Volume I Part 4

PROCEEDINGS

OF THE

INSTITUTE OF RADIO ENGINEERS

(INC.)

CONTENTS:

EDITED BY

ALFRED N. GOLDSMITH, Ph. D.

NEW YORK, DECEMBER, 1913

Manuscripts and letters bearing on the Proceedings should be sent to Alfred N. Goldsmith, Editor of Publications, The College of the City of New York, New York.

Requests for additional copies of the Proceedings and communications dealing with the Institute matters in general should be addressed to the Secretary, Emil J. Simon, 81 New Street, New York City, New York.

The Proceedings appear quarterly, and the cost of separate copies is $1.00.

It is understood that the statements and opinions given in the Proceedings are the views of the individual members to whom they are credited, and not binding on the membership of the Institute as a whole.

In closing the first volume of the Proceedings of the Institute of Radio Engineers, the Editor wishes to extend to the contributors of papers the thanks of the Institute for their valuable co-operation.

Officers, Board of Direction and Committees for 1913

Greenleaf W. Pickard	*President*
Robert H. Marriott	*Vice-President*
Emil J. Simon	*Secretary*
John Hays Hammond, Jr.	*Treasurer*
Alfred N. Goldsmith	*Editor of Publications*

In Addition to the above Officers, the Board of Direction Includes the following Managers:

Lloyd Espenschied — John L. Hogan, Jr.
John Stone Stone — Roy A. Weagant

Thomas T. Trapnell	*Assistant Treasurer*
Ralph H. Langley	*Assistant Secretary*

Committee on Papers

Alfred N. Goldsmith, *Chairman*

Frederick A. Kolster
Greenleaf W. Pickard, *Ex-Officio*

Committee on Standardization

Robert H. Marriott, *Chairman*
Alfred N. Goldsmith, *Secretary*
John L. Hogan, Jr.
A. E. Kennelley
Roy A. Weagant
Greenleaf W. Pickard, *Ex-Officio*

Committee on Publicity

John L. Hogan, *Chairman*

Emil J. Simon
Greenleaf W. Pickard, *Ex-Officio*

Committee on Increase of Membership

John Hays Hammond, Jr., *Chairman*

Thomas E. Clark
Charles P. Edwards
George S. Davis
Cyril F. Elwell
V. Ford Greaves
Capt. Francis J. Behr, U. S. A.
Oscar C. Roos
Lieut. Stanford C. Hooper, U.S.N.

Greenleaf W. Pickard, *Ex-Officio*

THE MULTITONE SYSTEM.

By Dr. Hans Rein.

In an earlier article[1], I have shown the connection between freedom from interference with communication in radio telegraphy and the use of transmitting sets which send out signals having the quality of a musical tone. Even were this point alone considered, such systems as employed not merely a single note but a series of definitely chosen notes would be regarded as superior. As compared with the usual quenched sets, the "Multitone" sets have another feature wherein they are more desirable. The production of the musical tone should be independent of the characteristics of the source of electrical energy, and also of the constants of the radio frequency circuits. In this respect, the method of transmission which I worked out in the laboratories of the C. Lorenz Company of Berlin is the most general solution of the problem so far obtained. By the use of this method, as many tones as may be desired can be simply and easily produced. Furthermore, any influence on the pitch of the musical tone by the source of electrical energy or by the radio frequency circuits is completely avoided. The electrical behaviour of such sets may now be considered in greater detail, in connection with a number of illustrative diagrams and photographs.

A. THE PRODUCTION OF THE RADIO FREQUENCY ENERGY.

One of the most important requirements of all modern radio telegraphic equipments is that they shall permit the radiation from the antenna of electromagnetic waves of a single frequency, appreciably that of the free electrical vibration of the open or radiating system. Up to the present, there have appeared two practically satisfactory solutions of the problem. The first method consists in placing a Poulsen arc directly in the antenna, thereby exciting the antenna in its own period.

(1) Rein, Physikalische Zeitschrift, XI., 1910, page 591.

The second method depends on the principle of electrical impulse excitation, which was first theoretically predicted and experimentally demonstrated by Wien[2]. It is the electric analogue of the mechanical phenomena observed with coupled sympathetic pendula, providing one of them is uncoupled from the other at the moment that its amplitude of vibration passes through the value zero.

The following method for the production of radiation of single frequency depends on a type of impulse excitation, which, in contradistinction to that previously mentioned, may be characterized as "ideal" or "perfect." In this connection, the idea arises that the discharges between the electrodes may be considered as simple spark phenomena; but we shall see later that this assumption requires amplification.

Referring to Figure 1; if a source of direct current, E is connected to a condenser C_1, parallel to which is connected a discharge gap, under certain circumstances this system will function as a current transformer, which converts weak currents at high potentials into powerful currents at lower potentials. Such an effect will be produced only when the rate at which the condenser is charged is less than the rate of discharge. If this latter condition is fulfilled, a series of current impulses will be obtained in circuit II. The number of such impulses per second is determined by the time required for the voltage across the capacity, after a condenser discharge, to rise anew to the value required for a discharge across the gap; that is, to the sparking potential. In general, the number of discharges per second increases as the rates of charge and discharge approach equality.

The exact course of the discharge in the radio frequency circuit and the resulting effects are dependent on a number of factors, the influence of which will be given. They are:

(1) The shape, material, and temperature of the discharge, and the separation of the electrodes.

(2) The values of the capacity and inductance in the radio frequency circuit which is connected to the gap, and of any further radio frequency circuits which may be coupled to the former.

(3) The method of supplying energy to the gap.

(2) M. Wien, Physikalische Zeitschrift V., 1906, page 871.

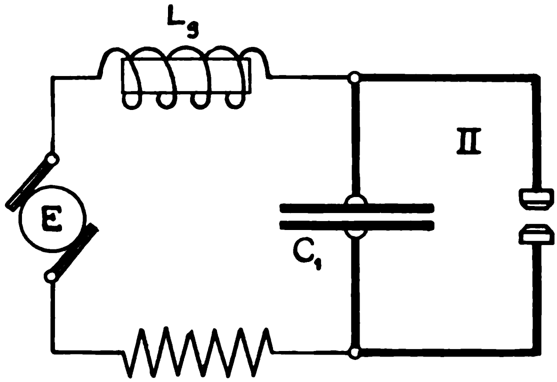


Fig. 1

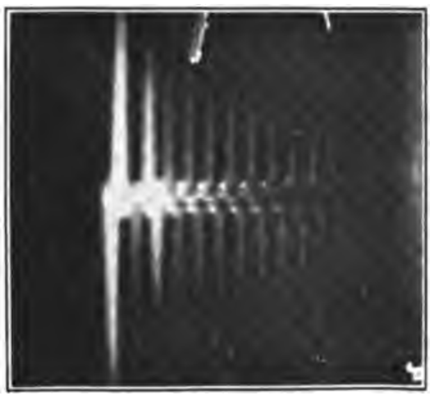


Figure 2

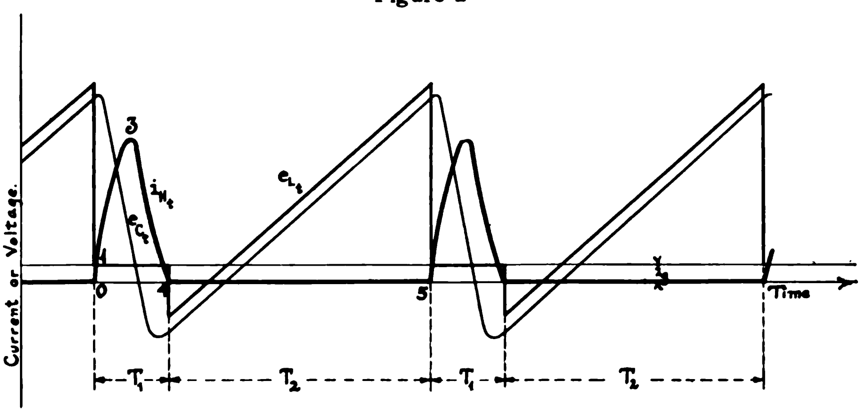


Fig. 3

(1) THE GAP DISCHARGER. The type of gap discharger used in the Multitone system was worked out by Scheller [3]. It consists of an approximately hemispherical piece which fits into a hollow hemisphere, the two parts being separated by a small distance, and the discharge taking place, as in the Poulsen arc, in an atmosphere of continually renewed vaporized alcohol. The peculiar properties of this gap depend on the fact that, when the discharge passes between two electrodes which are separated by a small distance (less than 1. mm.), ionisation (and consequent conductivity) of the gap very rapidly disappear. Wien was the first to make use of this property of short gap dischargers, in his method of impulse excitation involving the usual beat phenomena. The spark ceased at the moment when the entire energy of the primary circuit had been transmitted to the antenna. In the radiating system, a current having the natural period of that system will persist until all the stored electrical energy has been radiated or dissipated as heat. In this case, we are obviously dealing with a system wherein the source of direct or alternating current energy is, in effect, disconnected from the radio frequency circuits until the electrical disturbances in that circuit have entirely disappeared. Monasch [4] has employed the same gap discharger for the production of another phenomenon, namely the excitation of sustained alternating current in the radio frequency circuit. It is easy to see how the same means were employed by two independent workers for the production of particular types of electric currents.

To obtain the quenching action in the gap discharger reliably, some of a number of particular methods of construction of the gap must be used. Thus, the use of metal electrodes is to be recommended exclusively, because they readily conduct away the heat; and it is further possible (following the suggestion of H. Th. Simon) to cool them by flowing water. All methods of insuring a uniform distribution of the successive sparks over the sparking surface are especially advantageous, because in this case the spark always passes at a new and cool point. Lepel [5] obtains this wandering of the spark by sep-

(3) Scheller, German Patent, No. 237,714.

(4) Monasch, German Patent, No. 193,328.

