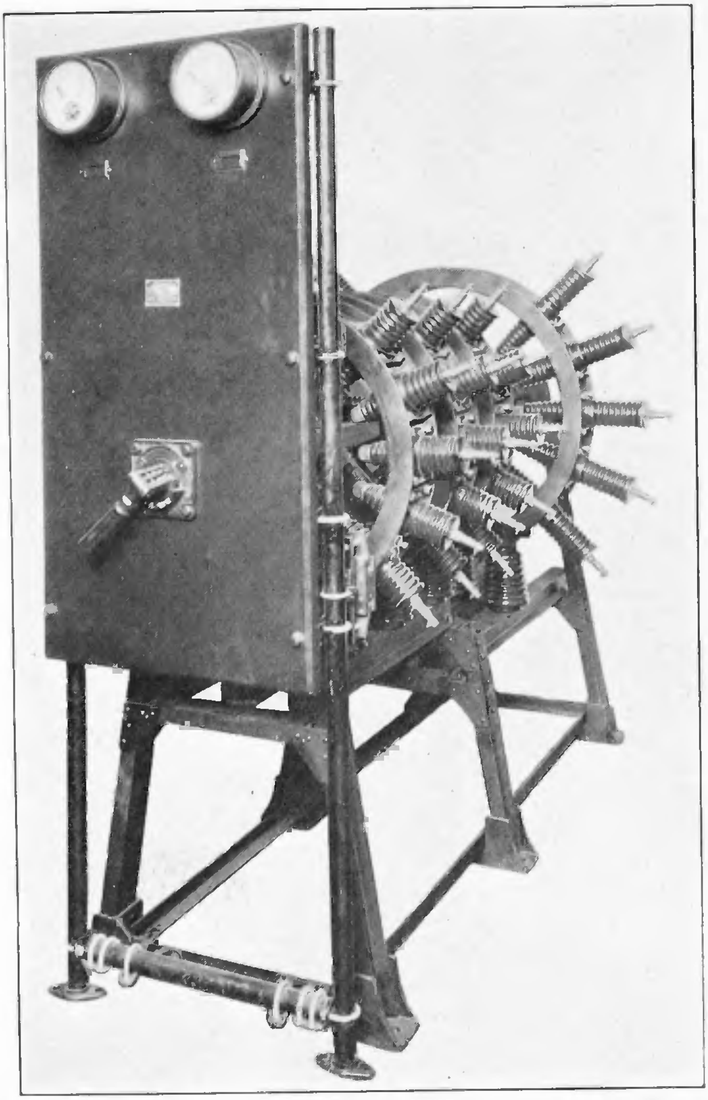


FIGURE 27—Wave Change Switch (Signal Corps) Type SW-83 (Front View)

In connection with the development of the transmitters first described, investigations were made to secure data upon which to base closer computation of the predicted performance of transformers and reactors, particularly filter and modulation reactors. An accurate, economical design of such reactors which carry an alternating current superimposed on a direct current, has been made possible by careful investigation of "incremental" and "decremental" permeability. These investigations have brought to light much useful data for the design of this equipment which was not hitherto available, and it is hoped that the results of the tests will be made the subject of a separate paper.

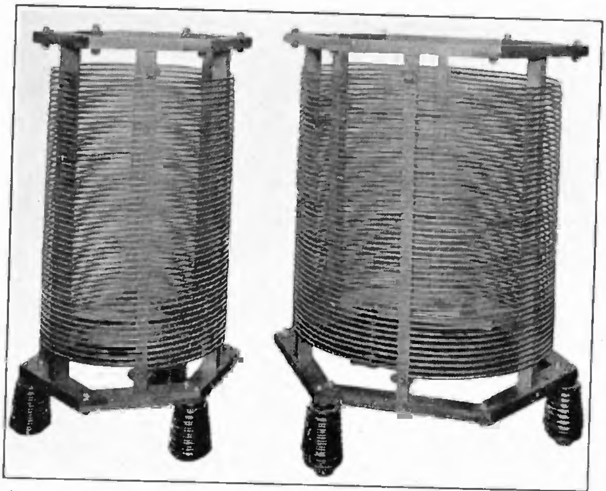


FIGURE 28—Antenna Loading Coils (Signal Corps) ID-6 and ID-7

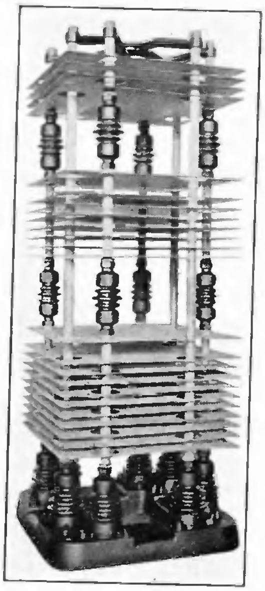


FIGURE 29—Intermediate Circuit Condensers (Signal Corps)

KEYING CIRCUIT

After a considerable amount of development work and service tests with various types of keying circuits, the one shown in Figure 35 has been adopted for low power vacuum tube telegraph transmitters. This figure shows the essential elements of the keying circuit without reference to the oscillating circuits.

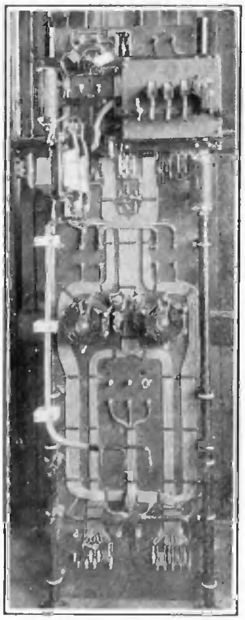


FIGURE 30 — Service Panel, 10-KW. Telegraph Set (Back View Showing Wiring)

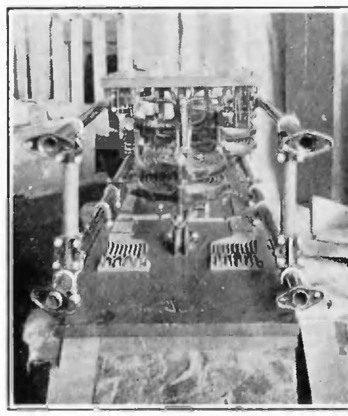


FIGURE 31—Service Panel 20-KW. Telegraph Set (End View Showing Wiring)

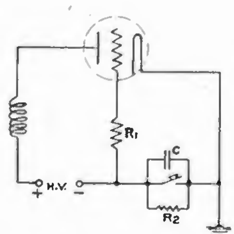


FIGURE 35

The filaments are grounded as usual. The grid, or grids of the tubes, are returned to the negative side of the high voltage supply with suitable grid leak resistors. The key is placed between the negative side of the high voltage supply and ground, and is shunted by a condenser C and a resistance R_2. The function of the condenser is merely to absorb sparking at the key contacts. The function of the resistance R_2 is to place a definite bias on the grids of the tubes when the key is up. In this position a small current, in the order of several milliamperes, flows thru resistance R_2, placing a bias of several hundred volts on the grids of the tubes, resulting in a very positive keying system. This circuit is utilized in the majority of the medium power transmitters about to be described.

SCR-136 Mule Pack Transmitter

The manufacture of a vacuum tube mule pack transmitter was completed for the United States Signal Corps. The preliminary development of this transmitter was carried on by the Signal Corps at Camp Alfred Vail, New Jersey, and the further development and design was fundamentally the carrying out of the work which was started there.

The building of this set incidentally included the development of a gas engine driven generator, which is illustrated in Figure 36. This figure illustrates the power equipment in its carrying position, in which the generator is mounted apart from the gas engine.

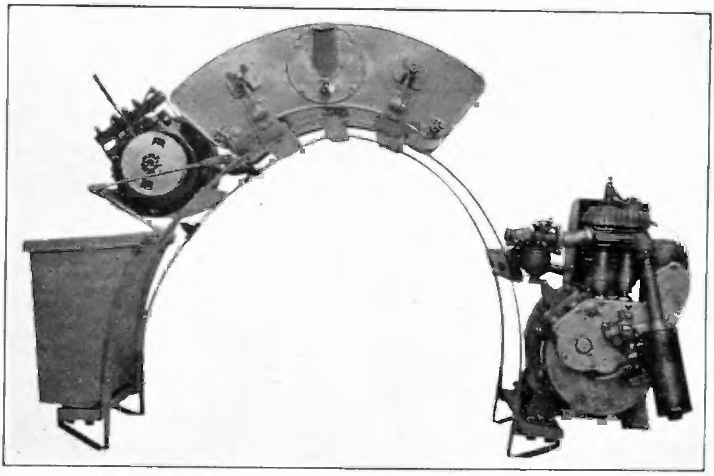


Figure 36—Mule Pack Power Unit for United States Signal Corps

The gas engine is a 4½ horse-power unit, and weighs 64 pounds (29 kg.). It is equipped with a governor, which provides 5 percent regulation from no load to full load. The engine runs at a speed of 2,500 revolutions per minute, and drives the generator directly at that speed.

The complete power equipment shown in this figure, including the gas engine, generator, gasoline tank, gasoline and tool box, weighs 250 pounds (118 kg.).

The generator, under full load, delivers 0.6 amperes at 900 volts, and 15 amperes at 11 volts. The power unit is rated at one hour's continuous operation.

Figure 37 shows the gas engine-generator unit assembled for operation. The coupling between the generator and the gas engine is accomplished by a single thumb-screw. The power equipment is of course removed from the mule's back for operation.

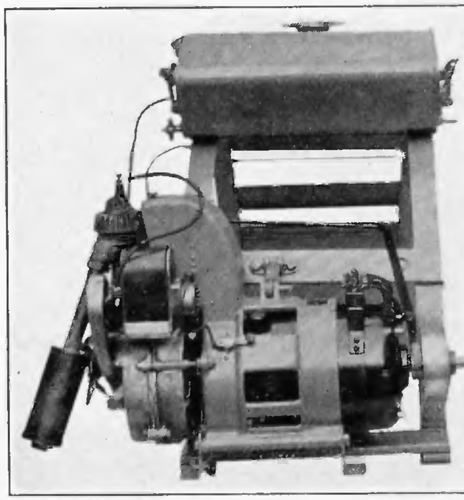


FIGURE 37—Mule Pack Power Unit for United States Signal Corps

The transmitter is completely housed in a weather-proof case for transportation, and provided with a vent in the top of the cabinet, which is closed in this condition.

Figure 39 shows the transmitter in operating condition. The vent in the cover automatically opens when the cover of the transmitter is lowered. The vent was found to be essential to assist the dissipation of heat generated by the tubes.

The weight of the transmitter unit alone is 43½ pounds (19.8 kg.). The containing case weighs 40 pounds (18.2 kg.), making a total weight of 83½ pounds (38 kg.). A circuit diagram of this transmitter is shown in Figure 40. It utilizes four 50-watt tubes; one as a master oscillator, one as a speech amplifier, one as a modulator, and one as a power amplifier.

The master oscillator tube is used in a Colpitts circuit, the wave length of which is controlled for the entire wave length range of the set by means of variometer L_7. The master oscillator is coupled to the grid of the power amplifier by means of the condenser C_4. The grids of the power amplifier and the modulator tubes are biased by means of a potentiometer, R_2 in the grid circuit of the power amplifier tube. Coupling between the speech amplifier and the modulator is accomplished by an iron core transformer T_2.

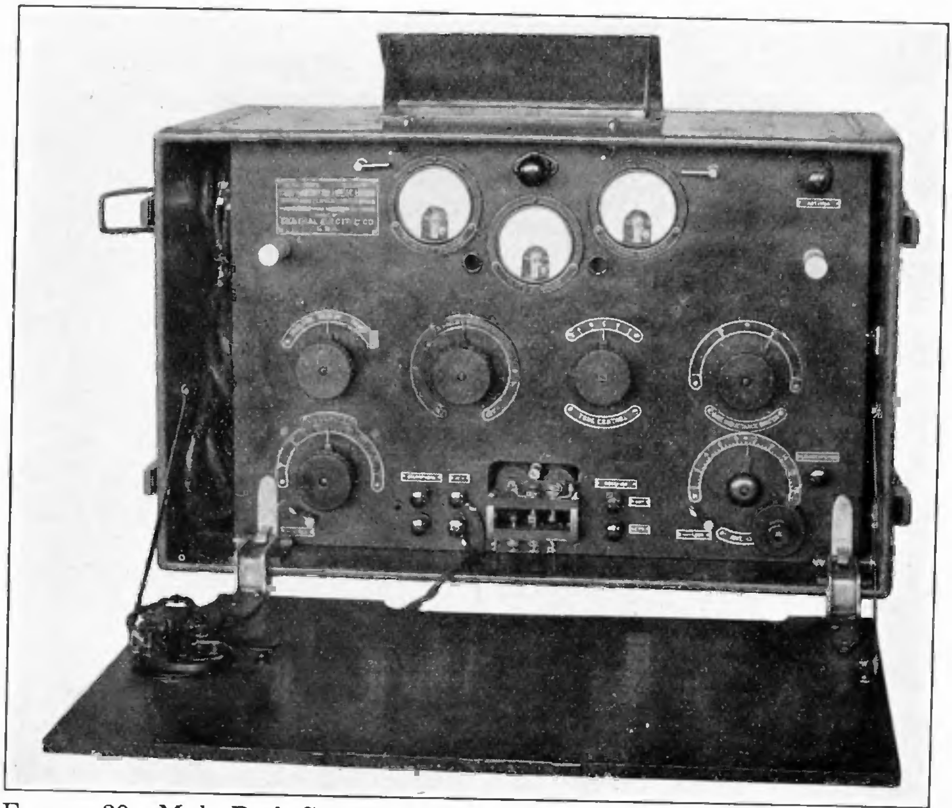


FIGURE 39—Mule Pack Set Radio Transmitter-Type SCR-136 (Front View Open)

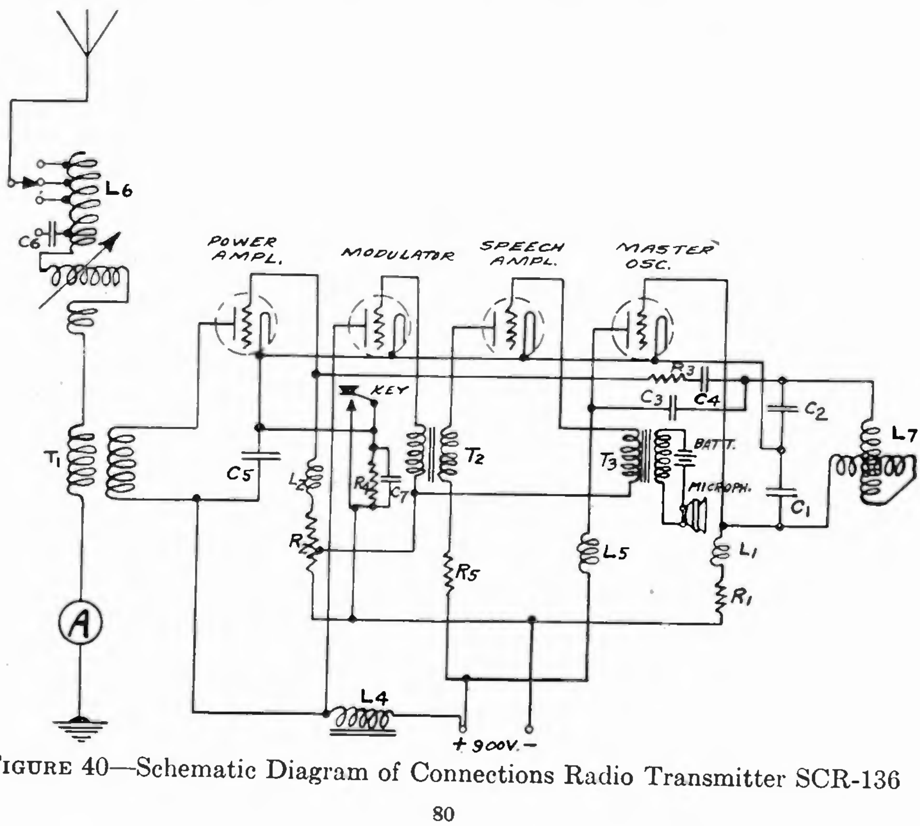


FIGURE 40—Schematic Diagram of Connections Radio Transmitter SCR-136

The transmitter is built for operation on telephone, continuous wave telegraph, and tone telegraph. Connections for the latter are not shown in the accompanying diagram, but they consist simply in the substitution of a small alternator for the microphone transformer. This alternator is of special construction, and is driven by a 6-volt battery. A rheostat in its field permits a selection of any one of five tones.

SCR-132 TRANSMITTER

A second transmitter, known as the SCR-132, was built in co-operation with the Signal Corps Laboratory at Camp Alfred Vail, New Jersey. The circuit, as used, was established fundamentally by the Signal Corps Laboratory.

The circuit of this transmitter is shown in Figure 41. It utilizes a total of seven tubes; three model UV-204-A (VT-22), and four Model UV-211 (VT-4-B). One of the latter is used as a master oscillator, two as speech amplifiers and one as an intermediate amplifier. Two of the former are used as modulators and one as a power amplifier.

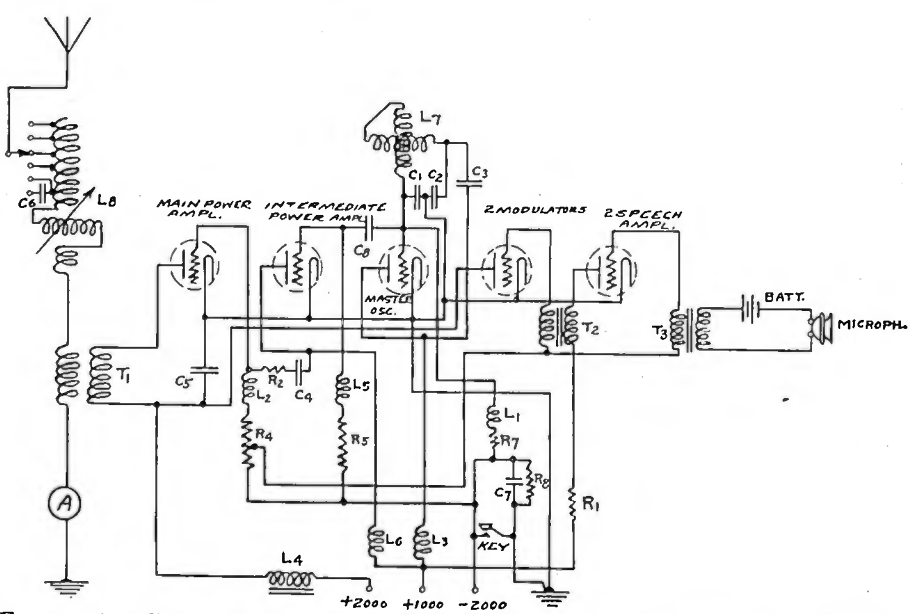


FIGURE 41—Schematic Diagrams of Connections Radio Transmitter BC-127

A Colpitts circuit is used for the master oscillator. The complate wave length range of the set, from 840 to 1,930 meters, is covered by the single variometer in this circuit.

In this, as well as in other medium power transmitters, the Colpitts circuit has been used for the master oscillator for two fundamental reasons: firstly, because of the mechanical simplicity of constructing a variometer as compared to variable air condensers, and secondly, because of the fact that the circulating KVA. in the Colpitts circuit increases with increase in frequency, which is conducive to stable operation.

The power amplifier received its grid excitation thru a capacity coupling C_4 to the plates of the intermediate power amplifier. Power is delivered to the antenna circuit from the plate of the power amplifier by means of a closely coupled antenna transformer. Sufficient reactance exists in the plate winding of this transformer to limit the power amplifier d. c. plate current when the antenna circuit is detuned or open. Audio modulation is obtained by two speech amplifiers and two modulating tubes, operating in a modified Heising circuit.

The intermediate power amplifier is provided more as a means to insure constant frequency than to provide additional amplification. The output of the master oscillator would be sufficient to excite the grid of the power amplifier, altho the load would be such that the frequency would not be constant, particularly in view of the tight coupling in the antenna transformer.

The plates of the 50-watt tubes are operated at 1,000 volts thru suitable radio frequency chokes. The plates of the modulator and power amplifier tubes are operated at 2,000 volts.

To obtain tone telegraph, a small alternator is put in circuit in place of the microphone transformer.

Keying is accomplished by opening and closing the ground connection to the grids of the master oscillator, the intermediate amplifier, and the power amplifier tubes.

The equipment is portable and is shown in Figure 42 in its carrying conditions. The arms provided for carrying are utilized as legs when the equipment is put into operation as shown in

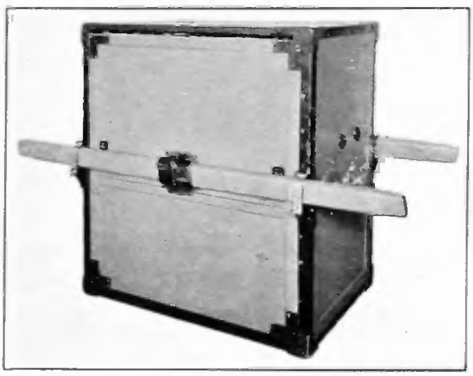


FIGURE 42—400-Watt Portable Radio Transmitter SCR-132 (Closed for Transportation)

Figure 43. The lower half of the cover forms a desk for the operator, and the upper half a partial shield against the elements.

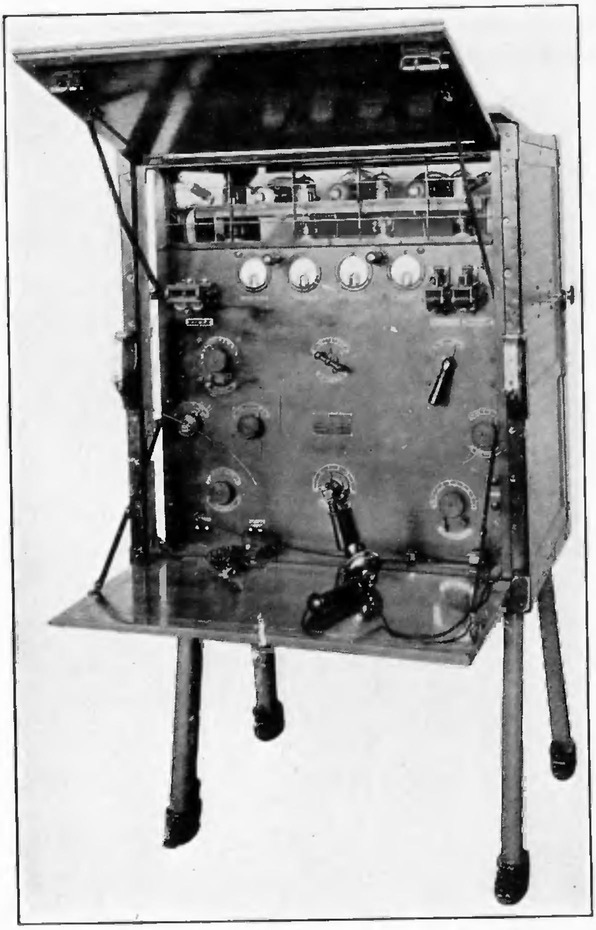


Figure 43—400-Watt Portable Radio Transmitter SCR-132 (Front View)

Figures 44 and 45 show end and rear views of the transmitter. Provision is made so that the transmitter may be remotely controlled for either telegraph or telephone communication. Transfer to remote control is made by means of a switch on the transmitter panel.

Post Office Aircraft Equipment

For installation on the planes of the Air Mail Service of the Post Office Department, there has been built a complete radio transmitting and receiving equipment. The design of this equipment includes many mechanical features, making the equipment extremely rugged and simple to operate.

The transmitter utilizes a total of six Model UV-203 50-watt radiotrons; one as a master oscillator, one as a speech amplifier, two in parallel as modulators, and two in parallel as power amplifiers. The normal continuous-wave output of the transmitter is 150 watts.

The transmitter has a wave length range of from 190 to 290 meters.

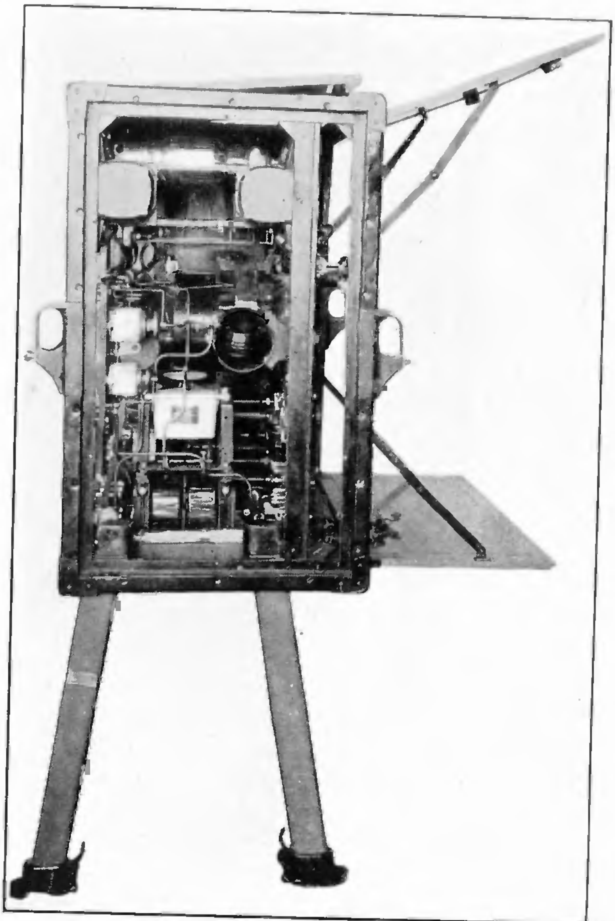


FIGURE 44—400-Watt Portable Radio Transmitter SCR-132 (Left Side Panel Removed)

Figure 46 shows schematically the circuit utilized in the transmitter. The master oscillator circuit is of the Colpitts type. With this arrangement, a calibrated variometer in the master oscillator circuit is set at the desired wave length. The antenna circuit is then tuned by the antenna variometer. This method of tuning is extremely simple and no skill is required to secure maximum output. Failure accurately to tune the transmitter removes load from the tubes.

The output of the microphone is used to actuate the speech amplifier. These tubes operate as a resistance-coupled amplifier and are coupled to the grids of the modulator tubes.

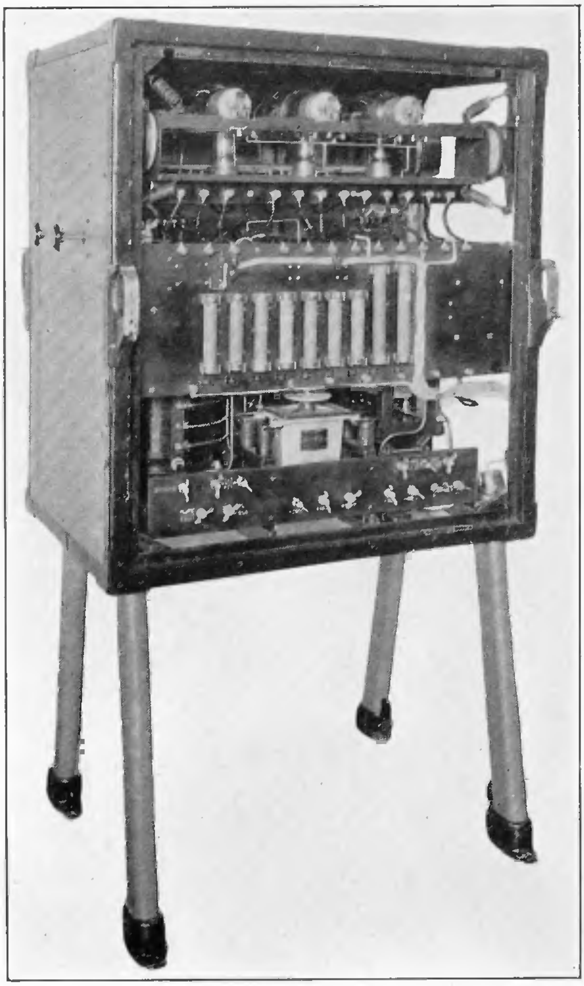


FIGURE 45—400-Watt Portable Radio Transmitter SCR-132 (Rear Panel Removed)

The power for the equipment is obtained from a dynamotor. This dynamotor has an output of 0.65 amperes at 1,000 volts, and is operated from a storage battery. The transmitter proper is divided into two units, that is, the transmitter proper and the control unit. The transmitter, which is shown in Figure 48, has only a single control, that is, the variometer in the master oscillator circuit. The assembly is supported on a duralumin frame, with a panel of insulating material. The tube sockets are rigidly mounted on the upper side of the transmitter. When installed, the unit is supported by eight straps and helical springs, the latter acting as a cushion to protect the tubes from vibration and shock. Where space for installation is limited, the transmitter may be mounted back of the operator or out of sight, since the controls are mounted in a separate unit.

The control unit, illustrated in Figure 49, is designed with the intention of mounting it under the pilot's seat in the average installation. It contains a send-receive switch and the antenna variometer. The send-receive switch is operated by a substantial vertical handle and performs the following functions:

(a) Starts and stops the dynamotor.

(b) Transfers the antenna from transmitter to receiver.

(c) Opens and closes the filament circuits of the transmitter and receiver.

(d) Controls the keying circuit.

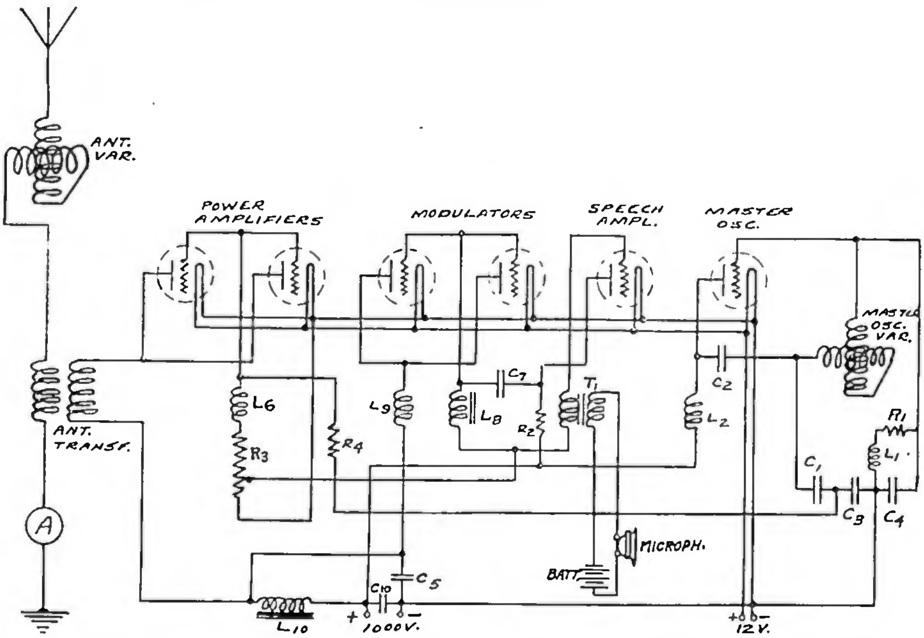


FIGURE 46—Schematic Diagram of Connections, Post Office Aircraft Receiver Unit

The antenna variometer, in series with the antenna, has sufficient range to tune the antenna circuit to any wave length covered by the master oscillator.

A telephone jack is included in the control unit, making a convenient connection for the operator's microphone.

A new antenna reel has been designed for this equipment, and is illustrated in Figure 50. The operator may release the handle of this reel at any time, and it will lock in place automatically. This prevents the loss of the antenna, which sometimes occurs with reels of other types that require a clamp and knob to hold them in place.

The receiver supplied with this equipment, which is illustrated in Figure 51, is of the super-heterodyne type, having the same wave length range as the transmitter. The inherent selectivity

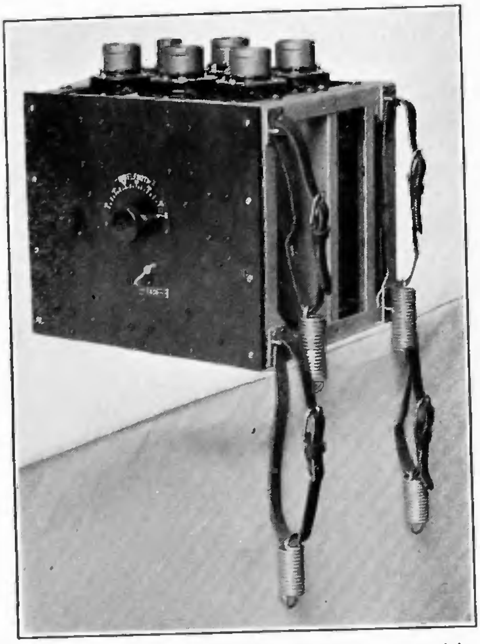


Figure 48—Radio Transmitter for Air Mail Plane (Front View)

Figure 49—Radio Control Box for Air Mail Plane

of this receiver, together with the practical elimination of engine noises by the use of several stages of radio frequency amplification, make the receiver well adapted to aircraft use. The receiver utilizes a total of seven UV-199 radiotrons as follows:

1 Radio frequency oscillator.
1 Radio frequency detector.
3 Stages of intermediate frequency amplification.
1 Stage of audio frequency amplification.

Its circuit is shown schematically in Figure 52.

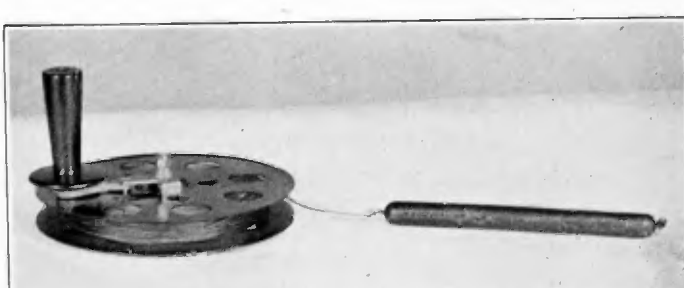


Figure 50—Antenna Reel and "Fish" for Air Mail Plane

Installation of this equipment for service tests on a plane of the Air Mail Service, is shown in Figure 53.

The transmitter is installed in the fusilage back of the operator. In this picture the top of the fusilage has been removed.

The receiver and antenna relay can be distinguished in the front of the operator, the former being installed under the control board of the plane. The control unit is mounted under the operator's seat, and is not easily seen in this photograph.

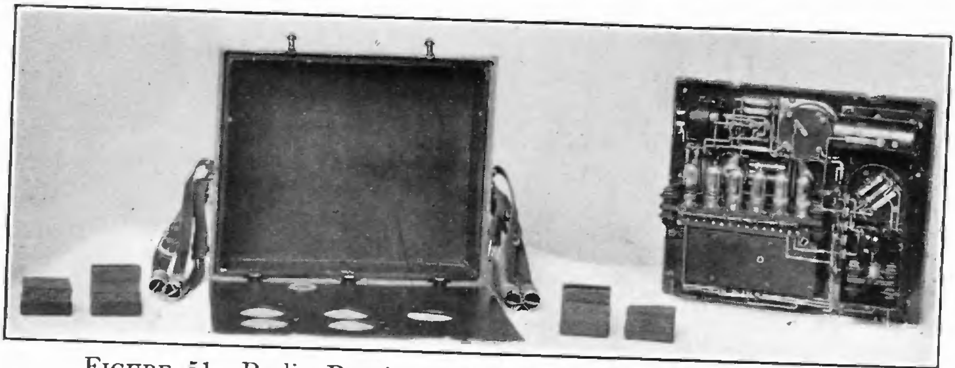


FIGURE 51—Radio Receiver—Air Mail Plane (Disassembled)

The service tests of this equipment have been very encouraging. The set has been operated by pilots with no previous experience in radio, and distances have been covered far in excess of the requirements of the set. The transmitter was required

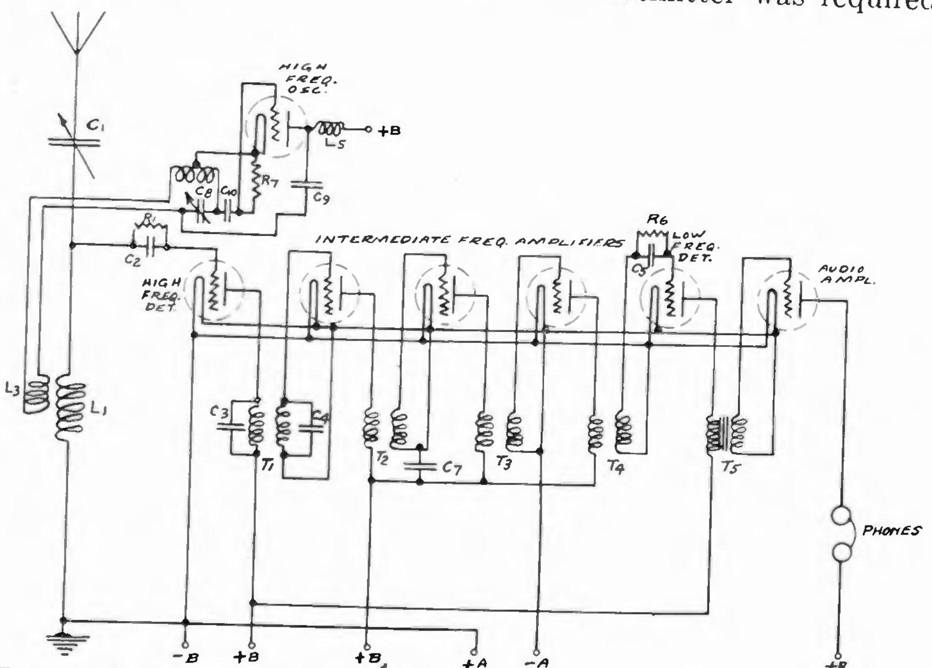


FIGURE 52—Schematic Diagram of Connections, Post Office Aircraft Receiver Unit

to have a range of 100 miles (160 km.) under specified conditions. This range was exceeded in the first service flight between Schenectady and New York, a distance of approximately 150 miles (240 km.), during which very satisfactory communication was maintained thruout.

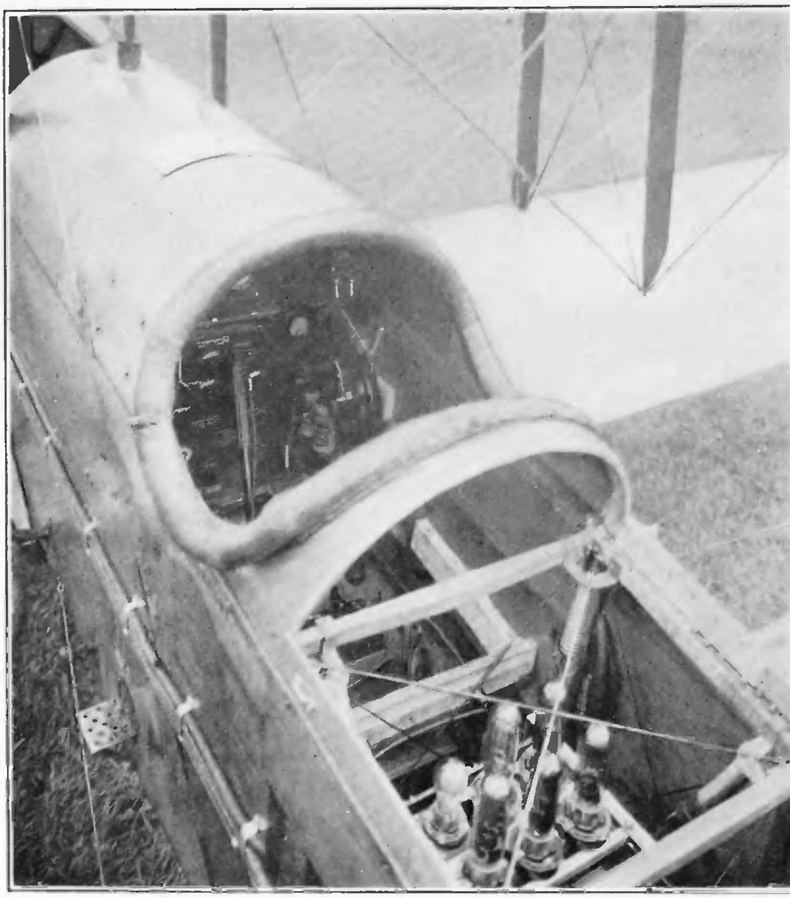


FIGURE 53—Radio Installation of Air Mail Plane, Showing Transmitter Receiver, Reel and Control Box

SELF-RECTIFYING TRANSMITTERS

Two types of transmitters have been produced, utilizing the so-called "self-rectifying circuit," that is, an a. c. plate supply is fed directly to the plates of the oscillating tubes, resulting in a continuous wave output, modulated at a frequency of 1,000 cycles.

The first of these is a "fog signal" transmitter, developed and designed for the United States Department of Commerce, Bureau of Lighthouses, for use on light ships and at shore stations, to enable ships to take radio compass bearings.

The design of this equipment was influenced by it being required that as much as possible of the spark transmitters used at present for this purpose be utilized in the tube transmitters. Also, it was necessary that the circuit used be one of extreme simplicity and reliability.

The circuit used for this transmitter is shown in Figure 54. It utilizes 2 UV-204-A tubes in a self-rectifying Hartley circuit, giving a continuous wave output modulated at 1,000 cycles. A separate machine is used to obtain filament supply, due to the poor regulation of the spark alternator which is used for plate supply, and also to introduce a frequency difference between the filament and plate supplies, thereby insuring longer filament life incident to a. c. filament heating. This practice has been adopted after full consideration was given to voltage regulating equipment which would permit filament illumination from the plate alternator.

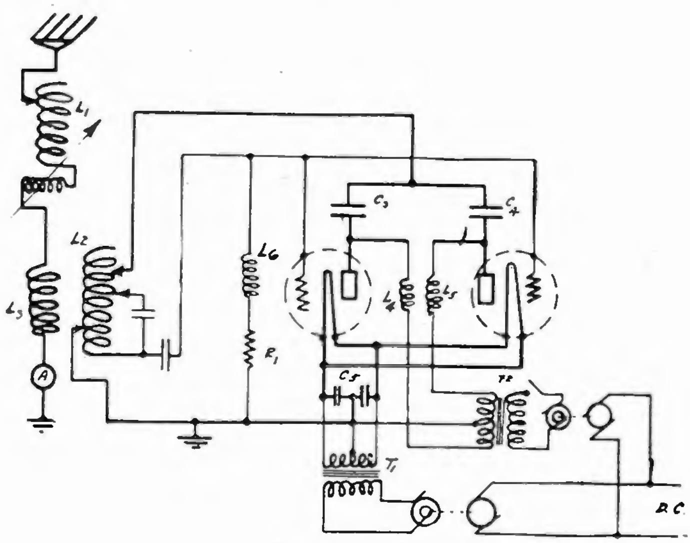


FIGURE 54

An intermediate circuit is used for the suppression of harmonics, since the primary object of the set is to eliminate the interference now being experienced with spark sets.