(5) C. v. Lepel German Patent, No. 232,174.

arating the electrodes by a sheet of paper of proper thickness, the presence of the paper causing the spark slowly to travel out from the center, thereby gradually burning up the paper. In Brown's gap discharger , one of the electrodes is kept in rotation; a method which had previously been successfully employed by Tesla. Furthermore, a rapid de-ionisation of the gap can be caused by a stream of gas (due to Thomson), or by a deflecting magnet (Tesla). The reliability of operation of such gaps is increased by air-tightness, the exclusion of oxygen, the employment of an atmosphere of hydrogen, or the introduction of other gases or non-conducting liquids.

To summarise, we may say that it has been established that all these discharges have the common property that the spark passes within the "critical zone," and that by one or the other of the means mentioned the quenching action is increasd in certainty. It is of importance—and attention has already been called to this—that the same types of charge and discharge currents can be obtained in a given gap, and may give the discharge the character of a spark or an arc. The type of discharge is determined solely by the electrical constants of the circuits, the closeness of coupling, and the method of supplying energy to the discharger.

(2) THE EFFECT OF THE ELECTRICAL CONSTANTS. If it is desired to produce in circuit II. (Figure 1) a rapid succession of damped oscillatory discharges, as represented in Figure 2, the decrement of this circuit, (d_1) must have a suitable value. In any case the decrement is given by the equation:

$$d_1 = \frac{1}{150} \cdot \frac{C_1 \ R}{\lambda_1}$$

where C_1 is expressed in cm., R in ohms and λ_1 in meters. At constant wave length λ_1, and approximately constant resistance R, the damping increases directly with the capacity C_1. The available energy per second is given by

$$W = N \cdot \frac{e_z^2 \ C_1}{2}$$

where N is the spark frequency, and e_z the sparking potential.*

(6) Brown, The Electrician. Vol. 58. 1906, page 201.

*The notation is that recommended by the Committee on Standardization of The Institute of Radio Engineers.

The value of N increases as

(a) the generator voltage E is increased, provided the sparking potential and primary capacity are kept constant,

(b) the sparking potential e_z is diminished, keeping the generator voltage and impulse circuit capacity C_1 constant,

(c) the capacity C_1 is diminished, keeping e_z and E constant.

(d) The choke-coil L_g (Figure 1) has a marked influence on the spark frequency, because it partly determines the time of charging. If this inductance possesses a sufficiently large value, the energy stored in it, namely, $\frac{L_g\ i_g^2}{2}$, is sufficient to charge the capacity nearly fully. In that case, after the sudden quenching of the spark, the next charging of the capacity to any desired voltage takes place in an extremely short time. Hereby the character of the discharge in circuit II is completely altered, particularly if the capacity C^1 has been much increased at the expense of the inductance L_1, thereby causing an increase in the decrement, d_1. The current and voltage curves then take forms which have also been observed with the Poulsen arc, when it is producing oscillations of the second class (this being the case in which the amplitude of the alternating current is greater than that of the direct current). Such curves are shown in Figure 3, where i_g is the direct current, i_{Hg} the arc current, e_{C_t} the voltage across the capacity C_1, and e_{I_t} the voltage across the arc.

It will be seen that current through the gap discharger starts at the point O, then rises to the point 1 during which rise the current is entirely supplied by the direct current i_g. Thereafter the current produced by the discharge of the capacity C_1 is added to it. The arc current attains its highest value at the point 3, after which it steadily decreases, until, after reaching the point 4, for a short time no current passes between the electrodes. Under proper circumstances, this short time suffices properly to distribute the electrical energy for the next discharge. The direct current i_g, which has maintained a constant value, charges the condenser until its plates reach a difference of potential equal to the sparking potential, this corresponding to point 5.

The system operates in this fashion only when a marked quenching power is inherent in the gap used, and when the damping of the impulse circuit is of proper magnitude. Otherwise, after the point of zero current is reached, the voltage across the gap discharger will produce a discharge in the reverse direction.

There will therefore be in the primary circuit a regular succession of current impulses, which, through the intervention of a transformer, charge the antenna capacity. After the electrical disturbances in circuit II cease, the energy in the antenna is gradually converted into heat and electromagnetic radiation. The wave length of the radiated energy is naturally solely determined by the electrical constants of the radiating system in this case.

In order to obtain a clear idea of the voltage and current relations, and the interaction of the impulse and antenna circuits, the current curves were made by the use of a sliding plate oscillograph. By an appropriate increase in both capacity and inductance (keeping their ratio constant, however), the frequency of each of the circuits was so diminished that the oscillograph reproduced the curves faultlessly.

The conclusions drawn from the curves obtained are as follows: Considering the current through the spark gap (Figure 4), or in the primary circuit (Figure 5), it is seen that there are rapid series of current impulses. Each of these produces in the closely coupled antenna a train of waning waves (Figure 6). It is worthy of note in connection with this process (perfect impulse excitation), that the impulse circuit and the antenna need not be tuned to each other. Proof of this is furnished by Figure 6, which shows the current curves for two antennae, both of which were coupled to the same impulse circuit and excited thereby. However, in order to obtain an efficient energy transfer, it is not desirable to tune the two radio frequency circuits to very widely different frequencies. If a receiving arrangement employing a contact detector and telephone is used, the signals will not be heard because the number of wave trains per second is of the order of magnitude of 10,000 or 20,000.

A comparison of the arrangement described with those employed in some of the systems in common use establishes the following facts. When an oscillator and a resonator are

Figure 4

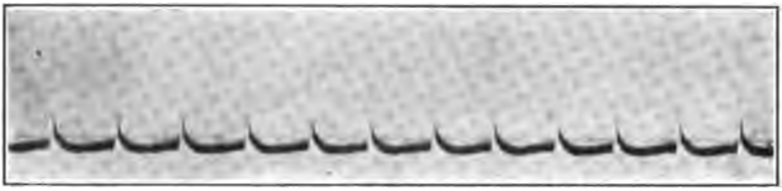


Figure 5

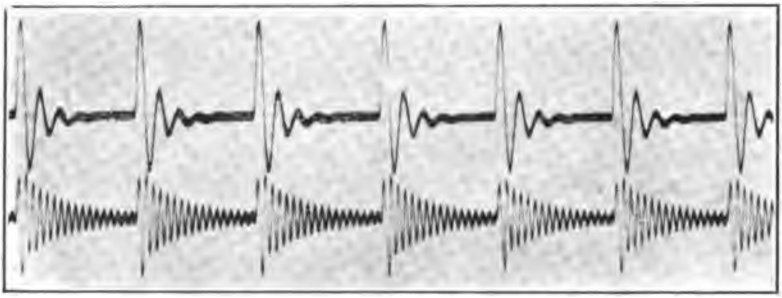


Figure 6

coupled in the usual way, there appear in each of these circuits two waves, which lie respectively above and below the free wave of each system. When Wien's method of impulse excitation is used, and the circuits are not sharply tuned, there appear three waves, and with proper tuning one wave. For the case of ideal impulse excitation, as described, the antenna vibrates *in all cases* with one wave, namely, that of its natural frequency.

An examination of the results obtained so far, shows that the process of ideal impulse excitation resembles the process of the production of oscillations of the second type with the Poulsen arc. Such currents are characterized by a very large ratio of the time during which no current flows through the gap discharger to the time during which the capacity is discharging itself across that gap. It is because of this that the necessity for sharp tuning of the primary circuit to the antenna is removed, and that in spite of very close coupling only vibrations of a single frequency are produced in the antenna.

B. THE MODULATION OF THE RADIO FREQUENCY ENERGY TO A CHOSEN WAVE FORM.

In order to appreciate the peculiar method of operation of the arrangement for the production of the note, an historical development of the method will be of advantage. The discovery of the Poulsen arc provided a system which furnished greater possibility of sharp tuning than any previous method. It seemed capable of improvement only in that a musical tone in the receiving set was missing. Because of this, some time ago Poulsen himself described means for radiating the energy in the form of rhythmical pulses, that is, at a definite pitch [7]. All of his methods involved periodically varying the antenna current by means of interrupters, or rotating condensers or variometers. Inasmuch as no arrangement satisfactory for practical purposes was thus achieved, the C. Lorenz Company of Berlin carried out a successful research intended to attain this end by other means.[8] One of the methods used was intended to impress a periodic variation of amplitude on the

(7) V. Poulsen German Patent, No. 207,159.

(8) H. Rein, Der Radiotelegraphische Gleichstromtonsender, Langensalza, 1912.