The keying equipment formerly used with the spark sets is utilized, operating in the primary of the plate transformer. The keying is automatic.

The transmitter is shown in Figures 55 and 56. The power input and power control circuits are brought out on a terminal board mounted back of a door on the lower section of the panel. This terminal board contains the main line contactor and the motor starting contactor.

This set is extremely simple in construction, due primarily to its being built for a very narrow wave length band, and for continuous wave telegraph transmission only. The plate transformer and the converter for filament supply are located at the bottom of the structure as shown in Figure 56. The tubes are mounted on a shock-absorbing mounting and are visible from the front of the panel. A lock is provided for the antenna variometer.

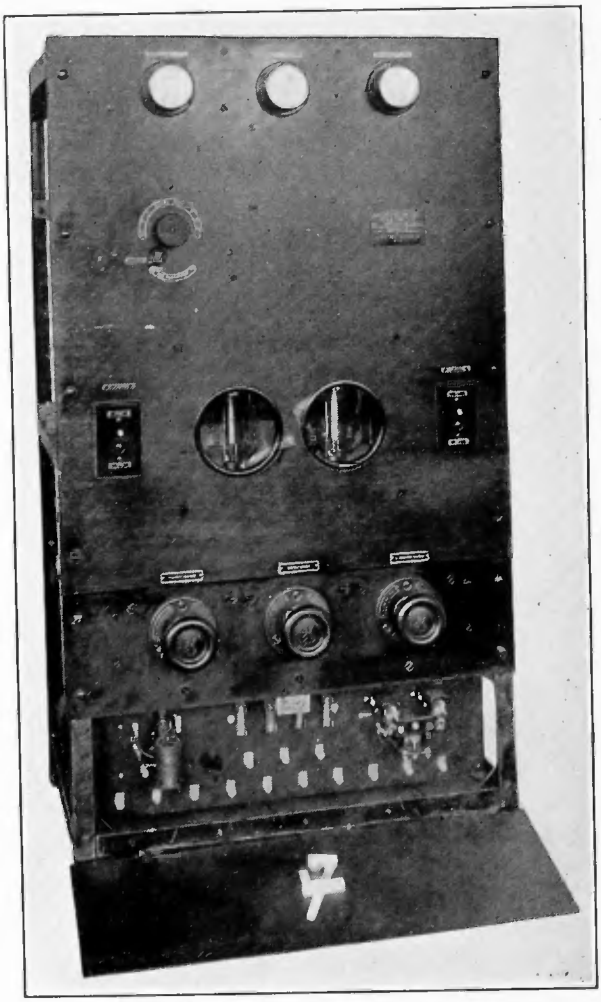


FIGURE 55—Radio Fog Signal Tube Transmitter

A second transmitter, designed to utilize existing spark equipment, is shown in Figure 57, in which the "tube attachment," as it is called, is shown mounted aside of a 2-kilowatt type P-8 Marconi spark transmitter. The design is such that the tube attachment lines up with the spark set.

The circuit for this transmitter is practically identical with

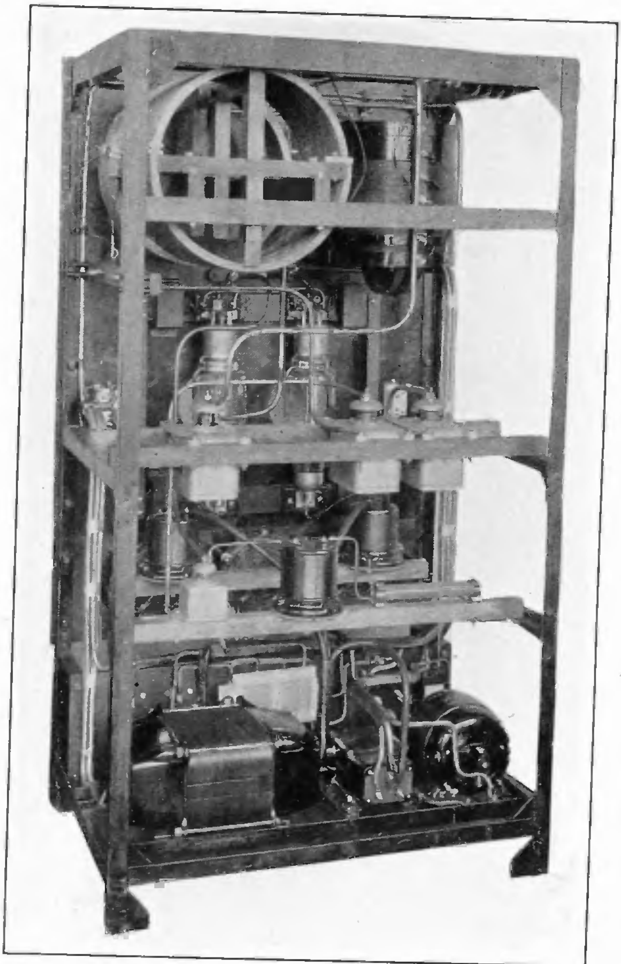


FIGURE 56—Radio Fog Signal Tube Transmitter
(Rear View)

that of the fog signal transmitter just described. It also utilizes two Model UV-204-A tubes, in a self-rectifying circuit, and receives its power from the alternator of the spark transmitter. The set covers a wavelength range of from 2,000 to 2,400 meters. A transfer switch is included in the rear of the set, operated from the front of the panel, which transfers the power supply from the spark to the tube attachment. Plugs are provided at the top of the panel to transfer the antenna from the spark set to the tube attachment, and to select taps on the loading inductance of the latter. Figure 58 shows another view of the tube attachment, indicating its structure more clearly.

BROADCASTING EQUIPMENT

It is not intended to take up a discussion of broadcasting equipment as such, in this paper, altho it is believed that a brief description of the recent equipment installed by the General

Electric Company at Oakland, California, and known as Station KGO, will be of interest.

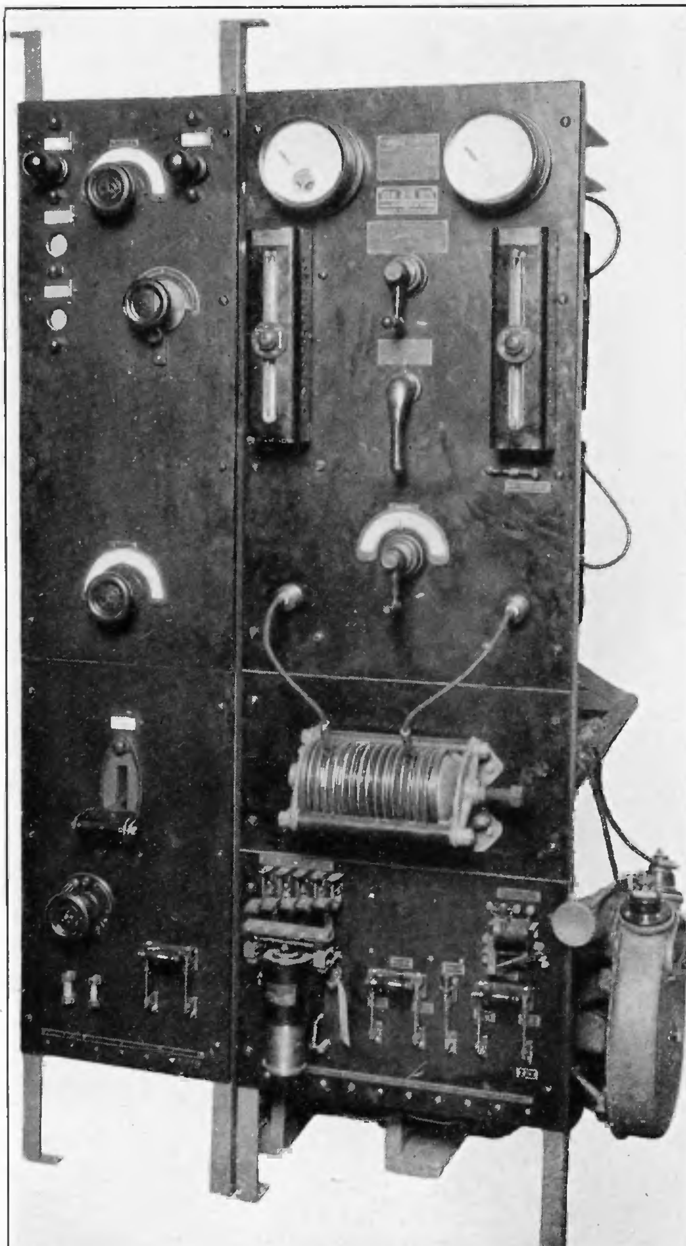


FIGURE 57—Vacuum Tube Transmitter Attachment for Use with Spark Transmitters

The transmitter at KGO operates from a 220-volt, 3-phase, 60-cycle power supply. The main power panel for the station is shown in Figure 59. This panel contains the equipment necessary for the control distribution of power, and the necessary motors, transformers and other apparatus. The power panel consists of four slate switchboard units. Controls and meters are provided for the excitation of generators, the operation of control circuits, kenotron filament supply, radiotron filament supply, modulator, and power amplifier units. Controls are also provided for the distribution of the power supply to the various amplifiers.

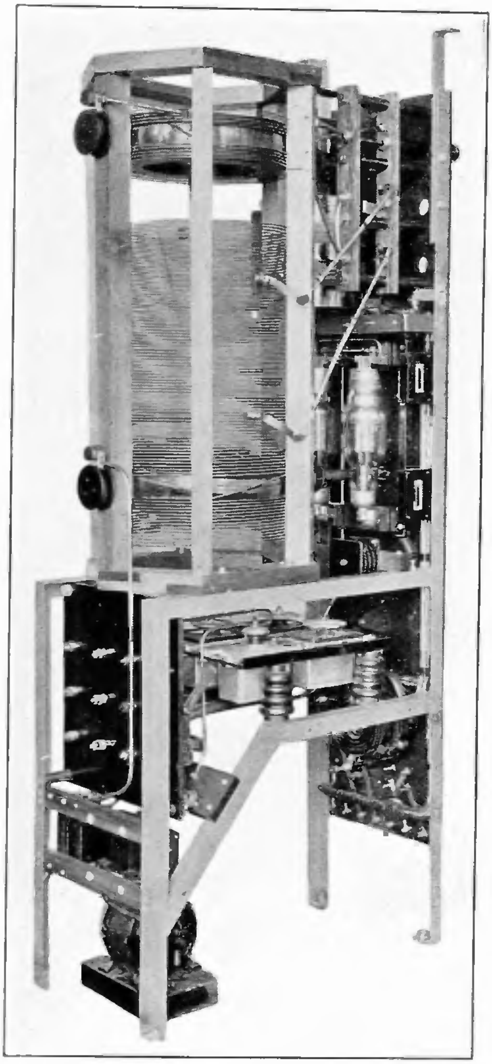


FIGURE 58—Vacuum Tube Transmitter Attachment for Use with Spark Transmetters

Figure 60 shows a rear view of the same panel.

A plate transformer is used to step up the supply voltage to the operating voltage of the kenotron rectifier. The kenotron rectifier, with its associated filtering circuit, is shown in Figure

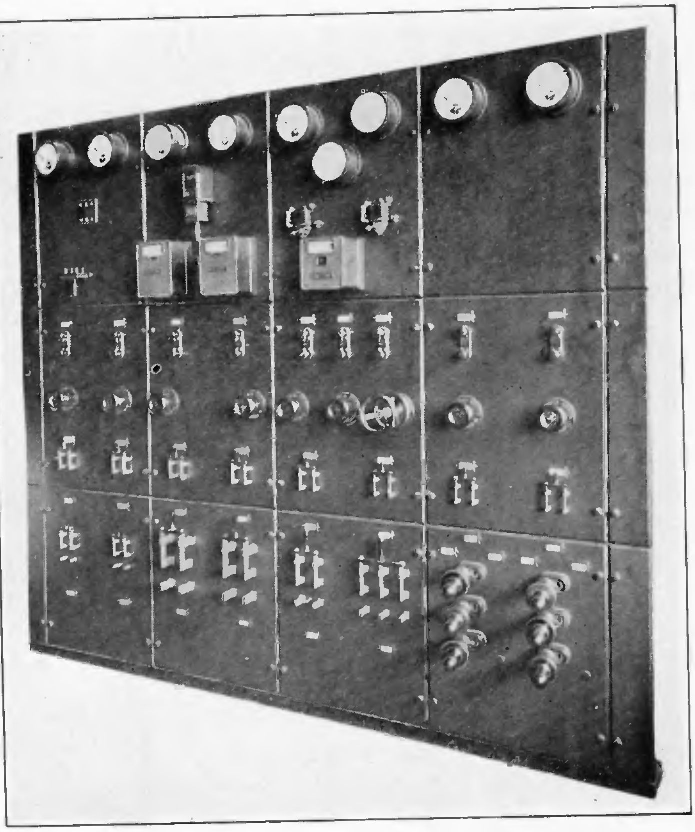


FIGURE 59—Power Control Panels (Front View)

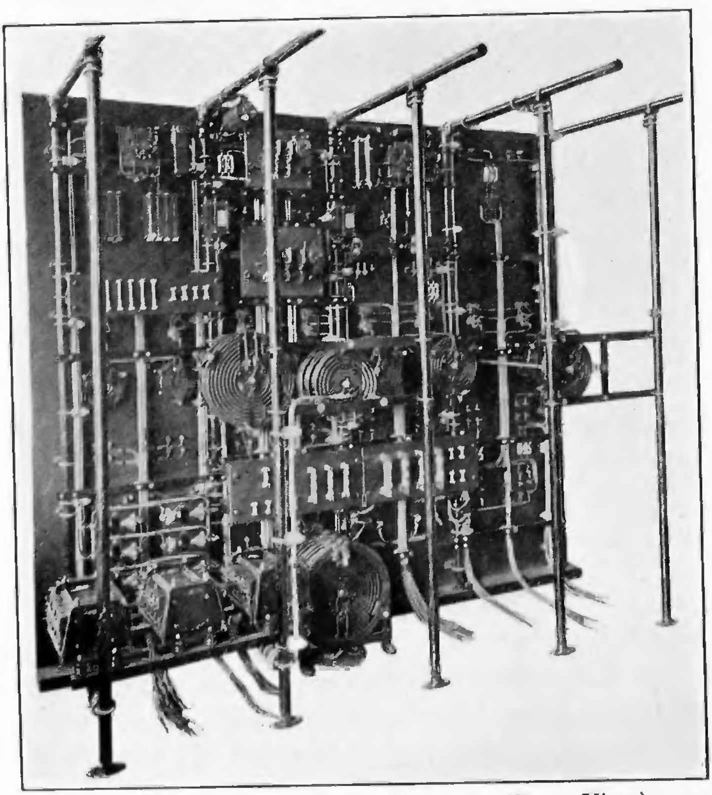


FIGURE 60—Power Control Panels (Rear View)

63. This rectifier provides a 15,000-volt direct current supply, with a ripple of less than one-tenth of one percent. An auto transformer is supplied with the rectifying equipment to provide a variation in output voltage, from 4,000 to 15,000 volts. A rear view of the rectifier is shown in Figure 64. It will be noticed that smoothing condensers are supplied considerably in excess of those required for commercial telegraph or telephone communication.

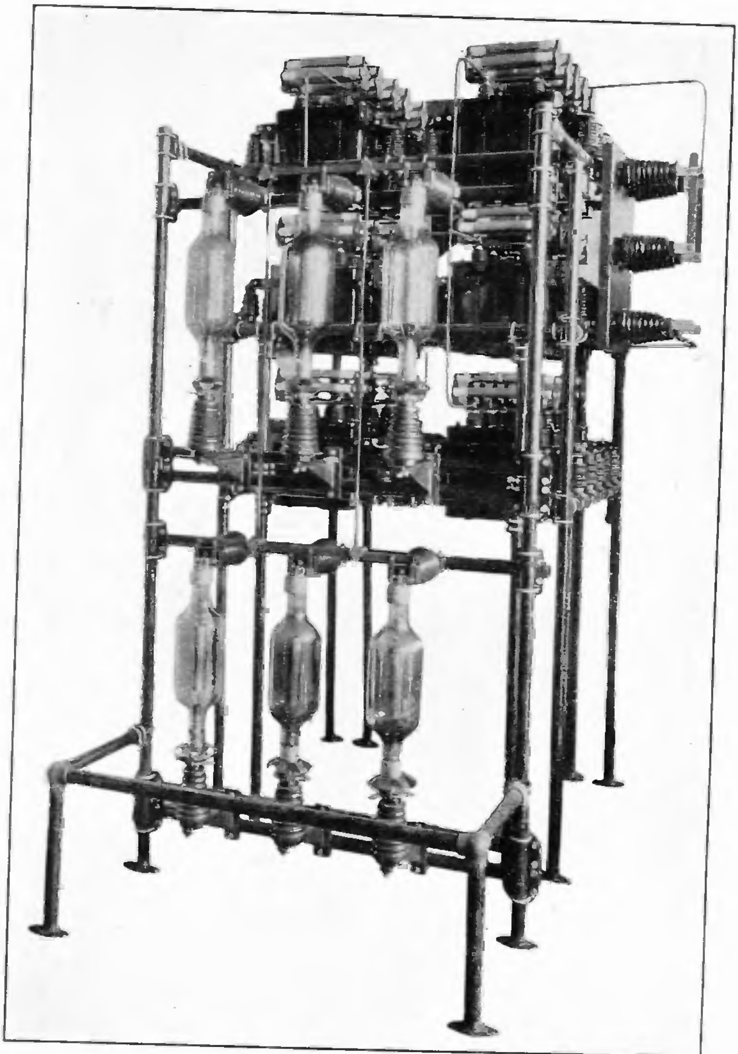


FIGURE 63—Kenotron Rectifier Unit

Figure 65 represents the "grid tuning unit." This unit, as is indicated in the photograph, is carefully shielded, inasmuch as its circuits are depended upon for maintaining constant frequency of output. This unit is designed to permit extremely close adjustment.

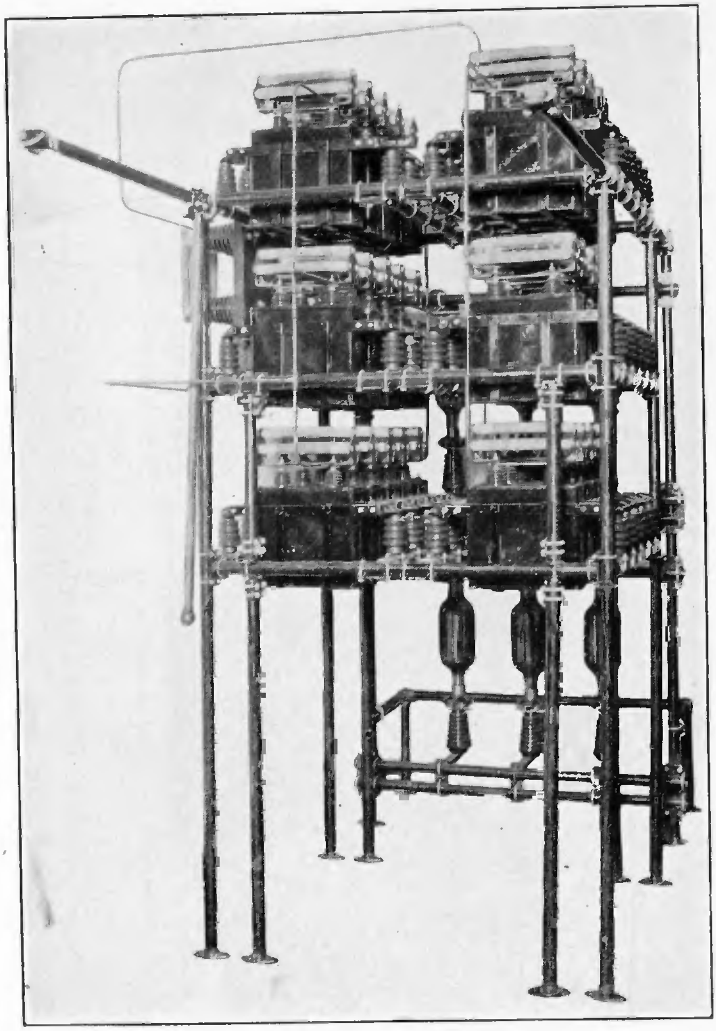


FIGURE 64—Kenotron Rectifier Unit

The oscillator tuning unit is shown in Figure 66. The rear view of this unit is shown in Figure 67. This unit provides an intermediate circuit which eliminates harmonic rediation from the antenna, and in addition, includes the transformer for coupling to the antenna. The edgewise wound coils mounted vertically, indicate the coupling transformer. The coil to the left is pivoted on the periphery, and coupling is varied by a control located on the front of the panel.