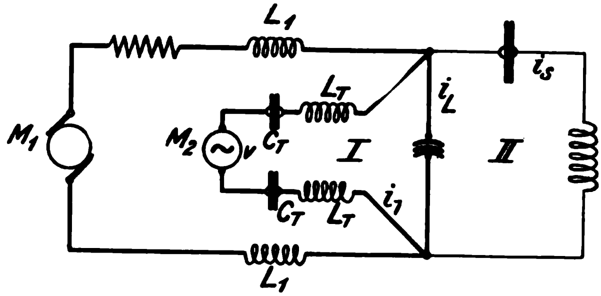


Fig. 7

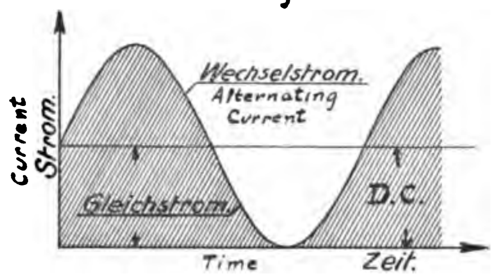


Fig. 8

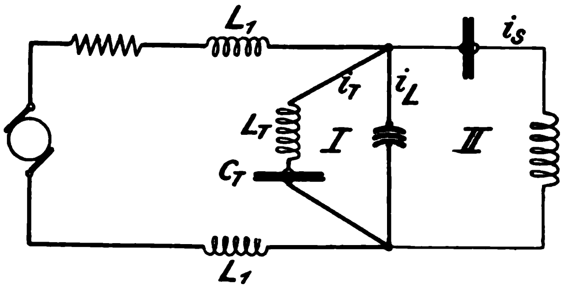


Fig. 9

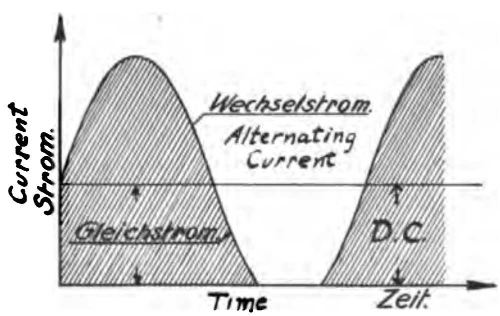


Fig. 10

energy obtained from a Poulsen arc by connecting it not only to the direct current generator M_1 (Figure 7), but also to an alternator M_2 of about 500 cycles. Figure 8 shows how, because of the effect of the pulsating direct current (represented by the cross-sectioned areas), the amplitude curve of the radio frequency current is similarly periodic.[9]

The choke coils L_1 prevent the current from the alternator passing through the direct current generator, while the "blocking" condensers C_T prevent the direct current from passing through the alternator. It is found with this arrangement that a reliable operation of the apparatus is obtained only when the frequency of n of the generator M^2 is the same as that of the free or resonant vibration of the circuit I that is, when the effective capacity and inductance combine to a zero reactance at that frequency. It will be noted that the direct current generator will then supply the actual energy, whereas the alternator will control the tone. Advancing a step beyond this arrangement, it is seen that the assumption is valid that nothing will be altered by the omission of the alternator M_2, and connecting together the wires from the condensers C_T formerly leading to the alternator.[10] Experiment verifies this conclusion, as will be seen below. Simple as this arrangement seems, if a Poulsen generator be used as the gap discharger, it is found not to be sufficiently certain in operation. The reason for this, as shown in Figure 10, is that after each alternating current impulse, in consequence of powerful deionisation, the arc is extinguished; and if the period of zero current flow is increased too much the discharge cannot start again unless the electrodes are approached to each other. Therefore the Poulsen arc could not be used, and a new type of discharger had to be devised which permitted the discharge to pass readily at the voltages available with consequent production of radio frequency currents. This discharger, which was designed from this new point of view, has already been described.

In order to give the radio frequency energy the periodicity of a musical tone; in accordance with the researches of Thomson and Duddell with singing arcs, another circuit I (Figure

(9) C. Lorenz Company, German Patent, No. 229,219.

(10) C. Lorenz Company, German Patent, No. 249,400. E. Nesper, Helios, Number 21, 1911.

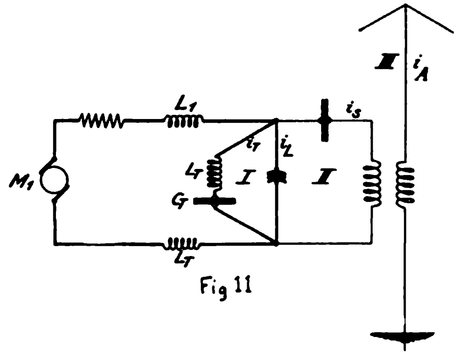


Fig 11

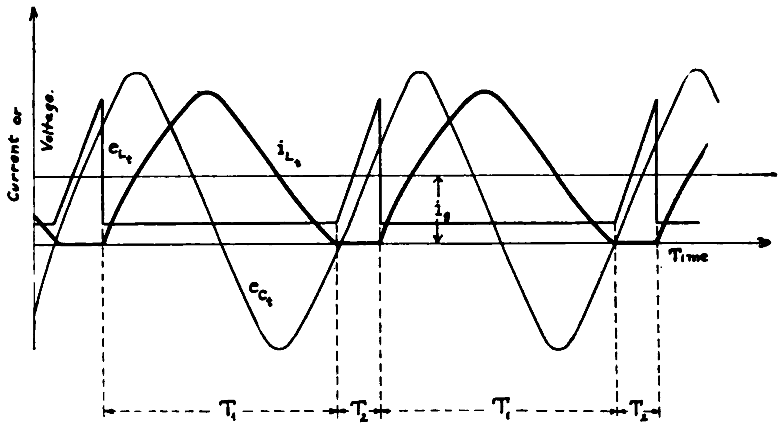


Fig. 12

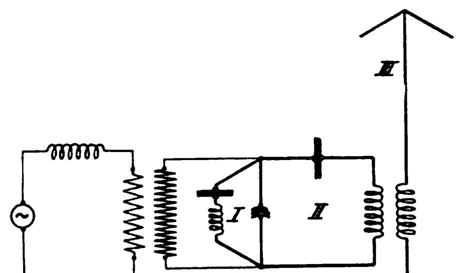


Fig. 17.

11) was placed parallel to the arc. The inductance and capacity of this circuit were so chosen that the natural frequency of the circuit falls within the range of audible musical notes. The effects observed in this circuit are practically the same as those observed in the impulse circuit II. In this case also the theory of the arc gives correct laws governing the forms of the current and voltage curves. These are shown in Figure 12, wherein i is the direct current, i_{L_t} the arc current, e_{C_t} the voltage across the capacity, and e_{L_t} the voltage across the arc. Just as in the impulse circuit II, current impulses of constant amplitude are present in the tone circuit I. The phenomena in the two circuits differ only in so far as the difference of the ratio of capacity to inductance in the two circuits may affect them. To produce large amounts of energy in the radio frequency circuit II the capacity in it must be increased at the expense of the inductance. The process is limited by the necessity of having sufficient inductance to couple closely to the antenna circuit. High damping of the individual current pulses together with properly chosen pauses between them prevent resonance phenomena in the system, and this is requsite for single frequency radiation. In spite of the large currents which then flow, the gap is not injured, because the pauses between the individual impulses are sufficiently long to permit complete de-ionisation.

The relations in the tone circuit are quite different. Here oscillations capable of giving marked resonance effects are desired; and the period of zero current thru the discharger is to be as short as possible. And the energy supplied should be only sufficient to furnish a reliable control of the discharges across the gap. These requirements lead to a small damping of the tone circuit, and a large inductance together with a small capacity. The eventual limitation of the process arises from the engineering necessity of preventing fusion of the slightly separated electrodes, and this becomes increasingly difficult as the current is increased.

The accompanying oscillograms (Figures 13 and 14) show how the impulse circuit and the tone circuit operate in conjunction. These oscillograms were made under the same conditions as those already shown. Figure 14 shows the influence of the two circuits connected across the gap on each other, and Figure 15 pictures the processes taking place in the antenna.

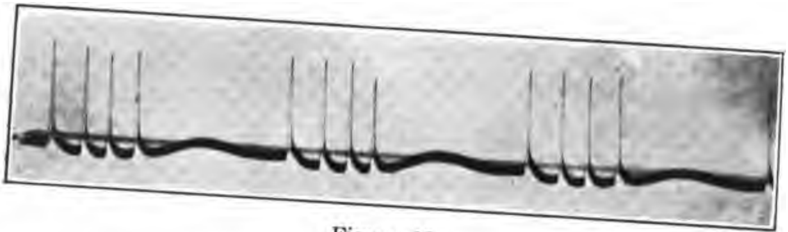


Figure 13

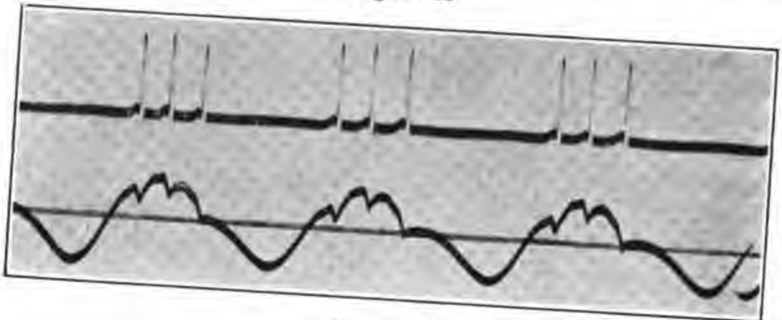


Figure 14

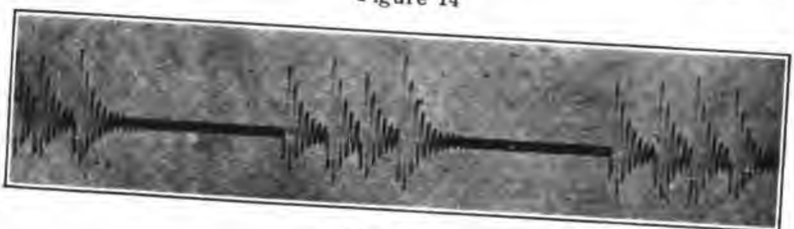


Figure 15

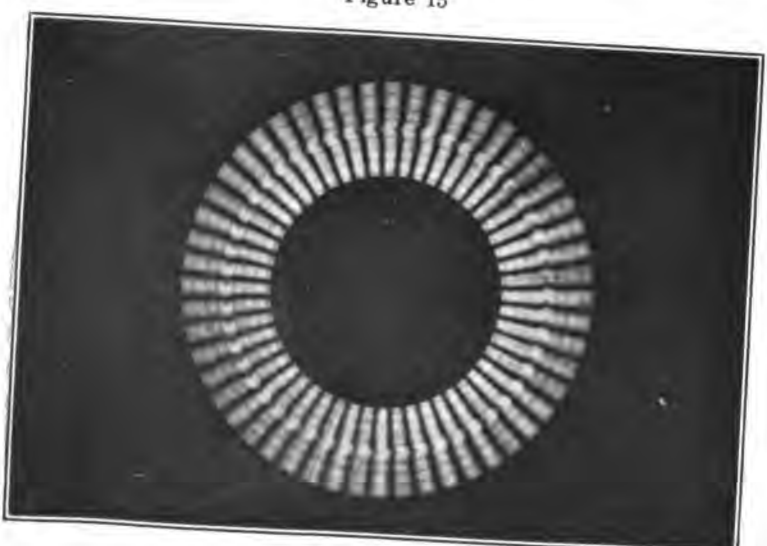


Figure 16

The trains of waves emitted from the antenna will then be heard in the receiving telephone as a musical note. If a rotating helium tube be connected in a circuit which is coupled to the antenna, so soon as the tone circuit is closed the helium tube appears as a star of light, each ray corresponding to a single wave train (or partial discharge).