The control room equipment consists chiefly of three amplifier and control banks. The first of these, shown in Figure 68, is the 5-watt microphone amplifier bank, containing the various low-powered amplifiers for the pick-up devices used in the studio. Means are provided whereby any pick-up device can be switched to the desired group of amplifiers. A rear view of the 5-watt amplifier bank is shown in Figure 69. The structure is composed of a number of sub-assemblies, any of which can be readily removed from the main structure for inspection or repair. Each section is completely shielded.

FIGURE 65—Grid Tuning Unit (Front View)

The output of the microphone amplifier bank is carried to the 50-watt intermediate amplifier bank shown in Figure 70. The amplifiers in this bank are arranged so that they may be switched rapidly to prevent any interruption in the program. Figure 71 shows a rear view of this panel. Figure 72 illustrates the monitoring control bank, and among other things, this assembly contains the time signal receiver, radio receivers for checking quality, an antenna power indicator, and the various selector relays. From this bank, the circuit passes underground to the power station. A rear view of this panel is shown in Figure 73.

Batteries are provided for the filament and plate supply of the amplifier tubes, to insure freedom from commutator ripple. A common control panel, illustrated in Figure 74, is supplied for charging all batteries associated with the station.

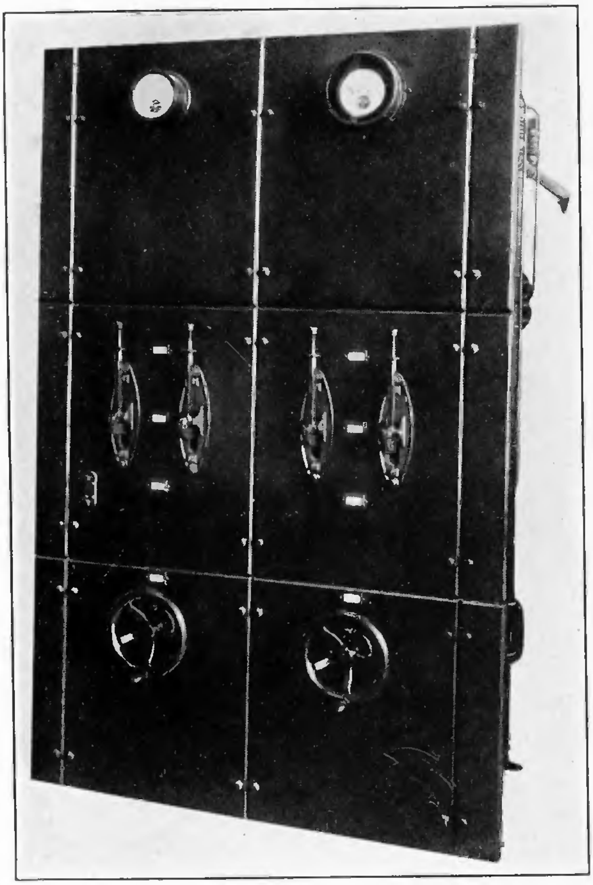


FIGURE 66—Oscillator Tuning Unit (Front View)

It is hoped that a future paper before the INSTITUTE will enter into a complete discussion of the functioning of this broadcasting station. Such discussion, however, is beyond the scope of the present paper. Figure 75 is shown, in closing, to illustrate the vacuum tubes which are utilized in transmitters described in this paper.

The first three of these are receiving tubes. The remainder are transmitting tubes, and are rated at 5, 50, 250, 1,000, 5,000, and 20,000 watts, respectively. All of these tubes, as now manufactured, include thoriated filaments, which has resulted in an appreciable decrease in the power required for the heating of the filament, and an increase in the filament life of the tube.

The 20-kilowatt tubes must be operated in conjunction with a water-cooling system. The anode is exposed directly to the circulating water.

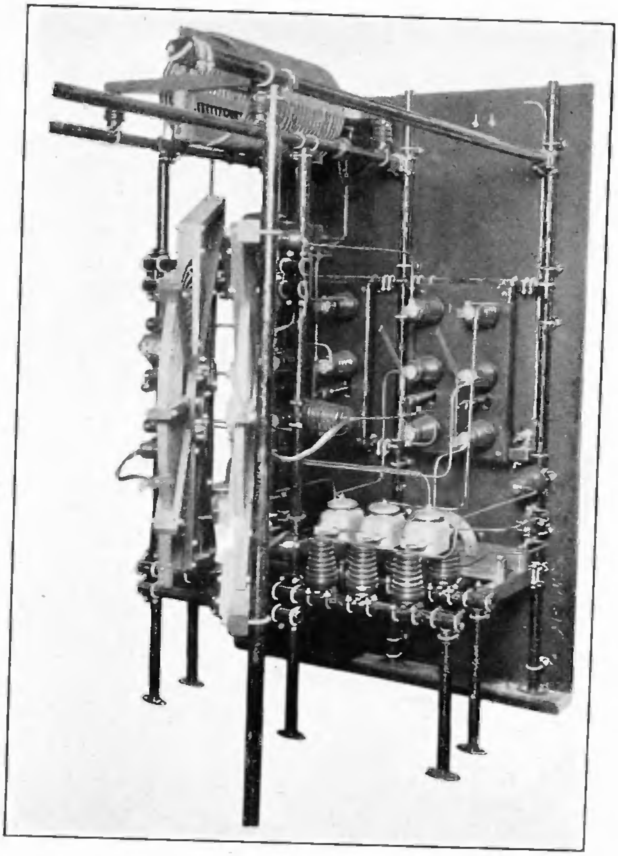


FIGURE 67—Oscillator Tuning Unit (Rear View)

The characteristics of the thoriated filament tube are such that filament voltage regulation becomes a matter of lesser importance. It has been found that the output of transmitters utilizing these tubes is constant thruout a comparatively wide variation in filament voltage, also, that the filaments have sufficient emission so that they can usually be operated at somewhat below rated voltage. It is apparent, therefore, that normal variations in supply voltage will not affect the output of the transmitter, nor decrease the filament life. The greater emission also practically eliminates change in frequency, due to change in filament temperature over a comparatively wide range of filament voltage.

SUMMARY: This paper describes a number of vacuum tube transmitters which have been developed and built during the past year, both for commercial use and the various governmental departments. It includes a discussion of the

circuits utilized, and the reasons for adopting the present circuits in place of the former "antenna oscillators."

The 20-kilowatt transmitters built for the United Fruit Company for installation in Central America, are described in detail, since they represent most completely the developments to date in medium power vacuum tube transmitters.

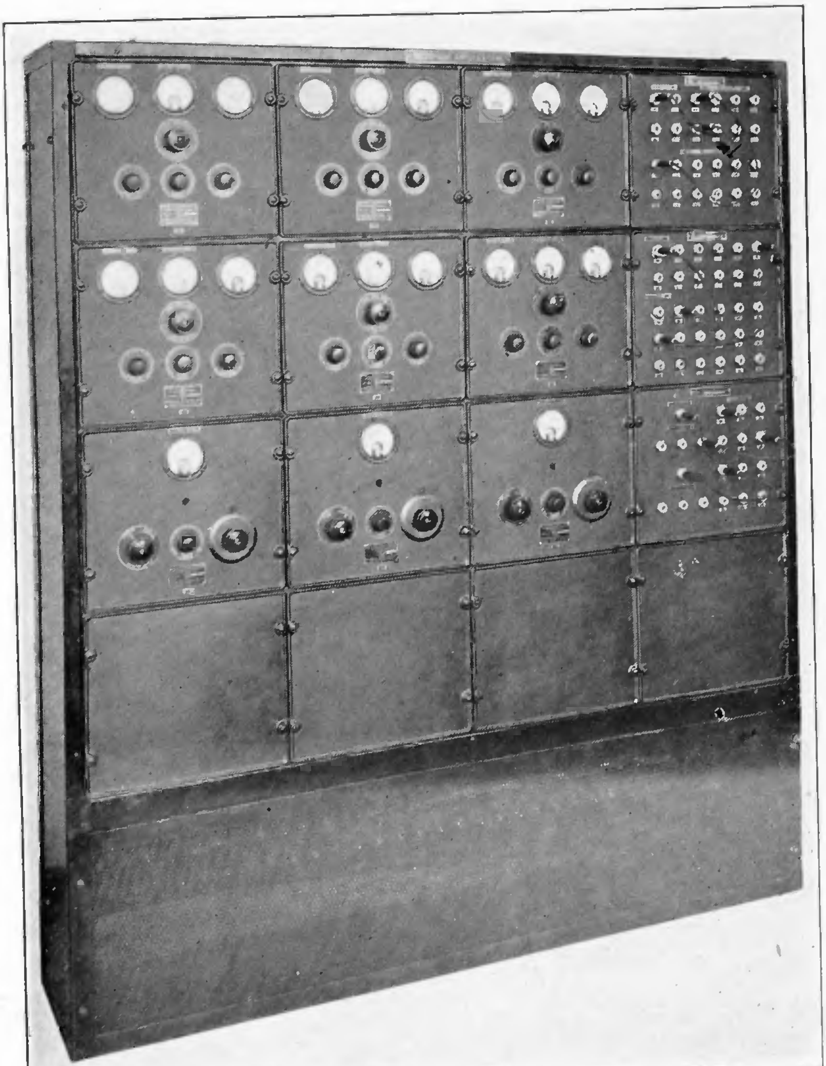


FIGURE 68—5 Watt Amplifier Bank (Microphone Amplifier)

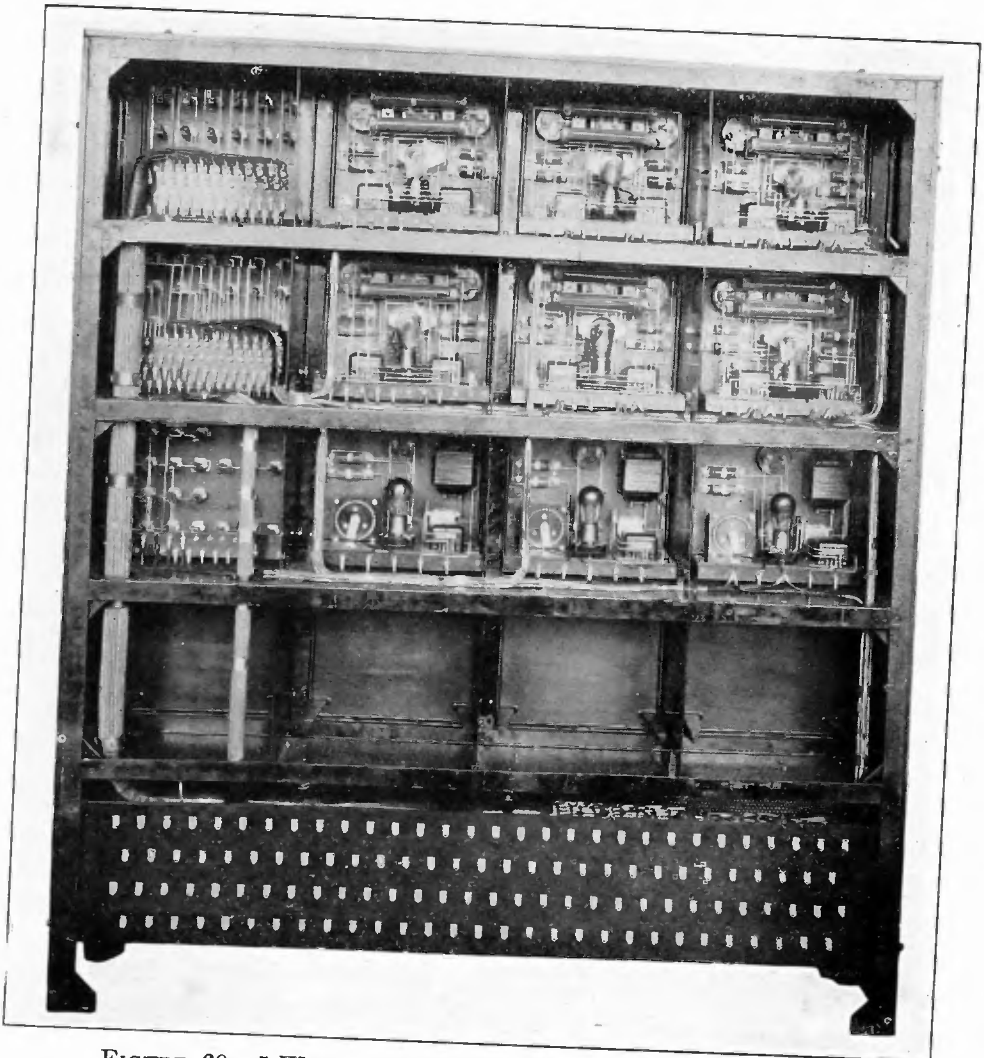


FIGURE 69—5-Watt Amplifier Bank (Microphone Amplifier)

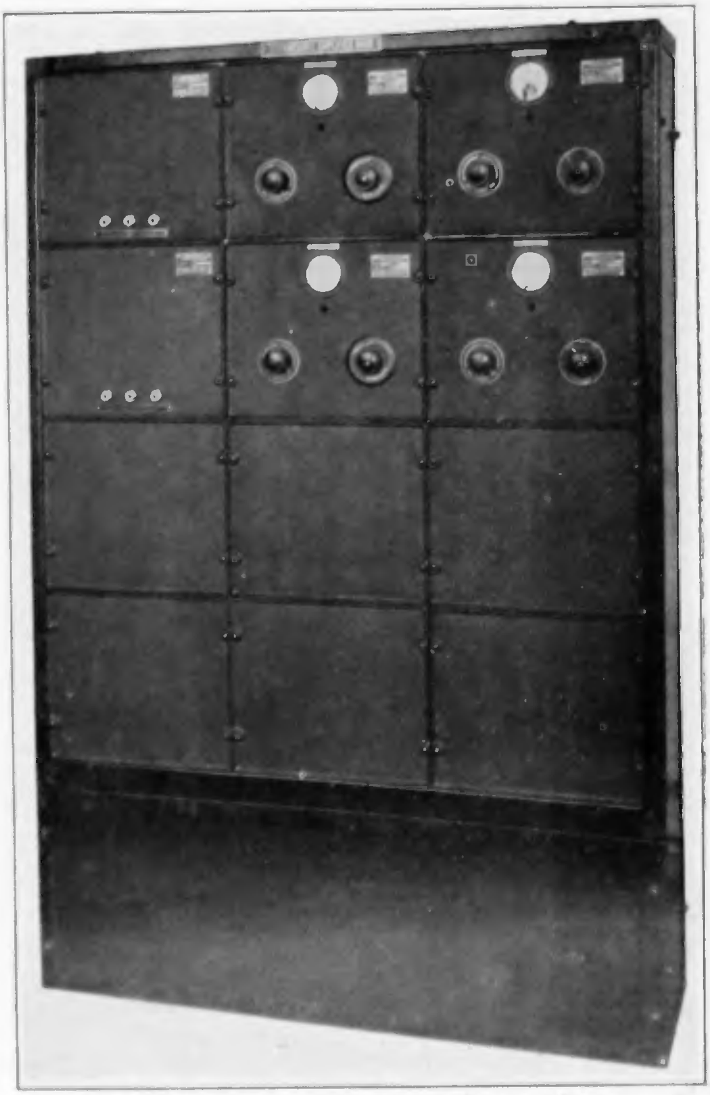


FIGURE 70—50-Watt Amplifier Rack (Intermediate Amplifier Bank) (Front)

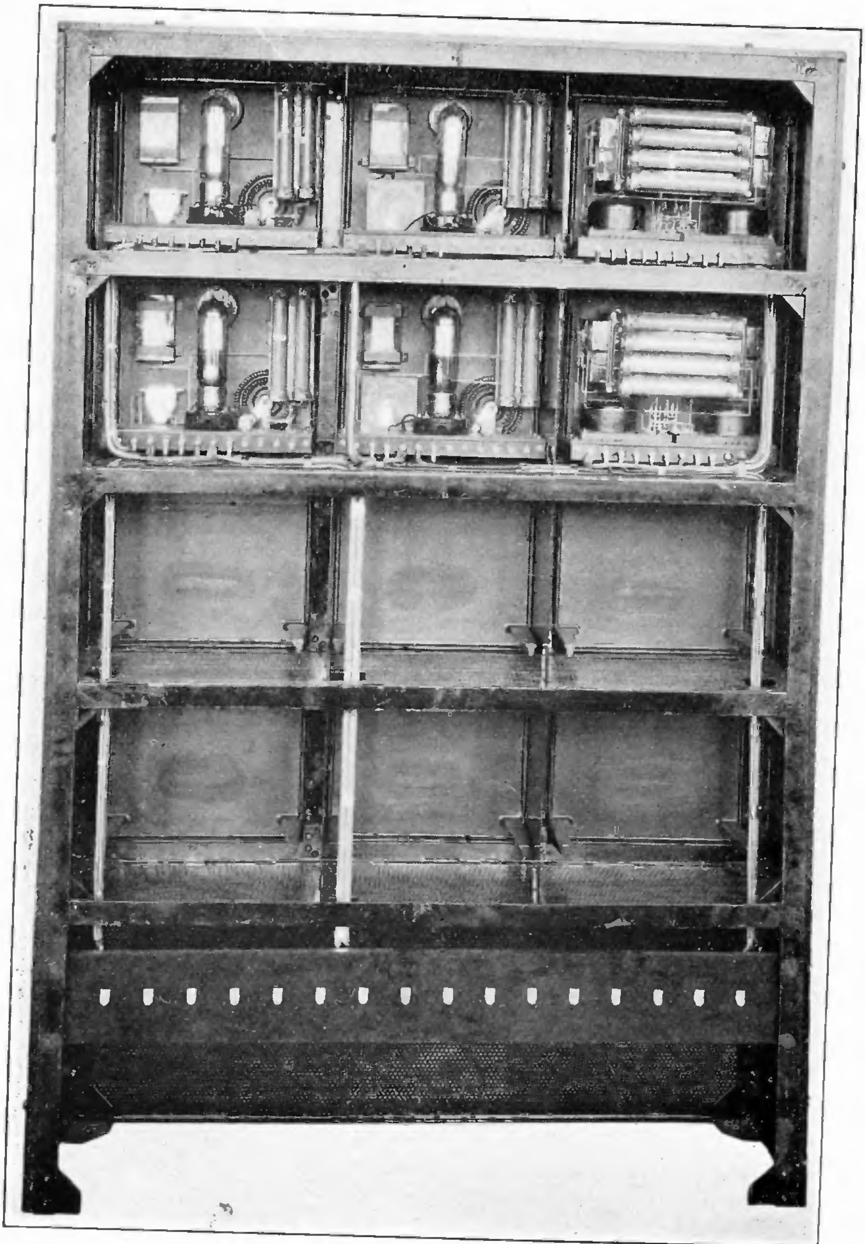


FIGURE 71—50-Watt Amplifier Rack (Intermediate Amplifier Bank) (Rear)

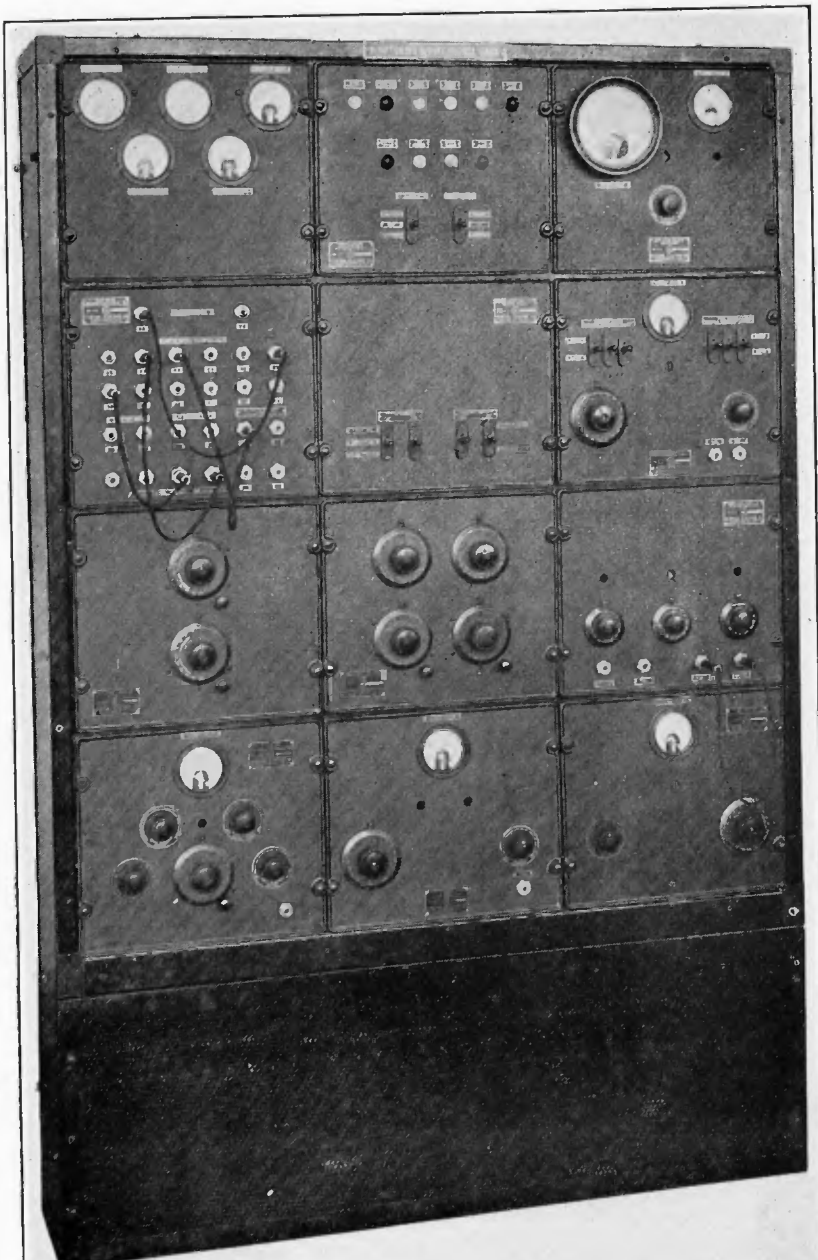


FIGURE 72—50-Watt Amplifier Rack (Monitoring and Time Signal Bank) (Front)