It has been tactily assumed that a direct current machine was the source of energy for this type of transmitter. Since the available radio frequency energy depends on the capacity in the impulse circuit, the sparking potential, and the number of impulses per second, it can be increased only by increasing one of these factors. If one considers that the spark frequency is limited by the type of gap which is used, and that the capacity in the impulse circuit must have a value appropriate to the wave length employed, it will be seen that increase in radiated energy can be attained only by an increase in sparking potential. Therefore, for stations of large range, the source of energy is a low frequency alternator (15 to 50 cycle), and the voltage is raised as far as may be desired by the use of a transformer (Figure 17).[11]

The effects obtained differ only slightly from those with direct current, and the more nearly the alternating current wave form is rectangular in form, the less the difference. If the curve is more peaked, in consequence of the slow alternations, the tone in the receiving station will resemble that of a trilling or throbbing flute.

In conclusion, the question may be asked: What marked advantages has this system of transmission? One answer to this question is that a single wave is radiated from the antenna, and that by a mere alteration of the capacity or inductance in the antenna the frequency can be altered without further necessity for tuning. Furthermore, the method permits of thoro utilization of acoustic resonance. With an ever-increasing number of radio telegraphic stations, the problem of the avoidance of interference becomes increasingly difficult to solve. Altho skilled operators can accomplish much with proper apparatus at the present time in tuning and reading thru interference, still acoustic resonance effects are an aid not to be neglected. For, by the use of the mono-

(11) H. Rein, Radiotelegraphisches Praktikum, 2nd Edition, Springer, 1912, page 200.

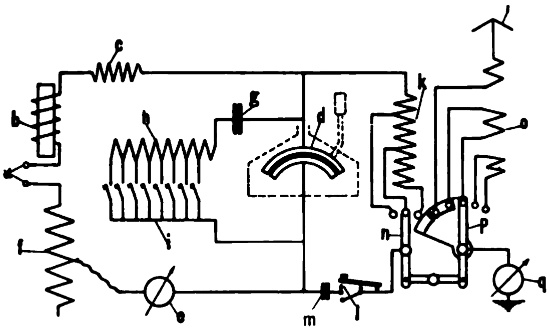


Figure 1

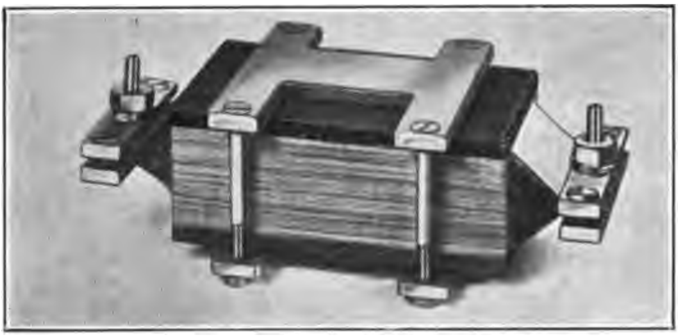


Figure 2

Figure 3

Figure 4

telephone or any other tuned receiver, reception can be restricted to musical notes of a definite pitch. If the inductances or capacities of the tone circuit are arranged so as to be controlled by keys similar to those of a piano keyboard, bugle calls can be readily transmitted, and methods of code transmission unintelligible to interlopers can be readily devised.

(Translated from the German by the Editor.)

ADDENDUM.

Thru the courtesy of the C. Lorenz Company and Dr. Rein, the Editor is enabled to place before the readers of the Proceedings some further information on the practical details of the Multitone System and some illustrations of the apparatus employed.

The principles underlying the Multitone apparatus having been adequately treated in Dr. Rein's paper, we shall restrict ourselves to practical considerations in connection therewith. In Figure 1 are shown the connections of the transmitter set. Here *d* is the connection to the source of high voltage direct or low audio frequency alternating current, *b* a reactance, *c* a fixed resistance, *f* a variable resistance, *e* an ammeter. Passing to the tone circuit, *d* is the Scheller gap discharger, *g* the mica dielectric tone circuit condenser, and *h* a reactance variable in steps. The tone is controlled by depressing one of the keys *i*. In the impulse circuit, *k* is a stepwise-variable inductance, *l* a special key, and *m* a high tension condenser. The antenna *r*, its loading inductance *o*, the hot-wire "radiation ammeter" *q*, and the ground connection are shown to the right. The switch *n*, *p* is so arranged that primary and secondary circuits can be tuned simultaneously by a single adjustment.

Passing to the elements used in making up these circuits, Figure 2 shows the type of condenser which is used in the tone circuits. It consists of sheets of mica as a dielectric between thin sheets of metal, the whole mass being tightly compressed. Such condensers may be mounted in oil when it is desired to use them with still higher voltages; and Figure 3 shows such a condenser taken out of its case. The pro-

Figure 5

Figure 6

Figure 7

Figure 8

tective gaps above the case, and the peculiar form of leading-in insulator are also shown. In Figure 4, a number of such sections are seen mounted in their case. By means of movable plug connections, any number of sections can be connected in circuits, and thus the tone may be readily varied. The copper condenser box shown in this figure is about 55 cm. long, 40 cm. wide, and 45 cm. long. It contains no less than 40 condenser sections, each of 0.11 μf., and the necessary connections. As regards space efficiency, it is greatly superior to Leyden jars.

A reactance, or "choke coil" for supply circuits is illustrated in Figure 5. It is of the multiple layer spiral type. The containing case of a step-wise variable inductance for the tone circuit is pictured in Figure 6. Above it is the under side of the tone key-board with the section contacts, and the taps running from these contacts to the sections of the inductance.

Figures 7 and 8 show two types of inductances used in the radio frequency circuits. In the type pictured in Figure 7, the spiral coil sections are woven on a series of radial supporting rods fastened to an insulating central piece. Taps are brought from the ends of each coil to a series of jacks on the top of the case, and the whole set of coils mounted in glass case under oil. This type is intended for use with high tensions. The inductance of Figure 8 is continuously variable. It consists essentially of two flat rectangular coils connected in series, each of the coils being then bent on the surface of a cylinder, and one of these coaxial cylinders being rotatable within the other. It is also under oil and intended for use on high tension. Multiply stranded wire ("litzendraht") is used on the inductances.

The construction of the tone-circuit key-board for the larger sets is shown in Figure 9. The white piano keys are intended for use when it is desired rapidly to change the note, whereas the black buttons on the top serve to lock the corresponding piano key in place, permitting sending on a fixed note using the regular transmitting key.

A series of insulators intended especially for radio frequency circuits are shown in Figures 10 and 11. Those of Figure 10 are of the so-called "egg" type, and those of Figure 11 are leading-in insulators. The engineering requirements of

Figure 9

Figure 10

Figure 12

Figure 11

insulation for radio frequency high voltages, namely, long leakage paths over the insulator, and small capacity between the insulated conductors, are well met.

In Figures 12 and 13 are shown the exterior and interior of the simplest form of unit gap discharger. The alcohol feed cup is shown at the top. Below it is the adjusting ring for gap length. The clamps for holding the two halves of the gap together on the large insulating ring, and the porcelain insulating feet are also visible. In Figure 14, the double gap is shown. It differs from the first only in that it consists of two separately adjustable sections, arranged so that the discharge can be readily started. It is used for slightly higher powers than the first form. When it is desired to use higher powers still, alternating current dischargers are employed. These are built with a number of sections in series, as shown in Figure 15, and are arranged for air cooling. A water-cooled double discharger for use with alternating currents and high powers is shown in Figure 16.

It is interesting to note that the ratios of the values of inductance to capacity in the tone circuit and in the radio frequency circuit are widely different. Their actual values (with inductance expressed in microhenrys and capacity in microfarads) are respectively approximately $6(10)^5$ and 12.

The connections of the receiving set are shown in Figure 17. Here *r* is the antenna, *s* a receiver variometer, and *t* a series tuning condenser. The coupling to the antenna circuit is through the coil *u*. The crystal rectifier *v* is shown in Figure 18. It will be seen that it is easily adjusted. Parallel to the telephone receiver may be connected the three condensrs *w*. Each section has a different value. For receiving long waves the halves of the variometer may be connected in series as shown in the left-hand diagram of the Figure 17.

The appearance of the receiving sets is shown in Figures 19 and 20. The first of these is the receiver which is used for small stations. The left-hand handle in the front of the case controls a variable condenser, and simultaneously, through the front gears, controls the tuning variometer and the coupling to the detector circuit. By simply turning the handle, and operating a single switch on the case, it is possible to tune continuously from 200 to 2,000 meters wave length. The type of receiving set used in larger stations is shown in Figure 20.

Figure 13

Figure 14

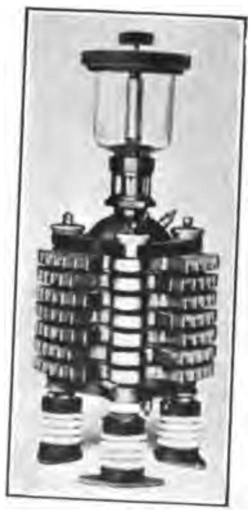


Figure 15

Figure 16

At the top is seen the inductive coupler, the primary of which is controlled in position by means of a special linkage mechanism. The secondary is connected to the main switch. The variable condenser is shown at the left of the base, to the right of which are placed the detector clamps and some small dry batteries for operating a test buzzer.

Passing now to completely assembled sets, the smallest of these is the aero type shown in Figure 21. To the left are prominently seen the tone circuit condenser and the direct current ammeter, in the center the discharger, and to the right the hot wire "radiation ammeter," the antenna coupler, and the control switch, or key. The apparatus is of very small dimensions (the greatest dimension being less than 52 cm. (20"), and the entire weight less than 100 pounds (45 kg.). Another small set, mounted somewhat differently, is shown in Figure 22. The arrangement of parts is quite similar to that previously shown. The Multitone apparatus is very well adapted for military uses. The power plant of a transportable set mounted on a wagon is shown in Figure 23. A water-cooled two-cylinder gas engine is direct-connected to the generator. In Figure 24 can be seen the remainder of the apparatus. The transmitter is arranged to radiate waves between 550 and 2,000 meters. The key-board, which permits choosing rapidly any note between about 500 and 1,200 cycles, is seen in the middle of the figure. The general appearance of an automobile station is given by Figure 25. The antenna used with these sets is of the umbrella type. Special reels are provided for the wire when not in use. A sectional mast which can be rapidly erected to a height of 18 to 25 meters, and which rests on an insulated ground plate, is a portion of the equipment.

Passing to the sets intended for use over longer distances, Figure 26 shows the large direct current set for ranges up to 150 miles (250 km.). It will be noted that the two-section gap is used. The ship sets are arranged in a particularly convenient fashion, the entire set being an integral portion of the operator's desk. Figure 27 illustrates a ship set intended for ranges of 500 to 600 miles (800 to 1,000 km.). The coupling and wave length of the transmitter are controlled by the two handles shown at the left. In the center is the keyboard and the air-cooled discharger. To the right is the receiving set, behind which the key relay is placed. When a fairly large station is needed, the type of construction shown in Figure 28 is employed. The tone circuit condensers, the two dischargers, the coupler, and the tuning variometer are all visible. All of these larger sets are fed with a low frequency alternating current (e.g. 30 cycle).

DISCUSSION.

DR. J. ERSKINE-MURRAY (by letter): In giving the theory of shock excitation, Dr. Rein has hardly laid sufficient stress on the importance of the form and dimensions of the gap itself. Considerable damping of the primary circuit due to large capacity and close coupling is, of course, useful, but the most important factors are the shape and size of the gaseous section, i.e., of the gap itself. With the usual (capacity)/(inductance) ratio of an ordinary spark set, there is no difficulty in obtaining shock excitation if the gap is short enough and the power small; as Wien indeed found. It is when larger powers, such as are necessary in radio telegraphy, are required that Wien's arrangement is no longer sufficient, and that the form of gap used by Lepel, or something equivalent, becomes essential.

With such a gap, the fact appears to be that the expansion of the gas in the discharge is hindered by its viscosity and constrained by the smallness of the space between the parallel surfaces of the electrodes. The pressure in the hot gas surrounding the spark therefore rises, and remains high for an appreciable time as the pressure wave is not able to escape. The resistance of the gap therefore rises rapidly and checks the passage of further current, i.e., damps the primary current.

Dr. Rein's suggestion that tuning is hardly necessary between primary and secondary is only partially in accordance with the results of other experimenters; Galletti, for instance, has found that the advantage of tuning, even when the primary current impulse is only a single half wave, is by no means negligible. From theory, one would certainly expect that the wave form of the primary current would have some influence on the secondary current induced by it.

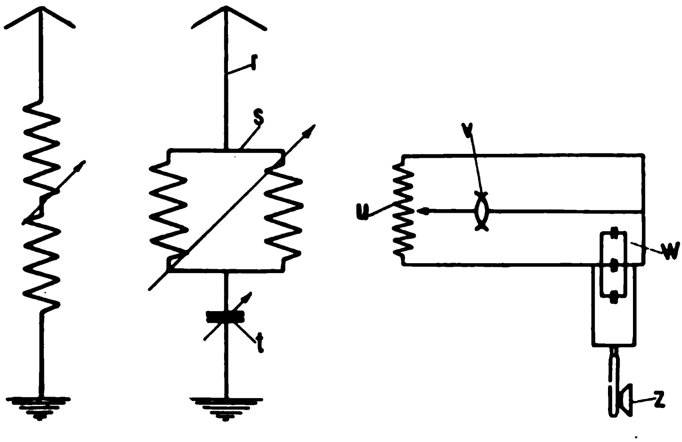


Diagram of the Receiver.
Figure 17

Figure 18

Figure 19

Figure 20

Figure 21

Figure 22

Figure 23

Figure 24

Figure 25

Figure 26

Figure 27

Figure 28

The appearance of three waves in the secondary is not in reality a matter of tuning, as Dr. Rein seems to suggest. Even with exact tuning they appear if the damping of the primary (from all causes, including coupling) is insufficient. The two side humps in the resonance curve represent, in fact, the conditions during the earlier part of the whole phenomenon, namely, the time before the primary is extinguished during which the action is that of an ordinary spark circuit with two waves due to close coupling. When the primary current dies out, the secondary continues to oscillate at its own natural frequency and gives the central peak, or third wave. The condition determining the appearance of three waves is therefore too small a damping in the primary.

The use of various musical tones, which Dr. Rein recommends, is obviously advantageous. I may mention that in the winter of 1909-10 I suggested the use of musical signals, such as bugle calls, when testing the shock excitation system designed by von Lepel and Dr. Burstyn, in which auxiliary circuits having acoustical frequencies were used to control the primary discharge so as to produce musical signals of various pitch.

London, September 11th, 1913.

ALFRED N. GOLDSMITH: There can be, as Dr. Erskine-Murray says, no doubt but that the shape and duration of the primary wave, even in the case of Dr. Rein's "ideal impulse excitation" with a half wave, do exert a marked influence on the secondary energy; or that the maximum secondary energy is uniquely determined by tuning to one or more wave lengths under such conditions. The experience of the Telefunken Company is given in The London Electrician for November 10th, 1911, page 172. It may be objected that "ideal" quenching was not obtained in this case. This objection does not apply to the observations given by Chaffee in the Proceedings of the American Academy of Arts and Sciences, November, 1911, page 267, and also in the Journal of the Franklin Institute, May, 1912, page 437. Chaffee worked with a copper-aluminum "quenched arc" gap in an atmosphere of moist hydrogen, and fed with (constant) direct current. By means of curves drawn from photographs made with a Braun oscillograph, it was conclusively shown that the primary current consisted simply of discrete loops. We have, therefore, the conditions of "ideal" impulse excitation. By varying the inductance in the primary or impulse circuit, the duration (and shape) of the current loop was changed, without, however, altering the number of complete secondary oscillations occuring between successive primary discharges. Under these conditions, the secondary current was measured as the primary inductance was altered. I quote from the latter of the articles mentioned above: "In this case the hot-wire ammeter reading was taken in the secondary circuit as an inductance, in series with the primary of the oscillation transformer was varied. . . . A variation of this inductance changes the natural period of the primary circuit, thus affecting the time of duration of the primary impulses without materially changing their frequency. . . . The curve of secondary current shows the marked maximum when, the inverse charge frequency (i.e., the number of complete secondary oscillations between successive primary discharges) remaining constant, the primary discharge loop has the best duration compared to the period of the secondary oscillation. . . . Several measurements were taken of the natural period of the primary circuit when adjusted to give maximum secondary current, for different secondary wave lengths, and it was found that this natural primary period divided by the corresponding secondary period was, in every case, within one or two per cent. of the quantity 1.71."

It may be of interest to present a sample set of observations made by Dr. Rein on the operation of one of the Scheller gaps, these observations being taken from his book, "Der radiotelegraphische Gleichstrom-Tonsender," page 38.

The capacity in the primary impulse circuit was $C_1 = 0.111\ \lambda$f., inductance in the same circuit $= L_1 = 1.915$ μh., resistance in that circuit $= W_1' = 0.45$ ohm, primary wave length $= \lambda_1 = 866$ meters, supply voltage $= 435$ volts.

In the following table W_g is the resistance in the supply circuit in ohms, L_g the inductance of the supply circuit choke coil in henrys, A the energy supplied by the generator in watts, $i_g^2 W_g$ the energy loss in the supply circuit resistance, A_H the energy in the primary impulse circuit, A_n the equivalent energy in the antenna or secondary circuit, EFF_f the efficiency of the gap discharger, EFF the over-all efficiency.

V	L_g	A	$i_g^2 W_g$	A_H	A_n	EFF_f	EFF
230	1.354	368	166	202	100	49.5	27.2
230	0.796	369	166	203	100	49.2	27.1
230	0.294	355.5	154.5	201	98.6	49.0	27.7
230	0.0693	347	147	200	94.6	47.3	27.3

EMIL J. SIMON: The only practical systems of radio communication using direct current at the present time, to my knowledge, are those of Lepel, Lorenz, and Poulsen. In 1907 or 1908, Dr. Seibt, then chief engineer of the Poulsen Company, in Germany, began to work on this type of apparatus. At that time the German Poulsen Company was affiliated with the Lorenz Company.

I cannot find that the Duddel tone circuit was used around the direct current arc or spark dischargers prior to 1909, by which time the Amalgamated Radio Company (Poulsen system) had failed and was therefore no longer associated with the Lorenz Company. After that time, therefore, the work of Dr. Seibt was independent of that of the Lorenz Company. It must be admitted that the arrangement used by Lepel in his sets is quite similar to those of the Multitone sets. The Lepel arc discharger, which consists of two plane sheets of water-cooled copper separated by a thin layer of paper which is gradually burnt up by the discharge, is known to be effective in practice; and stations of this type have been used for several years. One of them in Jamaica has been working since 1909. I believe that the Lepel discharger has a sufficiently high inherent damping to make tuning between the antenna and impulse circuits unnecessary.