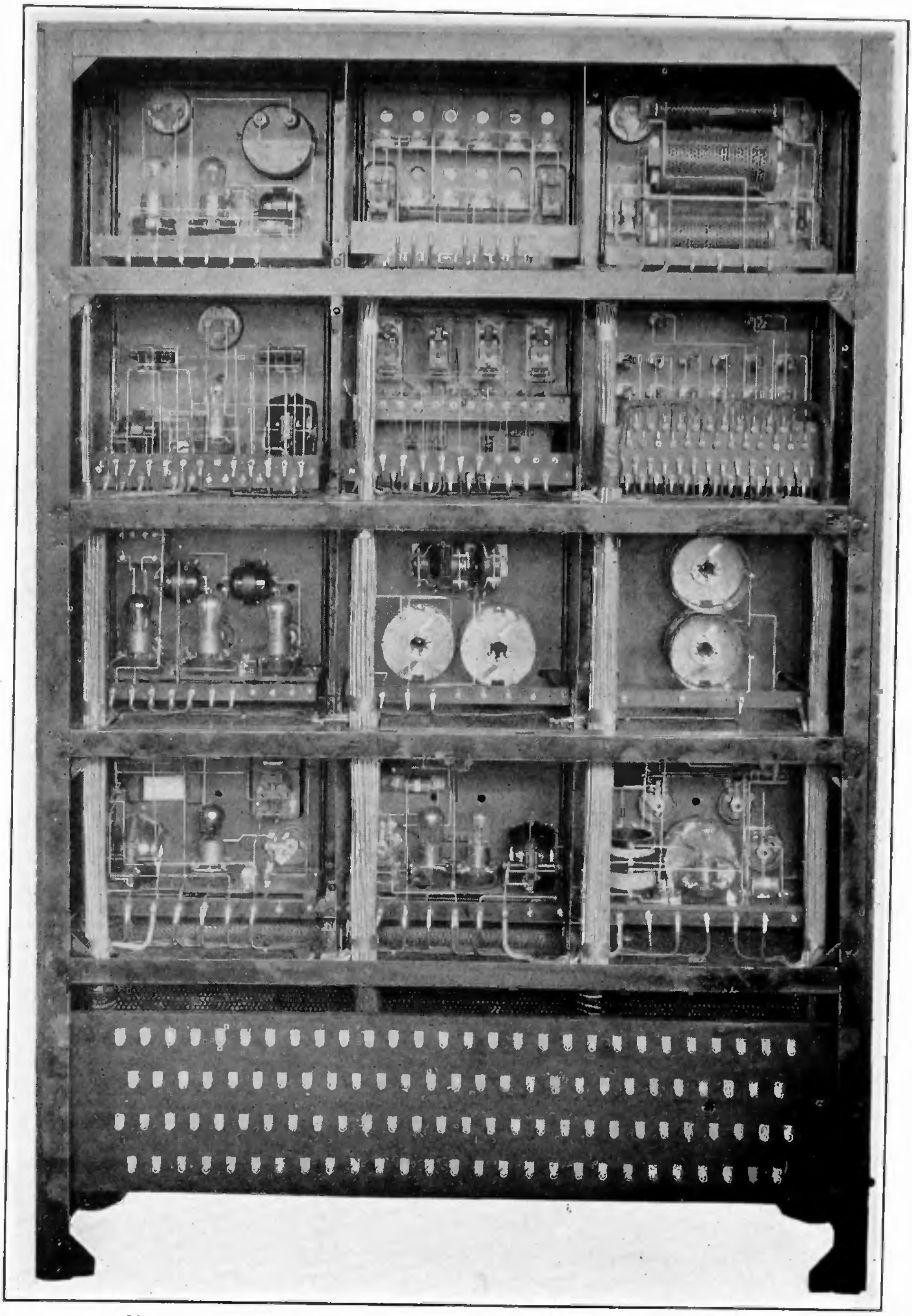


FIGURE 73—Monitoring and Time Signal Bank (Rear)

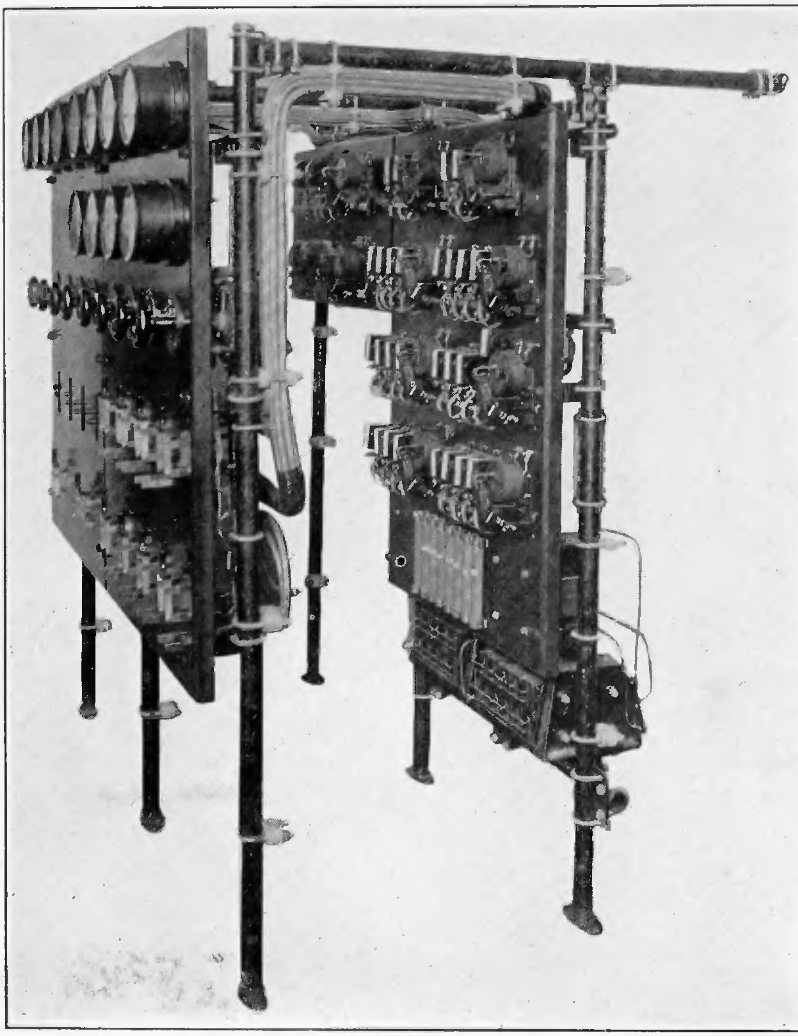


FIGURE 74—Battery and Generator Control Panel (Side View, Front)

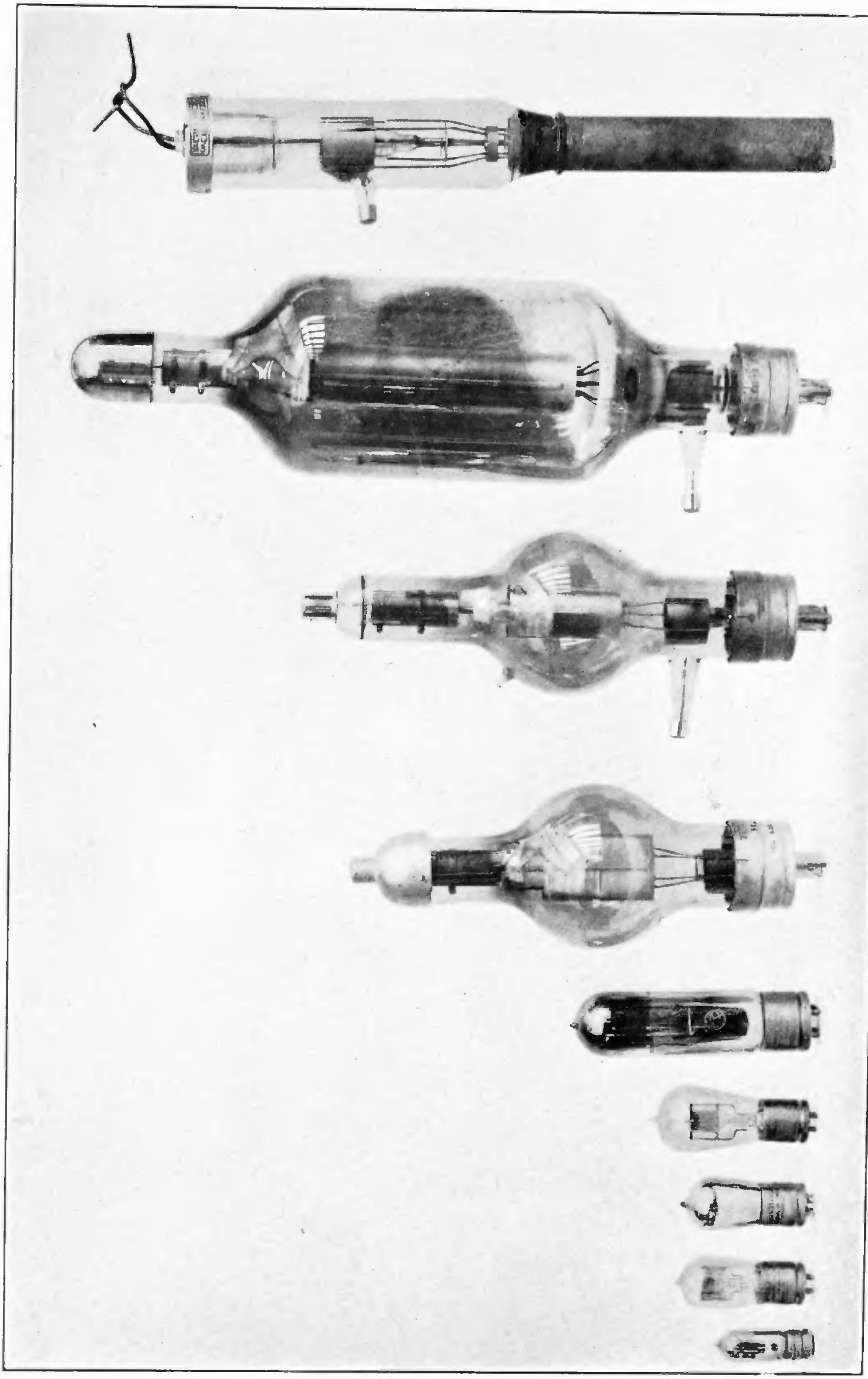


FIGURE 75—Radiotron Vacuum Tubes

A METHOD OF MEASURING AT RADIO FREQUENCIES THE EQUIVALENT SERIES RESISTANCE OF CONDENSERS INTENDED FOR USE IN RADIO RECEIVING CIRCUITS*

By

Charles N. Weyl

(Moore School of Electrical Engineering)

and

Sylvan Harris

(Consulting Engineer)

Introduction

The purpose of this paper is to show the desirability of measing at radio frequencies the equivalent series resistance of condensers intended for use in radio receiving circuits, and to set forth a method, recently developed by the writers of this paper, of making such measurements. It is believed that the method to be described will serve not only as an aid to the choice of particular condensers for particular purposes, but also that its use will lead to a better understanding of the theoretical and practical aspects of condenser design.

No detailed theoretical discussion of the factors which enter into the losses of condensers will be considered. For such material as is available on this subject the reader is referred to the scientific papers which have been issued from time to time by the United States Bureau of Standards.[1]

Practically every radio receiving circuit makes use of the phenomenon of resonance. In a vast majority of cases it is desirable to produce as sharp a resonance as possible, which indirectly means that all losses of power in the circuit must be reduced to a minimum. Since a resonant circuit consists essentially of an inductance (usually a coil of some sort) and a capacity (some type of condenser) it is important that the designer reduce the losses in both coil and condenser as far as is possible.

Much work has been done on the resistance of coils used in

*Received by the Editor, September 6, 1924.

[1] See particularly Article 34, Bulletin 74. Bureau of Standards.

radio frequency circuits, but the writers of this paper have found that it is almost universal practice to determine the losses of receiving air condensers at audio frequencies, even tho the condensers are intended to be used in radio frequency circuits. This means that it has been thought possible, from the equivalent series resistance measured at audio frequency (for example 1 kilocycle) to compute the value for radio frequencies (for example 1,000 kilocycles). If the results of such a transformation are to be of value, the exact law connecting loss and frequency must be known, since the orders of magnitude of audio and radio frequencies are so vastly different.

A study of the literature has led the writers to believe that these laws are not accurately known and at best would not yield readily to computation. We quote as follows: "The variation of the power factor and the equivalent resistance with frequency is a complicated matter, the laws of which are not accurately known. To a first approximation, however, the power factor of an absorbing condenser is constant. Since $r \omega C$ (power factor) is approximately constant, r (equivalent series resistance) is inversely proportional to frequency."[2] The curve which accompanies the material just quoted shows the variations of the equivalent series resistance of a glass plate condenser between 750 kilocycles and 97 kilocycles. This curve shows *definitely* that the inverse proportionality is not strictly true. Certainly extrapolation from 1 kilocycle to 1,000 kilocycles would be entirely unjustified.

A brief consideration of the elements which constitute the equivalent series resistance of a condenser will serve to show a few of the difficulties involved. Leakage resistance, dielectric absorption, and the resistance of the plates and connections all contribute to the losses in a condenser. All of these factors are subject to variation with frequency. It would be necessary to know precisely how each of these factors varies with frequency if we desire to compute the effect at one frequency when measurements have been made at another, bearing a ratio to the first 1-to-1000.

We shall stop to consider only one of these factors. At 1 kilocycle the skin effect in a parallel plate condenser is small, in fact, practically negligible. At 1,000 kilocycles the skin effect is unquestionably no longer negligible nor is it readily calculable to any reasonable degree of accuracy.

In recent months many laboratory tests have been made by various manufacturers to determine the equivalent series resist-

[2] Bulletin 74, Bureau of Standards, page 125, and following.

ance of condensers. These results have either been stated to refer to 1 kilocycle, which of course is not a useful figure for the radio engineer, or the result obtained from a 1-kilocycle test has been referred to some radio frequency assuming that the equivalent series resistance was *exactly* inversely proportional to the frequency. Since this assumption is not true, such radio-frequency values are practically worthless.

It was with this in mind that the writers developed the method of measurement at radio frequencies of the equivalent series resistance of condensers intended for use in receiving circuits.

The Principle of the Method of Measurement

The principle upon which the method is based can be explained by reference to Figure 1. The coil O is supplied with energy at any desired radio frequency by a vacuum tube oscillator. The loop L and the condenser C form a simple resonant circuit. A known resistance r_s is short-circuited by a heavy removable bar S. A is a thermo-galvanometer.

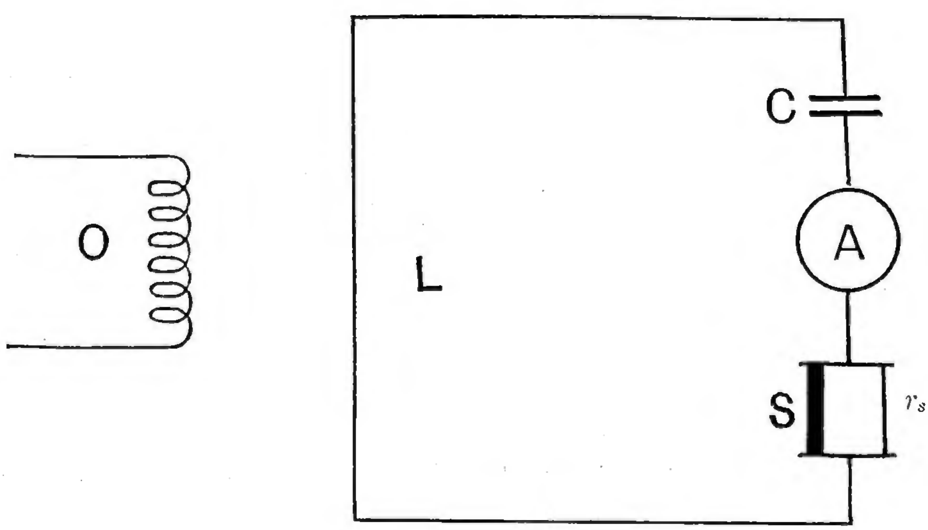


Figure 1

Suppose that the oscillator is adjusted to give resonance in the circuit $L\ C\ A\ S$.

If E is the emf. induced in the circuit by O,

r is the resistance of the loop and ammeter,

r_c is the equivalent series resistance of the condenser.

then $I_1 = \dfrac{E}{r + r_c}$ where I_1 is the resonant current.

Now if the bar S is removed and resonance still obtains

$$I_2 = \frac{E}{r + r_c + r_s}$$ where I_2 is the resonant current.

The justification for assuming E the same in both cases will be made later.

From the above equations

$$r_c = \frac{r_s}{\frac{I_1}{I_2} - 1} - r \qquad (1)$$

If r, r_s, and $\frac{I_1}{I_2}$ can be accurately determined we have a means of determining r_c.

It is at once apparent that unless r is smaller than r_c, a small error in the determination of the value of r will introduce a large error in the computed value of r_c. Therefore the resistance of the loop and meter must be as small as possible. The ratio $\frac{I_1}{I_2}$ must also be as large as is consistent with the accurate part of the range of the galvanometer being employed. Further, if the equivalent series resistances of condensers of different capacities are to be measured at the same frequency, a loop of variable inductance must be used.

Preliminary experiments showed that for air condensers hav ing a capacity of the order of magnitude of 500 micro-micro farads, the equivalent series resistance was in the neighborhood of an ohm at 1,000 kilocycles. Therefore it was necessary to make the loop and galvanometer resistance as much less than this as was possible.

A very sensitive thermo-galvanometer having a resistance of about 5 ohms was chosen. This meant, of course, that it was necessary to shunt the galvanometer with a low resistance.

However, reference to article 42, Bulletin 74, Bureau of Standards explains the difficulty of employing such shunts due mainly to the impossibility of determining accurately the division of the current between the shunt and the meter. It is to be noted that this difficulty was eliminated in the method used by the writers, since the expression for r_c depends upon the *ratio* of I_1 to I_2 and not upon their absolute values. It was assumed, and later justified, that altho the distribution of the current between shunt and meter could not be accurately determined, that *for a given frequency* the ratio of shunt current and meter current would be the same for different values of total current thru the loop.

Since a thermo-galvanometer was used, *for a given frequency,* the readings of this meter, which had been carefully checked against a standard, were *proportional* to the square of the current thru the loop and condenser.

As a shunt for the galvanometer, a three-inch (7.6 cm.) length of number 14 copper wire was used, which even at radio frequencies had a negligible resistance.

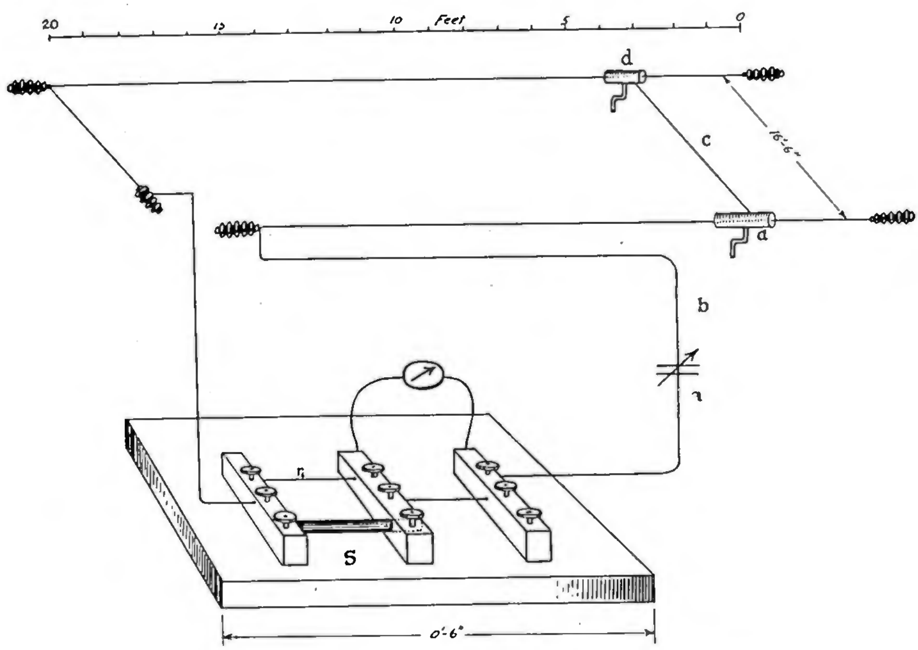


FIGURE 2

Before building the loop, curves of inductance and resistance per foot for various sizes of copper wire were calculated from formulas given in a paper by Rosa and Grover, Bulletin, Bureau of Standards, volume 8, 1912. The results of these computations appear in Figures 3 and 4.

The adjustable loop finally chosen (Figure 2) was made of number 8 Brown and Sharpe, copper wire and had maximum dimensions of 17.5 by 25 feet. The resistance of this loop for various adjustments is shown in Figure 5. With this loop, resonance was obtainable at 1,500 kilocycles for the capacities ranging from 250 to 500 micro-microfarads. At this frequency the total resistance of the loop including leads was calculated to be 0.8 ohms. No advantage could be gained by using heavier gauge wire since the increased diameter of the wire would necessitate the use of a larger loop, because the inductance of a loop of given dimensions decreases as the diameter of the wire increases.

However since the resistance of such a loop can be calculated with great accuracy and since the equivalent series resistance of a 250 micro-microfarad condenser is approximately 2 ohms at 1,500 kilocycles, this loop was quite satisfactory.

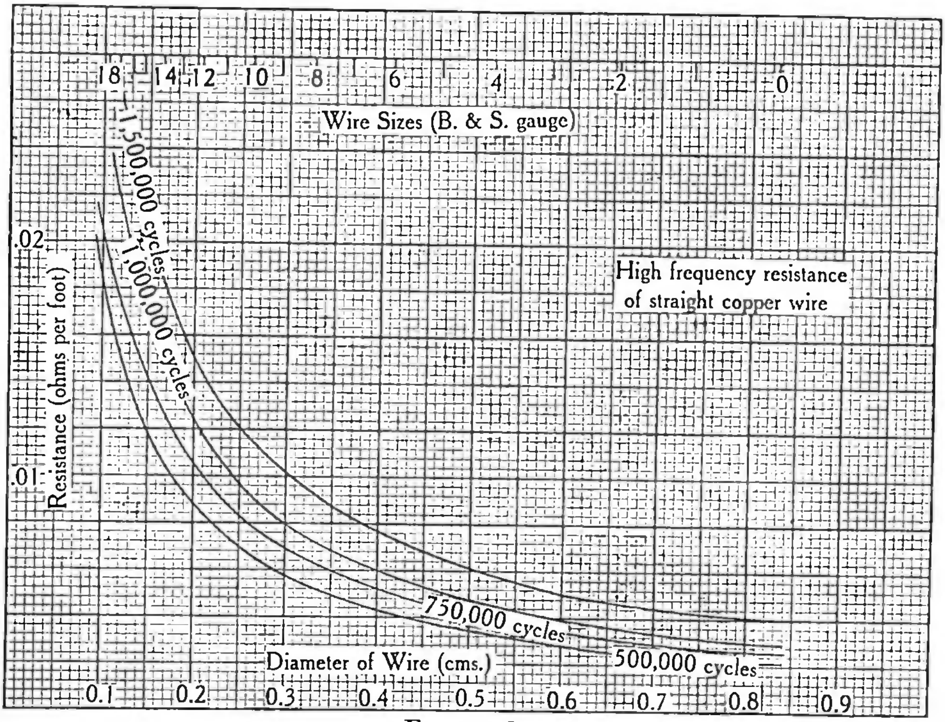


FIGURE 3

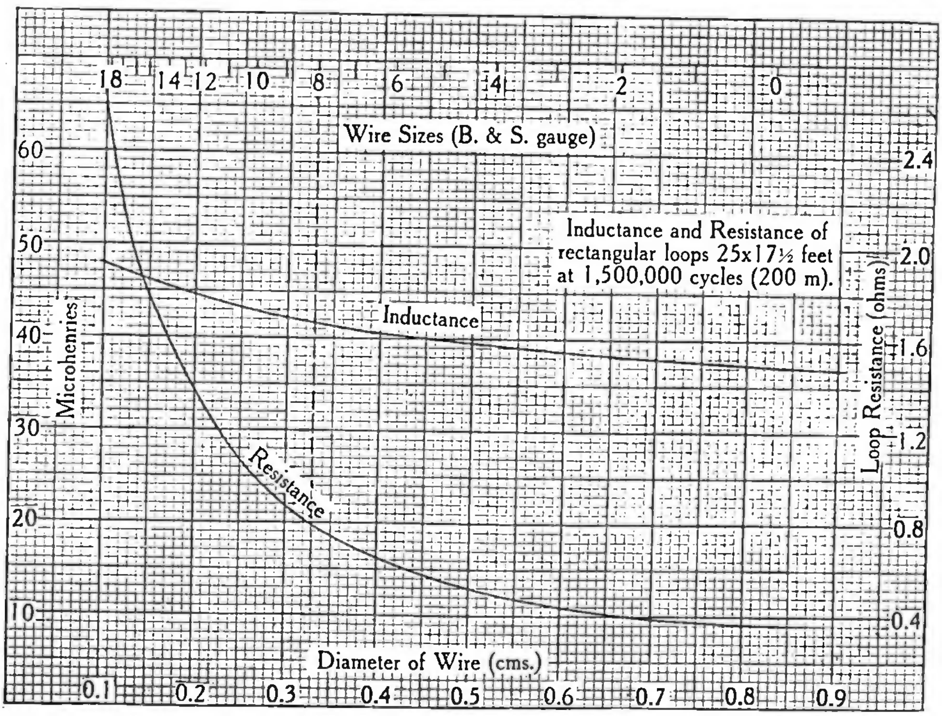


FIGURE 4

It is to be noted that larger condensers which, in general, have smaller resistances, required less loop and consequently r was proportionately decreased.

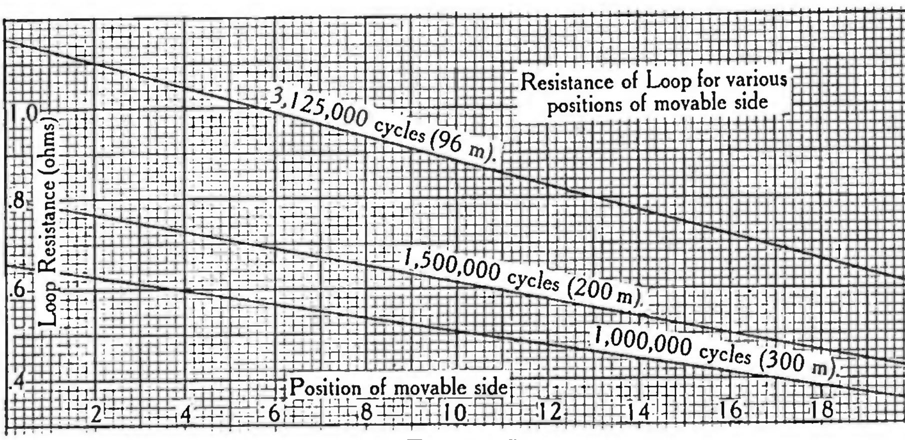


FIGURE 5

The resistance r_s (Figure 2) was a single strand number 30 Brown and Sharpe, manganin wire having a d-c. resistance (measured in place, by a Wheatstone bridge) of 2.10 ohms. Reference to Table 1, Chapter 2, Morecroft's "Radio Communication," will show that the resistance of a manganin wire of less than 0.29 mm. in diameter at 3,000 kilocycles or less, differs by less than one percent from the d-c., resistance. Manganin was chosen on account of its very low temperature coefficient of resistance.

The short-circuiting bar was made of copper and could be clamped into position by heavy set screws (Figure 2). It is important to note that the short-circuiting bar and the resistance r_s, were offset with respect to the loop in such a manner as to make the inductance of the loop virtually the same with the bar in or out.

A twenty-watt oscillator was employed with extremely loose-coupling to the loop. In this way a negligible reaction took place between the loop and oscillator.

PROCEDURE OF MEASUREMENT[3]

A measurement is made in the following manner:

1. The condenser is connected to the points a and b (Figure 2) with short heavy leads.

[3] All experimental work was conducted in the laboratories of the Moore School of Electrical Engineering, University of Pennsylvania.

2. The dial is set at the desired capacity, if a variable condenser is being measured.

3. By means of an accurate wavemeter the oscillator is adjusted to give the desired frequency.

4. With r_s short-circuited by means of bar S the adjustable side, c, of the loop is moved until resonance is indicated by the thermo-galvanometer. Non-conducting rods should be used to make the final adjustment of the loop in order to avoid body capacity effects. When the exact point of resonance has been found the clamps, d, are tightened.

5. The output of the oscillator is then adjusted to give approximately full scale reading of the thermo-galvanometer, the frequency being maintained constant, using the wave meter as a check.

6. A reading is taken of the thermo-galvanometer, the observer being careful not to touch any part of the apparatus.

7. The short-circuiting bar S is then unclamped and slid back, introducing the additional resistance r_s into the circuit.

8. A second reading of the thermo-galvanometer is taken.

9. The position of the adjustable side of the loop is noted.

Calculation of the Equivalent Series Resistance

Having obtained the ratio $\frac{I_1}{I_2}$ and the position of the adjustable side of the loop, the calculation of the equivalent series resistance is quite simple. By consulting the curves in Figure 5, the resistance of the loop and leads are determined at the given frequency. These data are then substituted in equation (1), which yields r_c directly.

Proof of the Validity of the Method

The equivalent series resistance of a 500 micro-microfarad variable air condenser was measured at 1,500 kilocycles by the method described above. A piece of number 30 Brown and Sharpe "Advance" wire was then carefully soldered between two heavy copper lugs. A careful measurement by means of a Wheatstone bridge yielded a resistance of 0.775 ohms for this wire. The wire with its lugs was then connected in series with the 500 micro-microfarad condenser and the combined resistance of the condenser and resistance wire was measured at 1,500 kilocycles. The value of r_c was then deducted from the combined resistance of r_c and the "Advance" wire. This yielded a result of 0.796 ohm or a difference of less than 2.7 percent, part of which difference is accounted for by skin effect. This test was repeated for several known resistances and at several frequencies, the maximum deviation noted being less than 3 percent.

A series of tests were also made to determine the effect of different loop and oscillator couplings and also different values of r_s varying from 0.56 ohms to 2.12 ohms. The deviation from the mean of the values was less than 3 percent.

The effect of foreign metallic bodies in the region of the apparatus was also determined, showing that under the conditions of these tests such effects were entirely negligible.

A careful test was made to determine the effects of any harmonics which might be present in the oscillator output, but the sharpness of the measuring circuit was so great as to render such effects entirely negligible.

Some Results Obtained by the Method

While it is the primary intention of the writers to present the method of measurement in such a fashion that other experimenters may be able to avail themselves of it, for the investigation of condenser losses, it may not be out of place to present briefly some results obtained by means of this method. No attempt whatsoever will be made in this paper to interpret these results.

The curve in Figure 6 is practically self-explanatory, showing the variations of the equivalent series resistance with dial setting of a standard make of air condenser of the so-called "low loss" type. The frequency was constant at 3,125 kilocycles (approximately 100 meters) thruout the test. The large resistance of such a condenser in the low part of its range, is clearly demonstrated.

The curve in Figure 7 shows the variation of the equivalent series resistance of the same condenser with frequency, maximum intermesh of the plates being maintained thruout the test. The regularity of the points is further evidence for the precision of the method. Figure 8 shows the same data plotted on logarithmic paper. While the frequency range is small, this curve indicates that the exponent of the resistance—frequency relation for this condenser is approximately 0.76. A measurement by the Bureau of Standards of this same condenser at 1 kilocycle yielded a result of 278 ohms which justifies an exponent of 0.7.

These results should serve to show the fallacy in referring 1-kilocycle measurements to radio frequencies, using the reciprocal law.

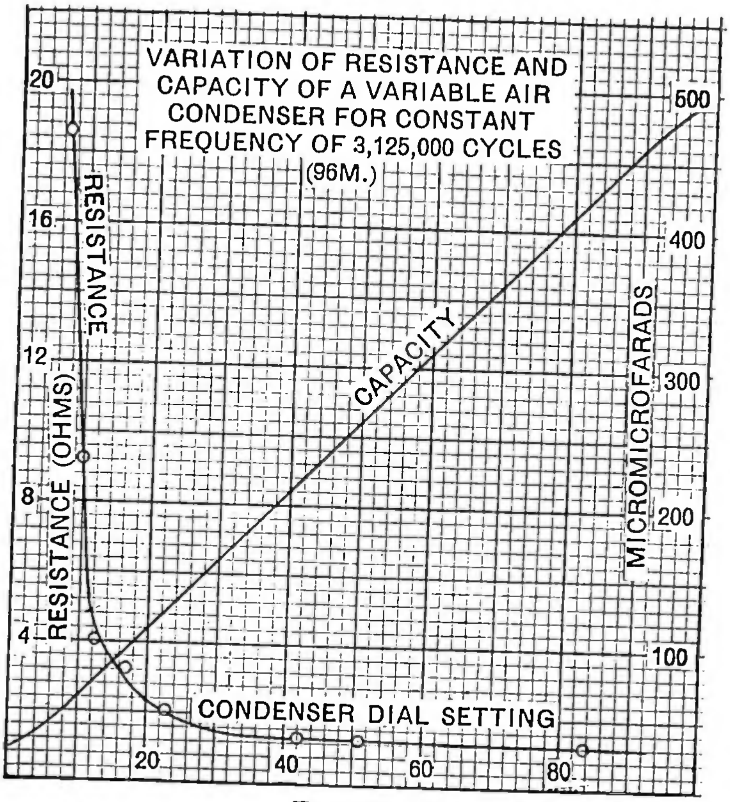


FIGURE 6

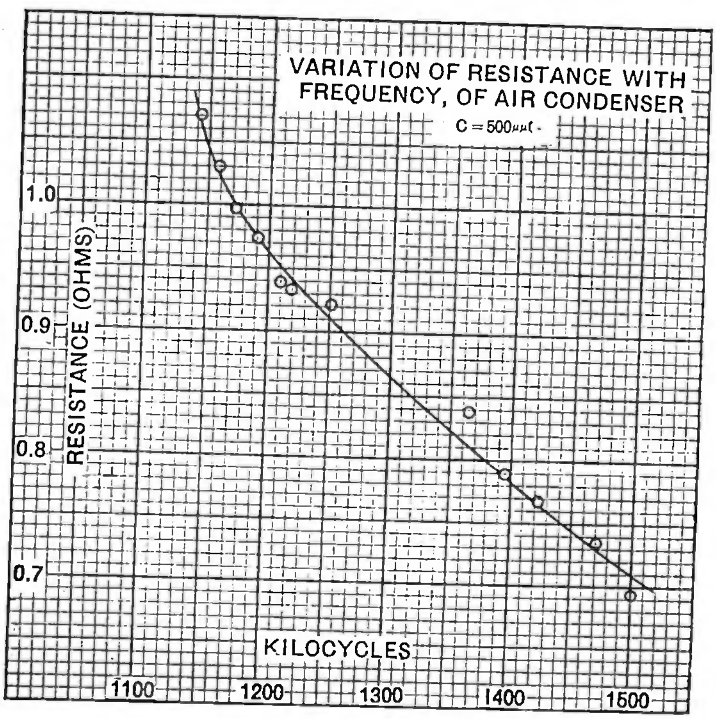


FIGURE 7

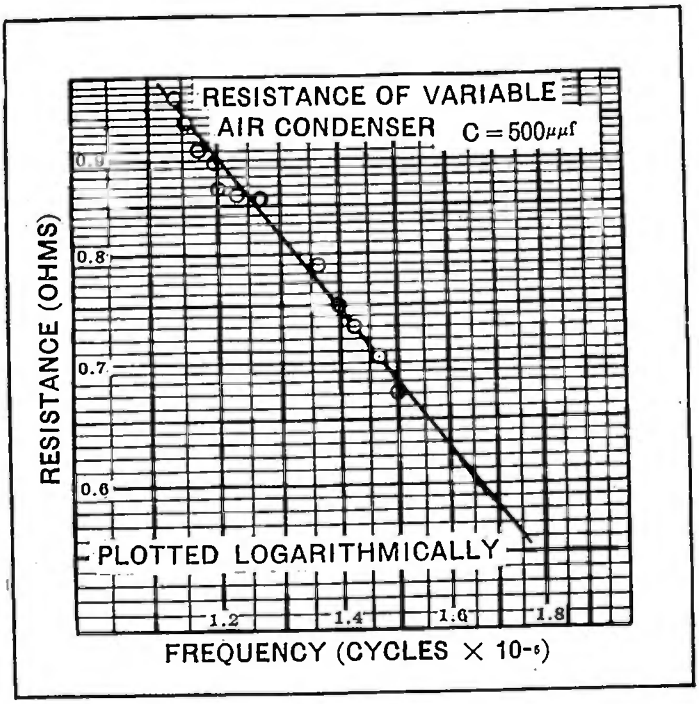


FIGURE 8

Table 1 shows the averages of tests made on over a hundred different air condensers of commercial manufacture.

TABLE 1

AVERAGE EQUIVALENT SERIES RESISTANCE OF AIR CONDENSERS AT MAXIMUM SETTINGS

Capacity of Smallest Cond.	Capacity of Largest Cond.	Average Equivalent Series Resistance	Number of Cond. in group
Micro-microfarads		Ohms at 1,500 Kilocycles	
200	500	1.02	75
500	800	0.75	22
800	2000	0.45	30

Table 2 gives the resistances of four sizes of typical "low loss" condensers at maximum capacity, all of the same make and design.

TABLE 2

Equivalent Series Resistances of a Set of "Low Loss" Air at Maximum Setting, of Same Construction and Design

Capacity in Micro-microfarads	r_c at 1,500 kilocycles
200	1.82
380	0.96
500	0.68
980	0.36

Table 3 gives the resistance at maximum capacity for a set of six condensers showing the effect of enclosing condensers in metal cases.

TABLE 3

Showing Effect of Metal Containers on Air Condenser Losses

Approx. capacity in micro-micro-farads	r_c in ohms at 1,500 kc. with metal container	r_c in ohms at 1,500 kc. without metal container
270	2.02	1.53
515	1.00	0.79
1075	0.57	0.45

A condenser of standard make having solid bakelite end plates was measured at 1,000 kilocycles. The end plates were then drilled leaving only a supporting skeleton of bakelite. A new measurement was made. A pigtail was then added. A third measurement of resistance was made, the results of these measurements are shown in Table 4.

TABLE 4

Effect of Solid End-Plates and Pigtail on Losses

800 Micro-microfarad Condenser

Condition	r_c in ohms at 1,000 kilocycles
Solid end plates (no pigtail)	0.85
Skeleton end plates (no pigtail)	0.81
Skeleton end plates and pigtail	0.73

Table 5 is self-explanatory.

TABLE 5

OLD STYLE VERSUS "LOW LOSS" AIR CONDENSERS

Old Style			"Low Loss"		
Average Capacity in micro-micro-farads	r_c ohms at 1,500 kc.	Number Tested	Average Capacity in micro-micro-farads	r_c ohms at 1,500 kc.	Number Tested
500	0.97	33	500	0.73	23
1000	0.57	23	1000	0.41	9

CONCLUSION

The above data and curves are indications of what may be accomplished with this method. The writers hope that its application to the problem of condenser selection and design will yield valuable results in the hands of other investigators as well as in their own.

SUMMARY: This paper shows the desirability of measuring at radio frequencies rather than at audio frequencies, the equivalent series resistance of radio receiving condensers. It further sets forth in detail a method of making such radio frequency measurements, and shows some preliminary results obtained from the application of this method.

THE "PIONEER BROADCASTER"

(Discussions on Mr. D. G. Little's paper on "KDKA, the Radio Telephone Broadcasting Station of the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania," by Messrs. Howard E. Campbell, D. G. Little, and Lee de Forest; summarized at the request of the Board of Direction of The Institute by Professor John H. Morecroft.)

In an art like radio, which had such a phenomenal growth all over the country, any one's claim to the distinction of being the "pioneer broadcaster" is sure to raise an argument. Mr. Little's designation of KDKA as the country's "pioneer broadcasting station" will not be questioned by most radio readers, but should any one dispute the claim, we must at once admit that the first radiophone broadcasting was not done by the Westinghouse Company at KDKA, but by Lee de Forest, who undoubtedly antedates all other claimants to the title "pioneer."

Ten or more years before any of the others, de Forest threw the human voice over a country almost devoid of listeners; we can well remember listening to him on our crystal receiver sets, and a real thrill it gave. In 1916, radiophone experimenting was carried on at the Highbridge laboratory of the de Forest Company; Governmental regulation stopped broadcasting for a while; then in 1919-1920 we had a real and permanent revival of the art. From the laboratory of Mr. Robert Gowan, in Ossining, the human voice was thrown over the ether waves at this time and, in late 1919, Mr. Frank Conrad, engineer of the Westinghouse Company, began to send out radiophone "programs" from his home. These early phonograph reproduction programs were undoubtedly the private enterprise of Mr. Conrad, and not a Westinghouse activity at all, but Mr. Conrad's success resulted in the transfer of the station from his home to the Westinghouse plant. Thus station KDKA began to function, getting its call letters from the Government on November 5, 1920.