In Dr. de Forest's laboratory, during the winter of 1908-1909, a number of experiments were carried on with a water-cooled copper-brass arc discharger, the arc taking place in an atmosphere of water vapor. The supply current was at a tension of 220 to 500 volts. In the spring of 1909, Duddell circuits were in use across this arc, and high notes were produced at the receiving station. Mr. Pickerell, then operator at the Waldorf, repeatedly heard these tones. In the summer of 1909, a larger discharger was built. Two wheels, 15″ and 24″ in diameter respectively rotated, and the arc took place between their nearest points and in water vapor. This 5 kilowatt transmitter enabled transmission to Philadelphia and Albany, using a tone circuit arranged to give a note of to 1,000 cycle pitch. The voltage, which was always less than 1,000, was obtained from two 500 volt machines in series. In all cases, tuning between the closed circuit and the antenna circuit *was* required, because the damping of the arc was not sufficient to produce aperiodicity. In the summer of 1909, the Seibt quenched spark gap was substituted for the arc. It was found that at least 500 volts was required to break down the gap and start the discharge. Only one gap could with advantage be used therefore, and the energy obtained was less than 0.5 kilowatt. At the Metropolitan Tower station, where 1,000 volts was available, two gaps were used in series. These gaps were of metal, diameter 5 to 8 cm., and separation of sparking surfaces less than 0.01″ (0.25 mm.). The gaps were water-cooled. Under these conditions, as much as 2 kilowatts output was obtained. The tone circuit was also used. It must be remembered that these arrangements were entirely experimental, because for larger energies, higher supply voltages than 1,000 were necessary, and such voltages were not at our disposal. Furthermore the apparatus was difficult to construct satisfactorily and not easy to operate. This work was therefore discontinued.

As regards Figure 17 of Dr. Rein's paper, I cannot believe that the arrangement is operative if circuits II and III are not syntonised. The quenched gaps used in 1909 under similar conditions always required such tuning. I should be interested to know to what extent the arrangement of Figure 17 has ever been used commercially.

ALFRED N. GOLDSMITH: Speaking on behalf of Dr. Rein, I may state that the patents of Lepel and Scheller in Germany are numbered 232,174 and 237,714 respectively. and, inasmuch as they cover gap dischargers intended to secure "ideal" impulse excitation, it is evident that the experimental work of these investigators must have been nearly contemporaneous. As regards the tuning of circuits II and III the highest efficiency (as measured by ratio of antenna power to power supplied by the direct current generator) is undoubtedly obtained when circuits II and III are tuned, yet even when they are not tuned there is considerable transfer of energy and the tone remains *pure.* This shows that the damping of the gap discharger is sufficient to secure perfect quenching without the influence of the reaction of the antenna circuit on the impulse circuit.

It has been mentioned in the paper that instead of using direct current to supply the gap, for higher powers particularly, low frequency alternating current (say at 15 cycles) may be advantageously used because of the ease of raising it to the high voltage necessary when several gaps are placed in series.

It has been questioned whether a pure tone can be obtained under such circumstances. If the wave form of the alternating current supplied is very flat-topped, the effect will be practically identical with that secured with direct current. Such flat top waves can be secured either by appropriate design of the alternator or by the use of a transformer, the iron of which is being worked near saturation. But even if a sinusoidal alternating current supply is used, the note obtained will be the result of superposing say a 15 cycle note and a 500 cycle note; that is, a throbbing or pulsing note which is in no wise objectionable or less easy to read than the pure and smooth tone.

ROBERT H. MARRIOTT: There can be no question as to the usefulness of these sets on low powers. Whether, in view of their lower efficiency, they can compete with the quenched spark gap sets is a matter for further consideration. The obtaining of a 500-volt direct current, and the danger of working with it, must be considered. It is interesting to note that in the case of "ideal" impulse excitation, where the primary and secondary circuits need not be sytonised, various patents covering such tuning are avoided. I am sure that we feel very grateful to Dr. Rein and the Lorenz Company for this paper, which has been highly interesting and instructive.

EMIL J. SIMON: In my opinion, sets supplied with low tension direct current are most useful in low powers. This is not necessarily the case for high tension direct current. Some time ago, the idea occurred to me that a special form of storage battery might be used to supply high tension direct current. Such a battery could be arranged in a number of sections to be charged in parallel and dischargers in series. A set of this type would meet the law governing ship installations inasmuch as it operates independently of the ship's source of power.

Objections may be raised to the high cost of such a battery, which for a moderate sized set may reach say $1,500. Against this must be set the saving resulting from the elimination of the motor-generator, transformer, and high tension condensers. The efficiency of such storage battery would probably be higher than that of a motor-generator set, and therefore the capacity of the battery need not be as large as might be expected from the power required to run the motor-generator. That this is the case is easily seen when it is considered that motor-generator efficiency may well be 50% and transformer efficiency 80%.

ROBERT H. MARRIOTT: Relative to Mr. Simon's proposal to use high tension storage batteries, I am convinced that the cost of such batteries would be excessive, and that their maintenance would be a very serious item.

EMIL J. SIMON: Such batteries can readily be secured with a two years' guarantee. Actual quotations on such batteries show the cost to be not excessive compared with that of the usual quenched spark equipment.

ROY A. WEAGANT: The Multitone system has one very interesting aspect, namely, the production of a uni-frequent radiation without the necessity of sharp tuning of antenna and impulse circuits. The variability of tone using a generator of commercial frequency is also of importance. These advantages are probably offset by the greater number of pieces of accessory apparatus, and the probably lower efficiency. So that the commercial advantages of the system are not sufficient to render it advisable to displace quenched spark apparatus in its favor.

As regards the damping which a properly constructed gap may introduce in a circuit, it is to be noted that under certain conditions an ordinary quenched spark gap will permit detuning without loss of energy in the secondary circuit. Of course, the range thru which this effect is present is limited. The more plates there are placed in series for a given voltage, the greater the degree of detuning permissible.

However, such gaps are not practicable because of the danger of short circuiting of sections in which the separation is so small.

ROBERT H. MARRIOTT: The Multitone system has certainly one marked advantage, namely that dots and dashes can be sent on different notes, and that a certain degree of secrecy and selectivity can be thus secured.

ALFRED N. GOLDSMITH: The use of a two note system of transmission, one note representing dots and the other dashes was proposed and operated by a Pennsylvanian inventor, Murgas, as early as 1905. It is not generally known that messages of this sort were sent between Scranton and Wilkesbarre at the end of 1905. Indeed, it is rather surprising that the system, which seems to have been considerably in advance of its time in a number of respects, should have fallen into oblivion. Among the advantages claimed for it were secrecy and speed, the latter in view of the elimination of all dashes.

H. E. HALLBORG: In the Clifden station of the Marconi Company, we have an instance of the use of a high tension storage battery acting as a direct current supply source for gap dischargers. In this station there are 8,000 cells in series, connected by an elaborate series of disconnecting switches. They are charged by four 5,000 volt generators in series, and the batteries are kept floating on the line. It is found that there is too much commutator sparking in the generators if the storage batteries are not used.

It is also found that, by a proper adjustment of the disc discharger, a single wave is radiated. The tone is determined by the rate of rotation of the disc. One of the most ingenious parts of the entire equipment is the automatic battery disconnector.

I find one very interesting point in Dr. Rein's paper, and that is the continual trend away from direct current and toward alternating current. In spite of the original design of the set, alternating current creeps in, and finally alternaters are used. The reason for this is not far to seek when one considers the problems of energy storage at low potentials and the almost insuperable difficulties in the way of generating and controlling high tension direct current.

As an example of the effect or the generator wave form on the spark tone, I recall some of my first experiments with quenched spark circuits. Dr. Rein found that a flat-topped generator wave form best suited his particular circuit conditions. However, I found that for the conditions which I desired, a sinusoidal, or single peaked wave was preferable. When these experiments were made, the obtaining of a pure note was of great importance, and presented a very baffling problem. After scores of experiments and failures, I found that a pure tone corresponding to one discharge per generator alternation could be obtained if the generator gave a very peaked wave, if the audio frequency circuit was accurately tuned to the generator frequency, and if perfectly air-tight gaps consisting of 18 to 20 plates separated by 3 mils or less were used. Under these conditions, the tone lacked the typical quenching twang, and was soft, even, and mellow. When all the conditions were identical, except that a flat-topped generator wave was used instead of the peaked wave, the note at once became ragged and broken by partial discharges. The over-all efficiency of the transmitter working under the conditions mentioned was a maximum, since full advantage was taken of transformer resonance, and the power factor was accordingly very nearly unity. However, the method was not practicable owing to gap troubles caused by the use of such small clearance between the sparking surfaces and the consequent difficulties in adjustment and maintenance.

Later experiments resulted in the now well known fact that a pure, twangy, quenched note is best obtained when the audio frequency circuit is about 30 to 40% detuned Under these conditions, the wave form has apparently no effect but the efficiency is far below that obtained by the method first mentioned.

JOHN L. HOGAN, Jr. (by letter): In connection with the Rein and Lepel systems, in which there is a definite wave frequency and a definite audible group frequency and often also a third pulse or excitation frequency, it is interesting to note some early work of R. A. Fessenden. By the use of cooled gas dischargers operating on high voltage direct current (which were exhaustively treated by Dr.

Austin, and are described by him in the "Bulletin" of the Bureau of Standards, May 1907, pp. 325-340) it was found possible to secure excellent efficiencies. Fessenden had two methods for securing audible variation in the wave amplitude, (1) by the static time constant of the arc charging circuit, and (2) by tuning the generator, inductance (so-called "choke coils") and condenser to the audio frequency desired. The three-frequency method of transmission is described in his U. S. patent 727,330, applied for March 21, 1903, and was intended for sets in which unvarying tone frequency was a desideratum. Various alternating current schemes have been found more useful in practice, from the viewpoints both of economy and simplicity, and therefore predominate in practice.

Some seven years ago, Dr. de Forest and I had occasion to transmit musical tones by radio, in distributing the alternating current music of the Telharmonium. The method found best involved superposing the Telharmonium currents upon a direct current source supplying a gap discharger, by connecting the terminals carrying the composite cross-currents to either end of the feed line impedance thru condenser banks of about 0.5 microfarad. Using small superposed energies it was possible to transmit music upward of thirty miles.

It is understood that the Rein-Lorenz Multitone system had had large and successful application abroad, and such records of service as may be announced from time to time will be welcome supplements to Dr. Rein's most interesting paper.

SOME RECENT RADIO SETS OF THE MARCONI WIRELESS TELEGRAPH COMPANY OF AMERICA.*

By Roy A. Weagant.

(*Designing Engineer of the Marconi Company.*)

The purpose of this paper is to describe some recent radio sets designed for the Marconi Wireless Telegraph Company of America to meet the new specifications of the United States Navy, and to consider further certain interesting points in the design and operation of such sets.

The manufacturing plant and laboratories of this company are located at Aldene, New Jersey, where a force of approximately two hundred men are engaged exclusively in the construction and testing of radio apparatus. For testing the sets under conditions of commercial operation, in addition to an artificial antenna, an outdoor aerial is provided. (Figure 1.) This aerial is supported by two 200 feet (65 meter) steel towers, 450 feet (148 meters) apart.

For the sake of clearness, we shall consider the apparatus beginning with the point of entry of the direct current power, namely the switchboard, and pass successively thru the automatic starter, the D. C. motor, the alternating current generator, the power transformer, the closed circuit of the transmitter, the open circuit of the transmitter, and the relay key and receiver.

The switchboard (shown in front view of Figure 2 and in rear view of Figure 3), consists of a slate panel approximately 6 feet by 2.5 feet, and carries the following instruments: D. C. voltmeter, D. C. ammeter, A. C. voltmeter, A. C. ammeter, A. C. wattmeter, frequency meter, motor field rheostat, generator field rheostat, main A. C. switch, main D. C. switch, D. C. circuit breaker, solenoid switch for opening the A. C. field circuit and one side of the A. C. armature circuit, (this solenoid switch is ordinarily remotely controlled by the aerial switch, but may be controlled by) a double pole

* Lecture delivered on October 1st, 1913.

Figure 1

Figure 2

Figure 3

switch on the panel board; a push button for controlling the automatic starter, and a spare switch.

Figure 4 shows the marine type of automatic starter supplied by the Cutler-Hammer Company, which is mounted on a slate panel, together with seven-pole double-throw switch the purpose of which is to connect the automatic starter to either of two motor generators. The entire assembly is enclosed in a metal case.

The motor generator provided with these sets, the armatures of which are shown in Figure 5, is supplied by the Crocker-Wheeler Company. The machine is of the two-bearing type, semi-enclosed. It consists of a two pole, 120 volt, 2000 R. P. M., D. C. shunt wound motor and a 220 volt, 500 cycle, single-phase generator. The generator is of the rotating armature type, the complete rotor being shown in Figure 6. This generator has special electrical characteristics which particularly fit it for use with quenched spark sets.

The protective devices employed consist essentially of condensers, spark gaps, and resistance rods connected between each side of the line and ground. Fuses capable of carrying the total current of the circuit to which the device is connected are provided, and so arranged that the short circuiting of any of the protective condensers or spark gaps blows the corresponding fuse. It is thus impossible to operate the set with a defective protective device in any of its circuits. The various units composing the device are mounted on a slab of insulating material, and enclosed in a cast iron case. An appropriate value of the condenser used has been found to be 0.05 μf. and this condenser must be capable of withstanding 1,000 volts continuously applied. The resistance rods have approximately 25,000 ohms resistance. The points at which these devices are inserted are as follows: motor armature and field circuits, generator armature and field circuits, primary of power transformer, blower and rotary gap motors, (one protective device common to both field and armature).

The operator's key controls the relay key, which is illustrated in Figure 7. In addition to breaking the main A. C. circuit, the relay key operates contacts whereby the ground circuit of the antenna is opened, the detector is short-circuited, and the telephone circuit is opened. The arrangement adopted makes it possible to receive between dots and

Figure 4

Figure 7

Figure 5

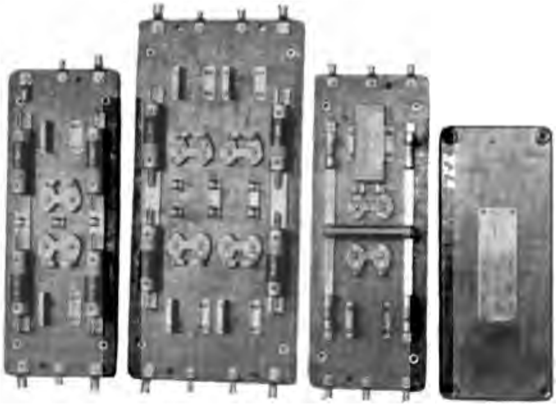


Figure 6

dashes, while transmitting. Figure 8 shows the relay key reactance, which can be adjusted to six different values by means of the switches mounted on its top. This reactance is used to reduce arcing at the main A. C. contacts of the relay.

Photographs of the exterior and interior of the transformer are given in Figures 9 and 10. The transformer is open core, air cooled. It is approximately 10 inches in diameter and 30 inches long (for the two or five K. W. sizes). The primary is wound with a number of insulated conductors in parallel, whereby eddy current losses in these conductors are considerably reduced. The core is of laminated silicon steel. A micarta tube is employed as a separator between the primary winding and the secondary sections. A perforated cover encloses and protects the secondary, while permitting a free circulation of air for cooling purposes. Two insulators on the top of the case carry the secondary terminals, and a third insulator carries a metallic ball connected to ground. The metal terminals at the tops of these insulators act as protective spark gaps and limit the potential strains between the secondary terminals or between the secondary winding and ground. The danger of puncturing the insulation between the primary and secondary windings thru resonance phenomena (and consequent enormous rises of potential) in the transformer secondary capacity circuit, when the connections to the spark gap are accidently opened, is thus obviated by the connection to ground on the third protective gap terminal.

The transmitter construction will next be considered in detail. The complete 5 K. W. transmitter is shown in front. side, and rear views in Figures 11, 12, and 13. The transmitter consists of a number of parts conveniently and compactly arranged, and supported on a slate panel. The units are as follows: a quenched spark gap with blower (A), leyden jar condenser and rack (B), an oscillation transformer (inductive coupler) (C), the aerial inductance (D), a switch for changing wave lengths (E), and an aerial ammeter (F).

The transmitter here shown is designed so that eight definite and predetermined wave lengths lying between 600 and 2,000 meters may be instantly obtained by the setting of a single rotary switch, E, which makes connections in both

Figure 8

Figure 9

Figure 10

open and closed circuits. A preliminary adjustment to suit the particular antenna used is necessary. The connections, (which are particularly well shown in Figures 12 and 13) from the switch in the aerial circuit to the aerial inductance are made thru very heavily insulated flexible cables. The calibration of the primary circuit is accomplished at the factory. The fixed wave lengths used in these sets are 625, 750, 875, 1,000, 1,300, 1,575, 1,800, and 2,000 meters.

It is also possible to obtain any intermediate wave length between the designated limits by setting the fixed wave length switch to the wave length lying immediately below that desired, and rotating the handle of the inductive coupler C until the primary circuit shows the desired wave length as indicated on a wave meter. The antenna is then tuned by rotating the handle of the aerial inductance D until the aerial ammeter F gives the maximum indication. During this process, the coupling between the primary and the antenna circuits must be varied, which can be readily accomplished by pushing the handle of the oscillation transformer C in or out. It will be seen by reference to the illustrations that the wave length changing switch E consists of two blades mounted on a micarta tube at a separation of about 24 inches (60 cm.), these blades being arranged to rotate with the switch handle. Supporting the jaws of the switch, which are connected to the appropriate taps on the inductances, are two micarta plates thru which the micarta tube supporting the blades passes. The support of the primary switch is the one nearer the panel, and the support of the secondary switch is at the extreme rear of the unit.

The oscillation transformer consists of two spirals, the primary one being fixed, and the secondary being movable in such a way as always to remain parallel to the primary. These coils, which are shown in Figure 14, consist of copper ribbon wound in a spiral groove cut in an insulating plate support. The plate supports are placed facing each other. Eight taps are taken from the primary to the wave length switch, and a sliding contact is arranged so that rotation of the handle of the oscillation transformer produces a continuous variation of inductance sufficient to cover the range between any two fixed wave lengths.