In the meantime a de Forest radio set had been put into operation by the Detroit *News*, and on August 31, 1920, this station sent out election returns. The station was not called WWJ until a year and one-half later, but it was evidently operating from the office of the Detroit *News*, as a news service, before the activities of Mr. Conrad had been transferred to the Westinghouse factory. So the Detroit *News* station antedates the Westinghouse factory station, the Conrad home station antedates the Detroit *News*, the Gowan home station antedates the Conrad, and de Forest's activities antedate them all. As to which was the "pioneer broadcaster" the reader may judge for himself.

DISCUSSION ON "A METHOD OF MEASURING VERY SHORT RADIO WAVE LENGTHS AND THEIR USE IN FREQUCNCY STANDARDIZATION"

BY FRANCIS W. DUNMORE AND FRANCIS H. ENGEL

BY

EIJIRO TAKAGISHI

AND

SHIGEYOSHI KAWAZOE

(THE ELECTRO-TECHNICAL LABORATORY, MINISTRY OF COMMUNICATIONS, JAPAN)

The above paper on frequency standardization (PROCEEDINGS OF THE INSTITUTE OF RADIO ENGINEERS, volume 11, number 5, October, 1923, page 407) interested us greatly, but the writers desire to point out some doubtful points in the paper. The paper states that the authors measured the length of the standing wave produced on parallel wires by marking on the wires the points where a thermo-galvanometer showed a maximum indication of current. According to the observations in our experiments on the same problem it was found that generally there exist two points corresponding to maximum indications of the galvanometer bridged across the parallel wires and between them a point of minimum indication as shown in Figure 1. At either point of maximum indication of the galvanometer, the whole nature of the standing wave on the wires has been so much affected by the insertion of the galvanometer that the ammeter at the point of excitation (or at the current loop) showed a rapid fall of current, but when the galvanometer is put at the point of minimum indication, hardly any decrease in the current has been observed.

From these phenomena they arrived at a conclusion that for the measurement of the wave length on the wires the point of minimum indication should be preferred to those of maximum indication, and this enabled them to get more accurate results. To analyze these phenomena rigorously by the help of mathematics involves many difficulties, but a simple conception may lead us to a fair understanding of the present problem. In Figure

*Received by the Editor, July 14, 1924.

2, the full lines represent the standing wave of current and the dotted ones represent that of potential, the distribution being as usual, and the fall potential due to line resistance being ignored. The potential difference across the both wires will be a minimum at A, A'. Therefore, if an ideal voltmeter which consumes no

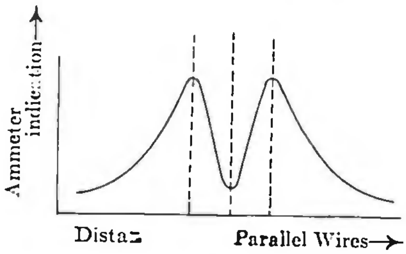


FIGURE 1

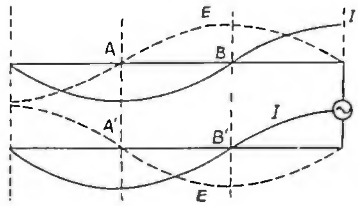


FIGURE 2

current be bridged across the wires, the voltmeter might have a minimum indication at this point, that is, at the anode of potential or the loop of current. If an ideal ammeter which requires no potential drop across it be used instead of the ideal voltmeter, it is clear that it would indicate maximum current at the same point owing to the well-known resonance phenomenon. This being the case it follows that in our practical cases the maximum indication may exist at a certain position other than A, A' and B, B', and if the meter bridged across the wires has a low resistance (as is the case for a usual ammeter) the maximum indication occurs near the points A, $A'$and on both sides of them. In such cases, within a small region very near the minimum point, the resonance condition on the wires is hardly affected by bridging a meter across them, and the indication is determined mainly by the normal form of potential distributions on the wires. It may be deduced also that the greater the resistance of the meter, the further the points of maximum indication may be moved away from the position A, A' and in both directions along the wires, and that if the ammeter has a negligible resistance, the two maximum points may practically coincide with each other. This also was actually observed in our experiments.

F. W. Dunmore and F. H. Engel (by letter):* The fact that two current maxima were found by Messrs. Takagishi and Kawazoe in their experiments with the parallel wire method of frequency standardization was no doubt due to the fact that the power output of the generating set was insufficient, thus requiring

*Received by the Editor, August 29, 1924. Published by permission of the Director of the Bureau of Standards of the United States Department of Commerce.

too close coupling between the generating set and the parallel wire system. The effect produced by this combination is quite similar to that encountered in spark transmitting sets when the coupling between the primary and antenna circuits is too tight,—the familiar double hump in the resonance curve is obtained. This "pulling" effect actually changes the frequency of the generating set in the parallel wire method of frequency standardization. The authors completely overcame this effect by using a 50-watt tube as the source of radio-frequency power, and by keeping this generating set as loosely coupled to the parallel wire system as possible. In this way the reaction between the parallel wire system and the generating set was reduced to such an extent that but one sharp hump could be found at each half wave length position along the parallel wire system.

A theoretical discussion of the above point may be found in Bureau of Standards Scientific Paper Number 491, "Theory of Determination of Ultra-Radio Frequencies by Standing Waves on Wires," by A. Hund.

August 15, 1924.
Department of Commerce,
Washington, D. C.

DIGESTS OF UNITED STATES PATENTS RELATING TO RADIO TELEGRAPHY AND TELEPHONY*

(Issued November 4, 1924–December 30, 1924

By

John B. Brady

(Patent Lawyer, Ouray Building, Washington, D. C.)

1,505,085—C. E. Brigham, filed July 15, 1922, issued August 19, 1924. Assigned to Dubilier Condenser and Radio Corporation, New York.

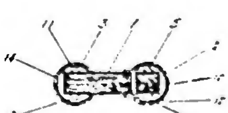


Fig. 1

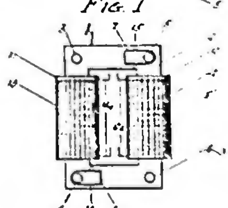


Fig. 2

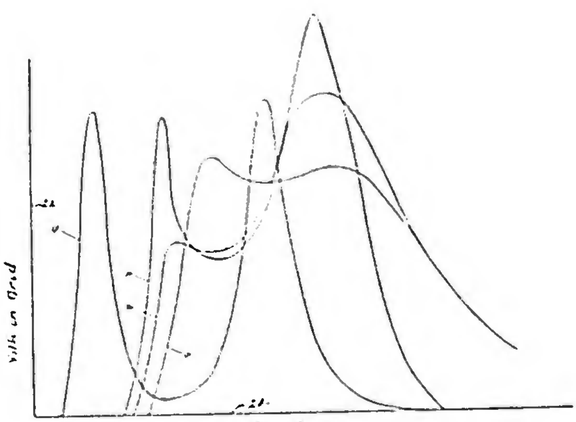


Fig. 6

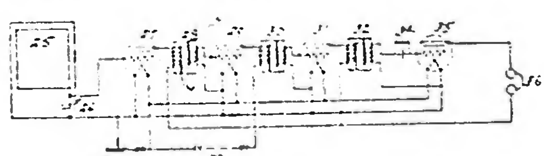


Fig. 7

Number 1,505,085—Radio Receiving Apparatus

Radio Receiving Apparatus, including a radio frequency amplification circuit wherein the tubes are interlinkedby coupling transformers designed to amplify incoming signaling frequencies over a broad band of frequencies. The transformer is designed to have extremely small distributed capacity at the frequencies for which the transformer is designed to operate. A magnetic leakage gap is introduced in the magnetic circuit for

*Received by the Editor, January 10, 1925.

producing losses to a degree necessary to enable the transformer to operate effectively over a broad band of frequencies. The patent shows a number of curves which have been taken on different radio frequency transformers and shows the relatively flat characteristic curve 21 which is possessed by the transformer of the present design.

1,513,973—F. M. Doolittle, filed February 21, 1924, issued November 4, 1924.

RADIO TELEPHONY system of broadcasting wherein the sounds reproduced at the receiving station may be so reproduced as to impart an effect of true tone values derived from a sense of location of the artists or the musical instruments at the broadcast studio. Two radio channels of transmission are provided each under control of separate sound pick-up microphones so relatively positioned as to receive sound in a manner simulating the reception of sounds by the ears of a human being. The radio channels are non-interfering and are each separately adjusted to bring in the transmission from the same studio.

1,514,295—J. F. Lindberg, filed July 5, 1922, issued November 4, 1924.

CONDENSER of the variable type in which both the stationary and the movable plates may be adjusted thru a vernier adjuster. The stationary plates are mounted at peripheries in such manner that they may be rocked with respect to the movable plates while the movable plates may be independently rotated in respect to the stationary plates.

1,514,369—H. A. Bremer, filed September 21, 1923, issued November 4, 1924.

ELECTRIC CONDENSER having a vernier adjustment, consisting of a supplemental plate element engaged by a spring connected with the movable plates and arranged to be rotated with respect to both the movable and the stationary plates. A spring element is included between the supplemental plates and the shaft which carries the movable plates which spring element is in the form of a U-shaped clip.

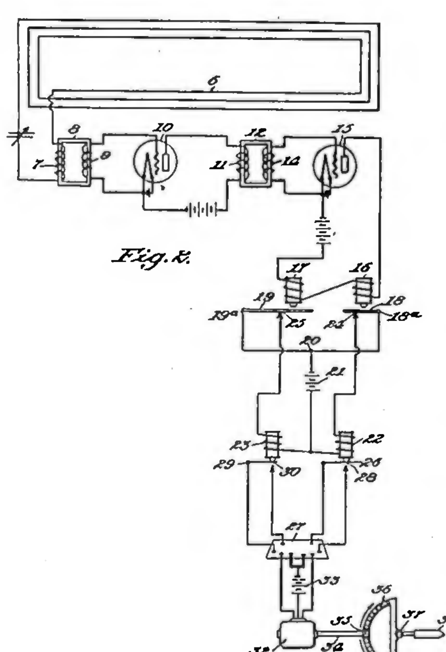
1,514,648—R. Bown, filed November 12, 1920, issued November 11, 1924. Assigned to American Telephone and Telegraph Company, New York.

DIRECTIVE RADIO SYSTEM, in which a plurality of antennas are arranged and each excited by a separate oscillator. The antennas are spaced apart for a distance corresponding to an even multiple of a wave length. A common modulating circuit is provided connecting by line wire with the several stations so that each oscillation circuit may be simultaneously varied. By arrangement of the transmitting stations signals can be transmitted in a desired direction.

1,514,661—M. W. Haub, filed November 6, 1922, issued November 11, 1924.

RADIO RECEIVING AND TRANSMITTING SYSTEM, comprising a circuit in which a condenser is connected in the antenna ground system and arranged with three sets of plates comprising a pair of dielectrically opposed plate members and a third set of plate members between the two sets of fixed plate members. The sets of fixed plate members have radio frequency energy impressed across them while the third set of plate members is connected with the lead from the grid of the electron tubes employed in the system.

1,514,699—E. C. Hanson, filed August 1, 1921, issued November 11, 1924.



NUMBER 1,514,699—Method and Apparatus for Radio Control for Torpedoes, and so on

Method and Apparatus for Radio Control for Torpedoes, and so on, wherein a pair of loops are carried on aircraft and independently energized with audio frequency energy which is picked up by a tuned system having mechanical relays tuned to the audio notes transmitted. The signals of different notes are employed to actuate different controls aboard the torpedo.

1,514,732—P. J. Ruddy, filed June 21, 1921, issued November 11, 1924.

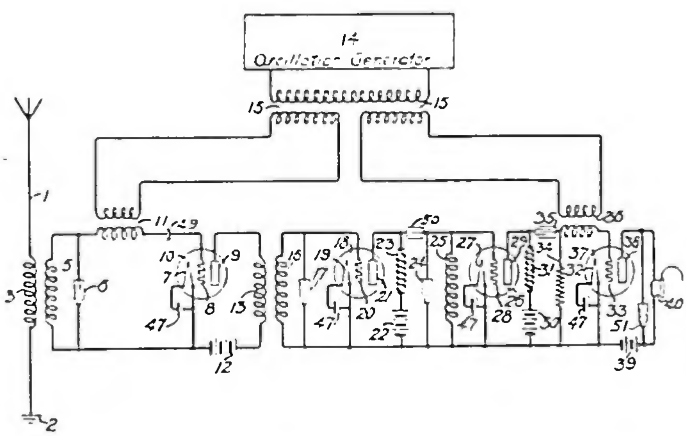
Electromagnetic Signaling Apparatus, in which the apparatus is self-contained and does not employ an antenna or ground connection. A device resembling a coherer is used at the receiver, consisting of a tube of non-conducting material, pole members at each end of the tube and groups of lead and magnetized steel balls between the pole members.

1,514,733—A. H. Sass, filed May 11, 1922, issued November 11, 1924. Assigned to Western Electric Company, Incorporated, New York.

Condenser, wherein both the movable and stationary plates are mounted on the same shaft, thereby decreasing the area occupied by the condenser. The shaft is insulated and arranged so that alternate plates are moved between the remaining plates which are immovable upon the shaft.

1,514,752—P. I. Wold, filed September 14, 1920, issued November 11, 1924. Assigned to Western Electric Company, Incorporated, New York.

Fig. 1



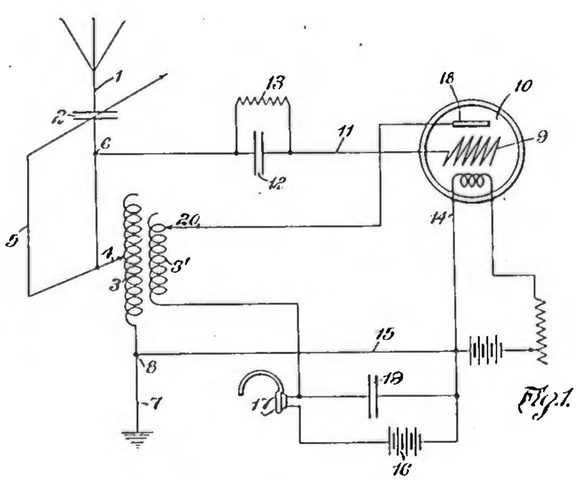
Number 1,514,752—Method of and Means for Receiving Radio Signals

Method of and Means for Receiving Radio Signals, which comprises combining the incoming waves with locally generated oscillations of a frequency different from that of the incoming waves. The resultant composite waves are transferred selectively with the substantial elimination of the locally generated oscillations and then the resultant selectively transferred composite waves again combined with the locally generated oscillations reducing the frequency in such manner that it may be observed. The patent describes a single oscillator at the receiver which reacts a number of times upon the incoming signaling energy at different points in the amplification system and when the received energy has been modified in different conditions.

1,514,898—G. L. Geisey, filed July 18, 1923, issued November 11, 1924.

Thermionic Device, in which the electrodes are stamped from blanks with extended tongues or straps which enable the electrodes to be folded upon themselves and mechanically supported within the tube. The electrodes are punched with checkered apertures therein.

1,515,186—F. Conrad, filed June 3, 1920, issued November 11, 1924. Assigned to Westinghouse Electric and Manufacturing Company, Pittsburgh, Pennsylvania.



Number 1,515,186—Aperiodic Receiving System

Aperiodic Receiving System, employing inductive coupling with capacitance loading in the antenna circuit and in which automatic control of the antenna system is secured. The coupled inductor and the condenser reactor are mechanically linked and varied simultaneously in the tuning of the receiver.

1,515,331—J. Bethenod, filed August 2, 1921, issued November 11, 1924.

RADIO TRANSMISSION SYSTEM, employing an antenna system which may be energized by a plurality of high frequency generators. All the generators may be operated simultaneously at the same frequency whereby the total generating power of the station is applied to the antenna, or these generators may be independently operated at different frequencies, in order to make possible multiplex transmission. The principle of the invention consists in that the antenna, which is a horizontal network extended in one direction, is divided into a plurality of sections each of which is supplied with current by a radio frequency generator, and provisions are made for modifying, if necessary, the effects of the electromagnetic or electrostatic induction between any two sections.

1,515,670—L. F. Fuller, filed September 25, 1919, issued Novembet 18, 1924. Assigned to Federal Telegraph Company, San Francisco, California.

RADIO TELEGRAPHY system, in which the ohmic resistance of the ground circuits is reduced with a view of raising the overall efficiency of a transmitting station. The specification points out that by reason of the large antenna current the I^2R losses in the usual ground system at a high power radio station have been so large as considerably to reduce the efficiency. By the present invention an ungrounded radiating circuit comprising a plurality of vertical loops in substantially the same plane is provided. The vertical sides of adjacent loops are near each other and current is supplied to each loop of such phase that the current in the adjacent vertical sides are opposed and substantially nullify each other. The resistance losses in the entire structure may be thus maintained at a desired low value.

1,515,900—C. J. Everett, filed May 5, 1922, issued November 18, 1924.

DETECTOR FOR USE IN RADIO CIRCUITS, in which the contact member comprises a spring positioned within a barrel and projecting out of the end thereof to engage the sensitive crystal surface.

1,515,990—R. D. Bangay, filed July 9, 1921, issued November 18, 1924. Assigned to Radio Corporation of America, Delaware.

RADIO TELEGRAPHY, in which the wave length of the transmitting system may be varied by movement of a variometer in the primary circuit. The primary inductance is in the form of a variometer while the antenna inductance is coupled with the variometer. By varying the angular position of the variometer coils in the primary circuit, the coupling is changed while maintaining the inductance constant.

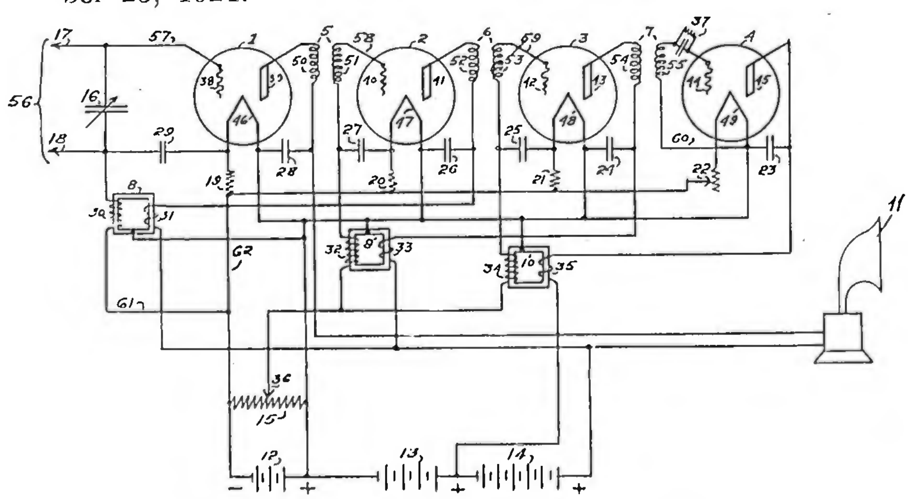
1,515,994—A. W. Bowman, filed April 4, 1923, issued November 18, 1924.

OSCILLATION DETECTOR of the crystal type, in which a crystal is disposed adjacent one end of a cartridge container while the surface is touched by a fine wire spiral spring projecting from the other end of the cartridge and controlled from a knob exterior of the barrel.

1,516,061—H. O. Rugh, filed November 16, 1922, issued November 18, 1924. Assigned to Rugh and Noble, Chicago, Illinois.

RADIO RECEIVING SYSTEM, which may be connected in the house lighting circuit similar to an incandescent lamp. A two-electrode tube is secured into the lighting socket and has its filament lighted from the source of current. A tuned circuit is provided across the input terminals while a responsive device is connected in circuit with the second electrode.

1,517,057—D. Grimes, filed September 19, 1922, issued November 25, 1924.

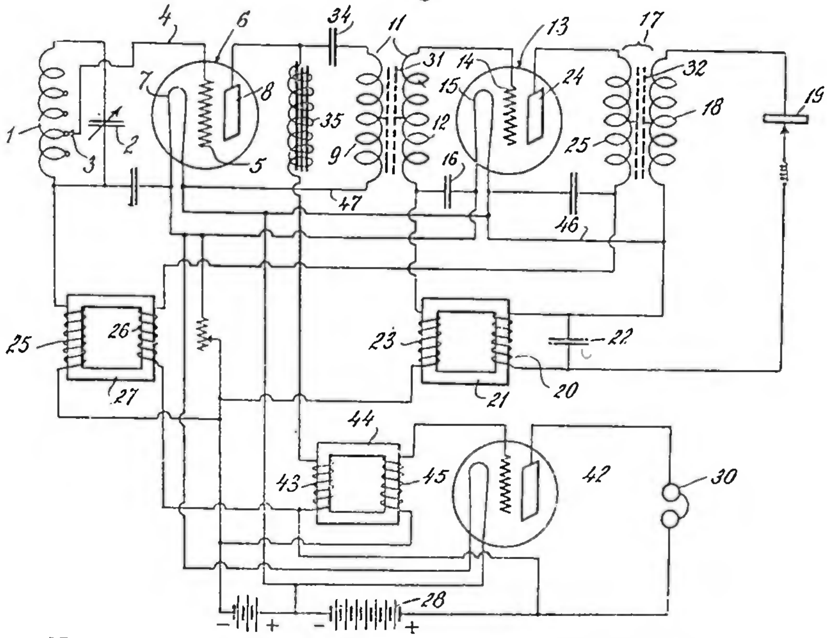


NUMBER 1,517,057—Vacuum Tube Amplifier

Vacuum Tube Amplifier, in which a plurality of tubes are provided so arranged that radio frequency current variations are repeatedly amplified by the electron tubes in a predetermined order with circuit connections whereby said tubes simultaneously operate repeatedly to amplify audio frequency current variations in the inverse order as compared with the predetermined order of radio frequency amplification.

1,517,058—D. Grimes, filed December 1, 1923, issued November 25, 1924. Assigned to Grimes Radio Engineering Company, Incorporated.

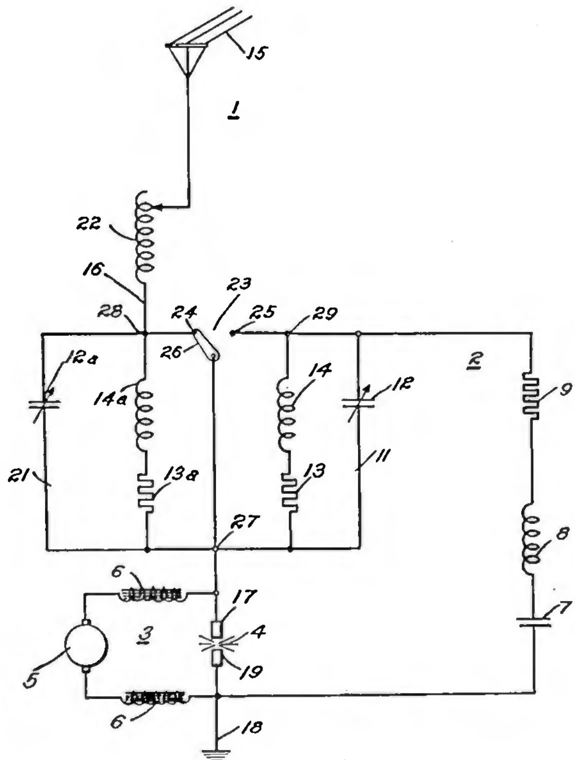
Fig. 6



Number 1,517,058—Inverse Duplex Vacuum Tube Circuit

Inverse Duplex Vacuum Tube Circuit, in which both radio and audio frequency amplification may be effected in tube circuits simultaneously. The radio frequency signaling currents are transmitted thru the amplification tubes in a certain order, while the audio frequency signaling currents are transmitted thru the same amplifier tubes successively in the inverse order with respect to the radio frequency amplification. Circuit connections are provided to prevent the effective transmission of audio frequency signaling currents from the output side of one amplifier to the input side of a successive amplifier in the order predetermined for radio frequency amplification.

1,517,277—O. B. Buchanan, filed August 18, 1921, issued December 2, 1924. Assigned to Westinghouse Electric and Manufacturing Company.



NUMBER 1,517,277—Signaling System

SIGNALING SYSTEM for transmission by means of an arc on a single wave without interrupting the arc which consists in alternately inserting and removing parallel resonant reactance devices in the antenna circuit of the arc system for production of signals. The absorbing circuit is connected in parallel with the radiating circuit and each contains impedance elements having predetermined electrical time constants with switching means which render the sets of impedance elements effective or ineffective in accordance with the signals.

1,517,370—R. E. Marbury, filed November 26, 1920, issued December 2, 1924. Assigned to Westinghouse Electric and Manufacturing Company, Pittsburgh, Pennsylvania.

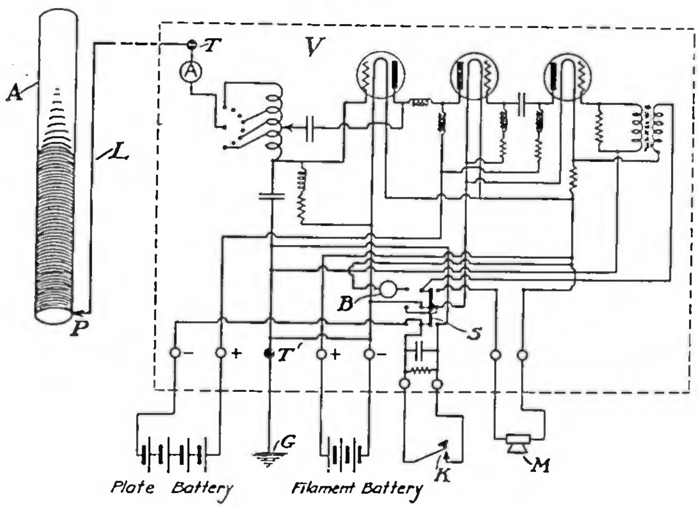
RADIO CONDENSER, in which the plates comprise metal foil coated with metal fusible below 200° C. The plates are alternately positioned between plates of solid dielectric. By this construction the condenser can be subjected to heat and great pressure so that the fusible metal will fill up all the irregularities in the dielectric sheets.

1,517,566—R. H. Marriott, filed November 1, 1921; issued December 2, 1924.

SPARK GAP unit for quenched gaps which has a spark chamber and a pressure relief chamber connecting therewith. The walls of the pressure relief chamber are expandible in such manner that on expansion of gas within the gap the unit will not develop leaks arising out of the tendency of the gas to escape from the unit.

1,517,569—J. O. Mauborgne and Guy Hill, filed June 3, 1921, issued December 2, 1924.

Fig. 2.

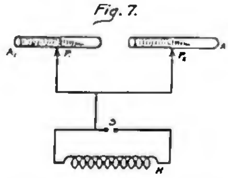


NUMBER 1,517,569—System of Radio Transmission

SYSTEM OF RADIO TRANSMISSION, in which a wave coil is employed in connection with a source of undamped high potential energy. A wave development is effected in the coil and the source of undamped oscillations modulated for the production of signals.

1,517,568—J. O. Mauborgne and Guy Hill, filed June 16, 1920' issued December 2, 1924.

Fig. 7.



NUMBER 1,517,568 —System of Radio Transmission

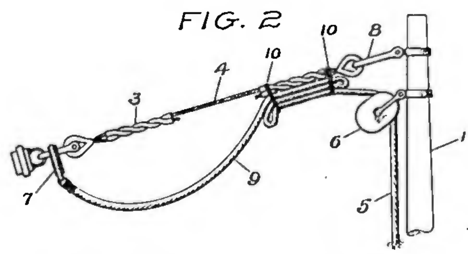
System of Radio Transmission which includes a power supply and two or more wave coils. Corresponding points are selected on the coils and a suitable high frequency potential from the power supply impressed between the points for causing wave developments on the wave coils. The power supply is modulated for the purpose of signaling.

1,517,570—J. O. Mauborgne and Guy Hill, filed February 17, 1921, issued December 2, 1924.

System of Radio Communication utilizing a wave coil as an antenna. An elongation of variable length is provided on one end of the wave coil and the capacity of the coil and the wave distribution thereon are thereby varied.

1,517,602—A. M. Trogner, filed July 30, 1920, issued December 2, 1924.

FIG. 2



Number 1,517,602—Antenna Safety Link

Antenna Safety Link having a weakened portion therein, which may be ruptured when the antenna wires are subjected to undue strain without injury to the antenna conductors. The object of the invention is to prevent the carrying away of the antenna as the result of an abnormal "whipping" of the masts on shipboard, such as happens in cases of collision, torpedoing, grounding, and the like.

1,517,654—H. J. Round and A. McLellan, filed March 30, 1921, issued December 2, 1924. Assigned to Radio Corporation of America, New York.

Radio Signaling System, in which the amplitude of the energy emanating from a transmitting station may be maintained constant. A tube transmitter is shown having an oscillation circuit and connections for impressing the oscillations generated on an antenna system. A relay is energized by energy delivered to the antenna system, so that upon tendency of the energy to vary, the relay operates to prevent the generated oscillations from falling below a predetermined value.

1,517,816—E. F. W. Alexanderson, filed June 24, 1921, issued December 2, 1924. Assigned to General Electric Company, New York.

Radio Transmitting System for a multiple tuned antenna divided into different portions with circuits for supplying the signaling energy to the different portions and varying the phase of the current so supplied to obtain maximum radiation of the signaling energy.

1,518,439—A. Meissner, filed September 3, 1921, issued December 9, 1924. Assigned to Gesellschaft für drahtlose Telegraphie, m.b.H., Hallesches, of Berlin, Germany.

Arc Transmitter for Radio Telegraphy, in which the arc generator is connected with the antenna system thru a circuit arranged to increase by an even or odd multiple of the frequency of the oscillations, the frequency of the radiated signaling energy. The patent discloses a magnetic frequency changer interposed between the arc generator and the radiating system.

1,518,564—T. S. Cole, filed October 27, 1922, issued December 9' 1924.

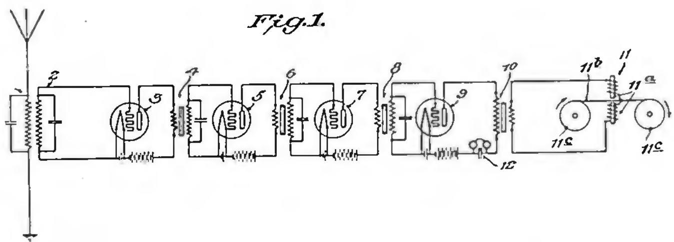
Radio Telephone and Telegraph Apparatus, consisting of a battery system for connection in the plate circuit of an electron tube with a switching arrangement associated with the battery system, whereby in periods of non-use of the radio receiving circuit the "B" battery may be connected in shunt with the "A" battery for enabling the "B" battery to be charged from the "A" battery. The "B" battery is constructed in the form of a secondary battery having its sections so arranged in parallel thru the switching arrangement that the filament battery may be utilized to charge the plate battery.

1,518,633—R. E. H. Carpenter filed May 20, 1924, issued December 9, 1924.

Radio Signaling System and Apparatus Therefor for the reception of signaling energy in which the receiver may be accommodated to various antenna systems and to suit the characteristics of such antenna systems to which the apparatus may be connected. A coupling system is provided between the receiver and the antenna circuit which consists of a resistance connected in series with a tuning condenser and in shunt with the antenna circuit. The resistance and condenser are varied in order to tune the receiving system for operation and connection with antennas of different characteristics.

1,518,655—W. L. Carlson and E. C. Hanson, filed January 14, 1920, issued December 9 1924.

Fig.1.

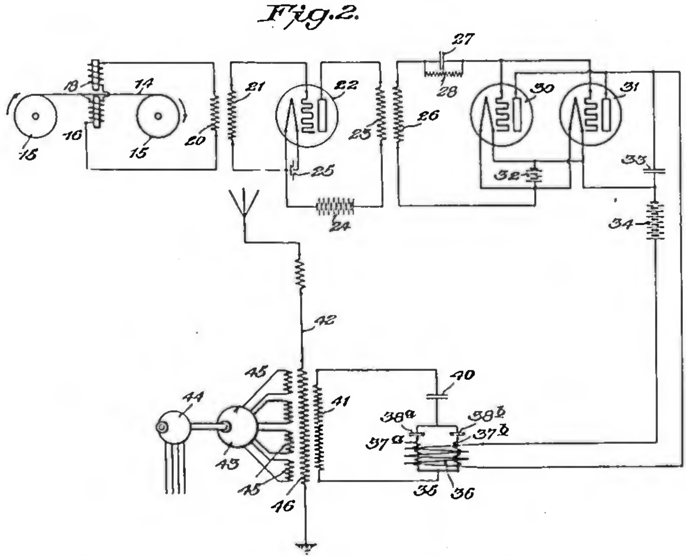


NUMBER 1,518,655—Radio Telegraph System

RADIO TELEGRAPH SYSTEM employing the telegraphone as a recorder of incoming signaling energy. An electron tube amplification circuit is provided, the output circuit of which contains a device for audibly reproducing the signals and also the recording heads of the telegraphone whereby a magnetic record of the incoming signals is simultaneously produced.

1,518,656—E. C. Hanson, filed March 11, 1924, issued December 9, 1924.

Fig.2.



NUMBER 1,518,656—Radio Telegraph System

RADIO TELEGRAPH SYSTEM employing a telegraphone upon the wire of which the signals are initially impressed and then the telegraphone operated at high speed to control the radiation of signaling energy from a source of sustained oscillations. The invention is directed to automatic high speed signaling from high power stations.

1,518,682—W. R. G. Baker, filed November 6, 1923, issued November 9, 1924. Assigned to General Electric Company of New York.

SIGNALING SYSTEM, in which an electron tube is employed as a generator of oscillations and is maintained in the condition of oscillation continuously while signals are produced by switching the oscillator alternately to a storage circuit and the radiating circuit. The system is intended principally for tubes of high power which will not permit the keying of the grid circuit.

1,519,398—H. F. Elliott, filed December 14, 1921, issued December 16, 1924. Assigned to Federal Telegraph Company, San Francisco, California.

ARC CONVERTER, including an arc chamber and a mechanical arrangement for exhausting and blowing out the arc chamber with a valve arranged to connect either the exhausting pump or the blower with the arc chamber. The arc is operated in an atmosphere of hydrogen or other gas having similar electro-mechanical properties. The apparatus disclosed in this patent is in association with the arc converter for controlling the condition thereof.

1,519,412—S. R. Mullard, filed October 2, 1922, issued December 16, 1924. Assigned to The Mullard Radio Valve Company, Limited, England.

SUSPENSION OF INCANDESCENT FILAMENTS for electron tubes for ensuring that the filament will be maintained under tension at all times. The filament is supported in spring suspension within the helix formed by the grid and inside of the vertical plate electrode.

1,519,615—R. A. Heising, filed June 5, 1920, issued December 16, 1924. Assigned to Western Electric Company, Incorporated, New York.

SIGNALING SYSTEM having a modulating system of the type wherein the unmodulated component of the modulated carrier frequency current is wholly or partly suppressed. An oscillator is provided for generating modulated current. A plurality of paths are arranged for the passage of this current and one of the paths includes a stiffly resonant circuit of zero reactance and resistance for the unmodulated component of the modulated current. Another of the paths includes a loosely resonant circuit tuned to the same frequency. The undesired side frequencies are passed into the branch paths while the main frequency is transmitted.

1,519,899—R. C. Benner, filed February 28, 1922, issued December 1, 1924. Assigned to National Carbon Company, Incorporated, New York.

Apparatus for Radio Communication, comprising a construction of "B" battery. The "B" battery comprises a plurality of cells each having a substantially flat zinc anode which is disposed parallel and in close relationship with another zinc anode of the succeeding cell. The plates are substantially overlapped. The battery, therefore, has a large concentrated capacitance and according to the specification the electron tube circuit becomes more sensitive to weak radio frequency currents.

1,510,027—A. A. Kent, original filed September 23, 1916, issued December 23, 1924. Assigned to Atwater Kent Manufacturing Company, Philadelphia, Pennsylvania.

Condenser and Holder Therefor, in which the condenser is gripped between a pair of pressure plates which form the holder for the condenser adjacent a pair of binding posts comprising the terminals of the condenser.

1,520,329—C. S. Cherpeck, filed August 26, 1922, issued December 23, 1924.

Variable Condenser of the book type in which plates which are normally paralleled may have their capacity varied by angularly varying the pistons between the plates by means of a screw which may be advanced to introduce a cam movement arranged to vary the angularity of the plates.

1,520,461—H. A. Bremer, filed September 21, 1923, issued December 23, 1924.

Electric Condenser, in which the plates are arranged in pairs and are dished in such manner that movable plates may be interleaved between the stationary plates, the offset portions of the movable plates moving between the offset portions of the stationary plates. In this way a smaller number of spacing members is required in the support of both the movable plates and the stationary plates.

1,520,580—Norman Lea and John Ree, filed September 26, 1919, issued December 23, 1924.

ELECTROMAGNETIC WAVE SIGNALING SYSTEM, consisting of an electron tube transmitter wherein the oscillation circuit has a permanent conductive connection between the control element of the valve and the negative lead of the high tension supply. The signals are produced by breaking the lead between the filament and the negative lead to the control electrode.

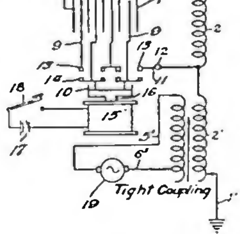
1,520,640—G. L. Geisey, filed November 20, 1922, issued December 23, 1924.

THERMIONIC DEVICE or electron tube in which the grid is formed by a checkered plate with spaced openings while the plate is formed from flat material having raised portions in checkered formation corresponding to the checkered spaces in the grid. The tube is constructed in such manner that the electrodes are spaced very close together.

1,520,835—A. Meissner, filed September, 1921, issued December 30, 1924. Assigned to Gesellschaft für drahtlose Telegraphie, m.b.H., of Berlin, Germany.

METHOD OF RECEIVING ELECTRICAL OSCILLATIONS, which includes heterodyning the received energy by a local source of current which has a frequency differing by an audio frequency from a multiple of the received frequency. The object of this invention is to provide a selective system of reception by choosing a particular frequency for the local source.

1,521,018—H. L. Godfrey, filed June 3, 1920, issued December 30, 1924. Assigned to Westinghouse Electric and Manufacturing Company, Pennsylvania.



NUMBER 1,521,018—
Signaling System

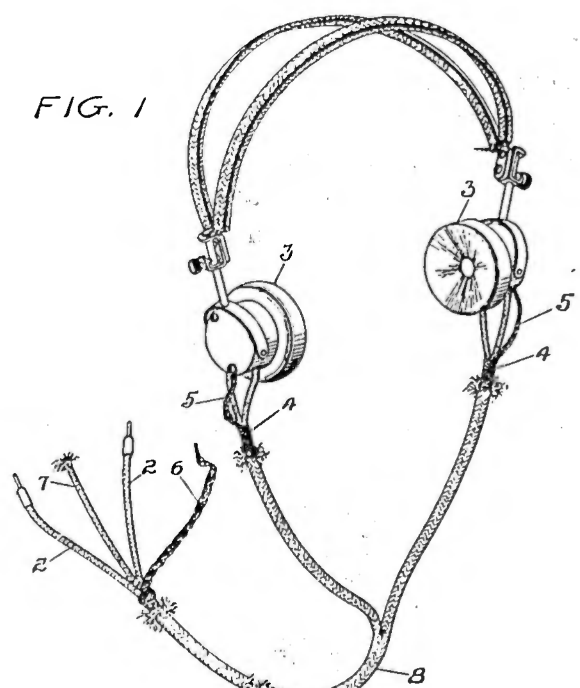
SIGNALING SYSTEM, in which the transmission of the signaling energy is controlled by opening and closing a frequency trap circuit. An inductor at the transmitter has a condenser connected in parallel therewith. The condenser is constructed of a plurality of units which may be simultaneously shunted in forming the signals.

1 521,205—W. S. Stephenson and G. W. Walton, filed March 24, 1924, issued December 30, 1924.

SYNCHRONIZING ROTATING BODIES at radio transmitting and receiving stations intended for operation of apparatus in the transmission and reception of photographs. Synchronizing signals are transmitted and received in such manner that they will control the operation of rotary apparatus at the receiver for maintaining the receiving apparatus in step with the transmitting apparatus for purposes of synchronizing the photograph process.

1,521,275—G. W. Carpenter and W. L. Carlson, filed January 29, 1921, issued December 30, 1924.

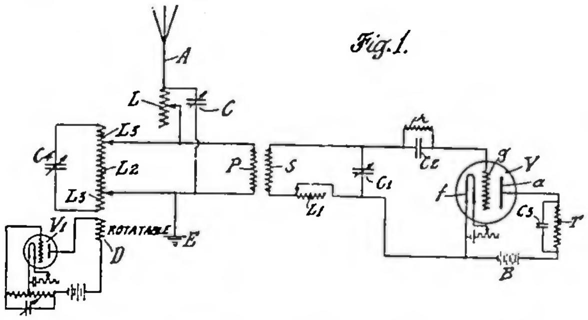
FIG. 1



NUMBER 1,521,275—Telephone Headset

TELEPHONE HEADSET where the cords of the telephone headset are electrostatically shielded by a flexible conductive plate, which consists of woven tinsel conductors. The shield extends over the telephone conductors and is grounded on the caps of the telephone receivers. The shielded headset is described for use with sensitive multi-stage electron tube amplifiers in long distance reception.

1 521,380—D. G. McCaa, filed November 17, 1922, issued December 30, 1924. Assigned to The Electric Apparatus Company, Parkersburg, Pennsylvania.



NUMBER 1,521,380—Receiving System

RECEIVING SYSTEM for radio signals in whicn a circuit arrangement is provided for discriminating against static atmospherics, strays and other disturbances. The received energy representing both the desired signal and the disturbing effect is divided into two paths, including reactive devices, one of which is employed for effecting the translation of the desired signals and with another of which is associated a local source of oscillations in such manner as to cause the effect of said reactance to fluctuate within wide limits resulting in the fluctuation in amplitude of the signal representing energy in the first reactance and at certain instants to be reinforced by energy from the local source to the substantial exclusion or great reduction of the effects of the simultaneously existing disturbing energy.

NUMBER 66,049—Advertising Support for Telephone Head Sets

66,049—L. J. Urich, filed September 3, 1924, issued November 18, 1924. Assigned to C. Brandes, Incorporated, of New York, N. Y.

Advertising Support for Telephone Head Sets, in which a window display statuette is arranged with indentations formed on the head of the statuette to receive and support a telephone headset for display purposes. The statuette has the appearance of a radio listener-in wearing the headset which is on display.