Attached to the secondary are three flexible leads. The

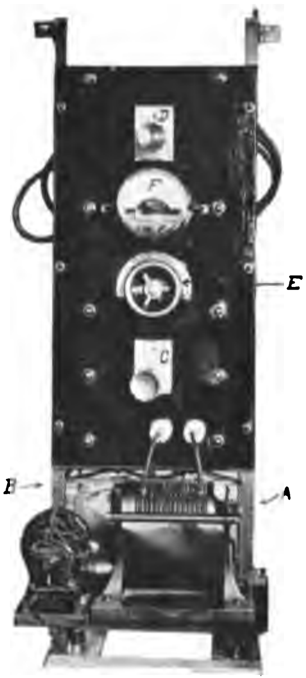


Figure 11

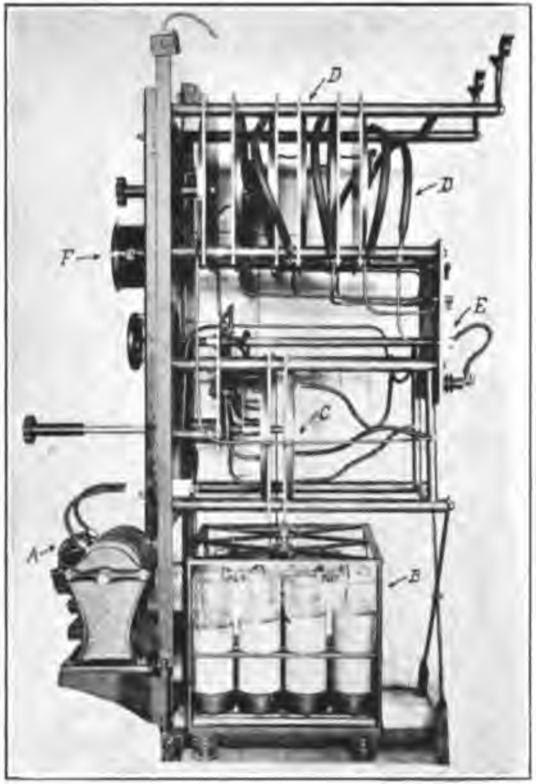


Figure 12

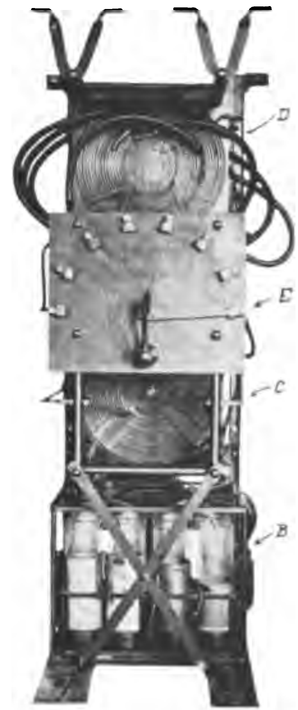


Figure 13

first of these is connected to the continuously variable portion of the antenna tuning inductance and thence to the ground. The second tap is connected to the first jaw of the wave length switch. The third tap is connected to the end of the antenna tuning inductance which is variable in steps. It will thus be seen that the aerial tuning inductance consists of two portions; a continuously variable portion which is nearer the ground than the secondary of the inductive coupler, and a portion which is variable in steps consisting of a number of coils placed nearer the antenna than the secondary of the inductive coupler. The basis of this arrangement is the necessity of using less than the entire secondary coil of the inductive coupler for tuning the antenna at short wave lengths and the further necessity of using the entire secondary coil of the coupler to obtain sufficient coupling at longer wave lengths. The advantage of placing the continuously variable portion of the antenna tuning inductance in the ground side of the inductive coupler is that it is then in circuit regardless of the position of the wave length switch. The portion of the aerial tuning inductance which is variable in steps consists of five spirals identical in construction with those of the inductive coupler. From these, seven are brought to the remaining jaws on the secondary portion of the wave length switch.

The primary condenser consists of sixteen Leyden jars, each having a capacity of 0.002 μf. The entire number is connected in parallel. The jars are of the usual silver and copper plated type. Each group of eight jars is mounted on a tray which can be slid out of the rack thru the front of the panel without disturbing any connections. This is accomplished after rotating the spark gap at the front of the panel on either of its hinges so that it will no longer obstruct the passage of the tray. Broken or defective jars are thus easily replaced. The rack and the sliding trays are shown in Figures 16 and 17.

The construction of the spark gap is clearly visible in Figure 18. It consists of fifteen plates with fourteen insulating gaskets between them. These plates and gaskets rest on a tube of insulating material, and lateral displacement is prevented by two more tubes at the sides. Thru these tubes run steel tie rods which hold the two vertical end castings

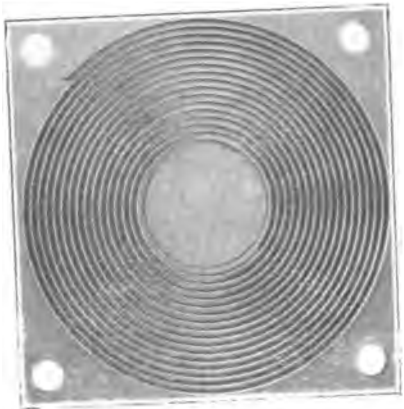


Figure 14

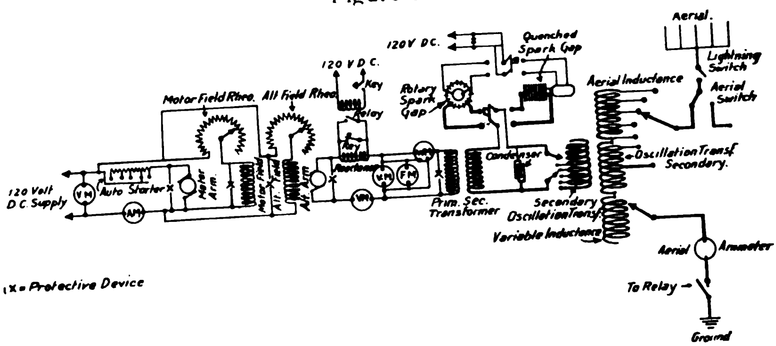


Figure 15

Figure 16

rigidly in place. A set screw at one end permits clamping the plates and gaskets very tightly against each other. Between the two end plates of the gap and the end castings are heavy discs of insulating material. The gap plates consist of copper castings, the sparking surfaces being inserts of electrolytic copper soldered and spun in place, and ground dead true, and parallel to the gasket bearing surface. The sparking surfaces are raised above the gasket bearing surfaces to such an extent that the separation of the sparking surfaces when the gap is assembled is approximately one-third the thickness of the gasket itself. The material used for the gaskets is press-board especially treated so that an air-tight joint between the plates is secured.

Attached to the gap is a motor-driven blower which forces air up between the flanges of the plates and prevents overheating. The construction of the side of the gap is such that the cooling air must pass between the flanges before escaping. The rotation of the gap and blower motor about either of two hinges is necessitated by the limited space available in many ship installations and the difficulty of reaching the back of the panel from either side.

In these sets an auxiliary rotary spark gap of the non-synchronous type is provided. It is intended for special naval service in times of war. A considerably larger number of studs than usual were required because of the comparatively high frequency of the alternating current supply.

A six-pole double-throw-switch provides means for shifting from the manually operated antenna switch to the relay key.

The receiver, the wiring diagram of which is given in Figure 20, is of the two-circuit, inductively coupled type. It contains the following parts: primary of the inductive coupler (A), secondary of the inductive coupler (B), antenna tuning inductance in the primary circuit (C), primary variable air condenser (D), secondary variable air condenser (E), potentiometer (F), carborundum detector (G), cerusite detector (H), test buzzer (I), coupling controller (J), detector protective condenser (K), detector stopping condenser (L), coupler primary switch (M), (dividing the transformer primary into steps of ten turns), coupler primary switch (N), (for variation by single turns), aerial tuning inductance switch (O),

Figure 17

Figure 18

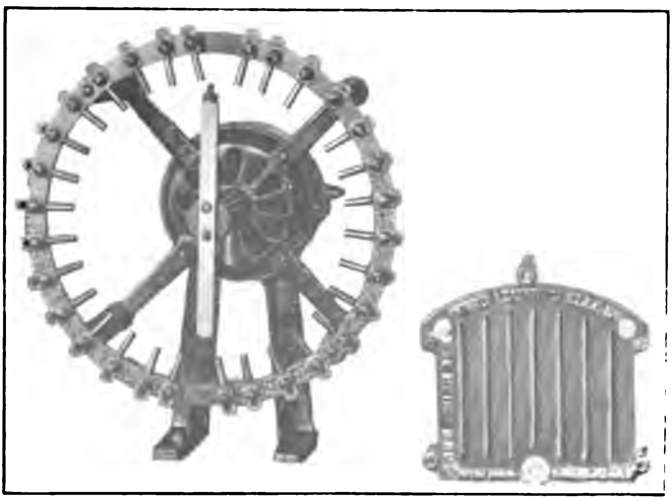


Figure 19

transformer secondary switch (P), test buzzer switch (Q), primary condenser switch for connecting condenser in series to, or in parallel with the total primary inductance or for disconnecting it entirely (R).

The inductive coupler consists of a fixed primary, and a movable secondary mounted on a rod and controlled in its motion by a flexible metal band passing over a number of pulleys. The coupling is thus varied thru a wide range by a single rotary motion of a knob. Both primary and secondary coils are divided into four sections connected to the controlling switches in such a way that dead ends are avoided. Sufficient inductance is provided in both circuits to work up to wave lengths of 7,000 meters in the case of the "long range" tuner, and up to 4,000 meters in the case of the "short range" tuner. Compactness of the coils (in combination with the unusual range of wave lengths) demands special coil construction in order that high efficiency may be obtained. The variable air condensers are of the conventional type, counterbalanced so as to rest in equilibrium in any position. The potentiometer, which provides for fine adjustment of the voltage across the detector, is of a rotary type.

Two detectors, of different operating characteristics, are provided. The carborundum detector is of moderate sensitiveness and great stability. The cerusite detector is of extreme sensitiveness. A switch is provided for using either of these at will. Separate binding posts are provided in order that any other detector can be connected in place of those furnished.

During transmission, a large condenser (K) is connected across the detector to protect it against being thrown out of adjustment.

The entire receiving apparatus is so mounted that the exterior case can be removed without interfering in any way with the connections, all parts being mounted on the heavy front panel which is supported by right angle brackets attached to the base.

The Marconi wavemeter, from the designs of Mr. Harry Shoemaker, is shown in Figures 24 thru 28. Figure 24 shows the instrument in its case. Figure 25 shows the various elements of the instrument, A, B, C, and D being the coils used to cover the various ranges of wave lengths. E is the con-

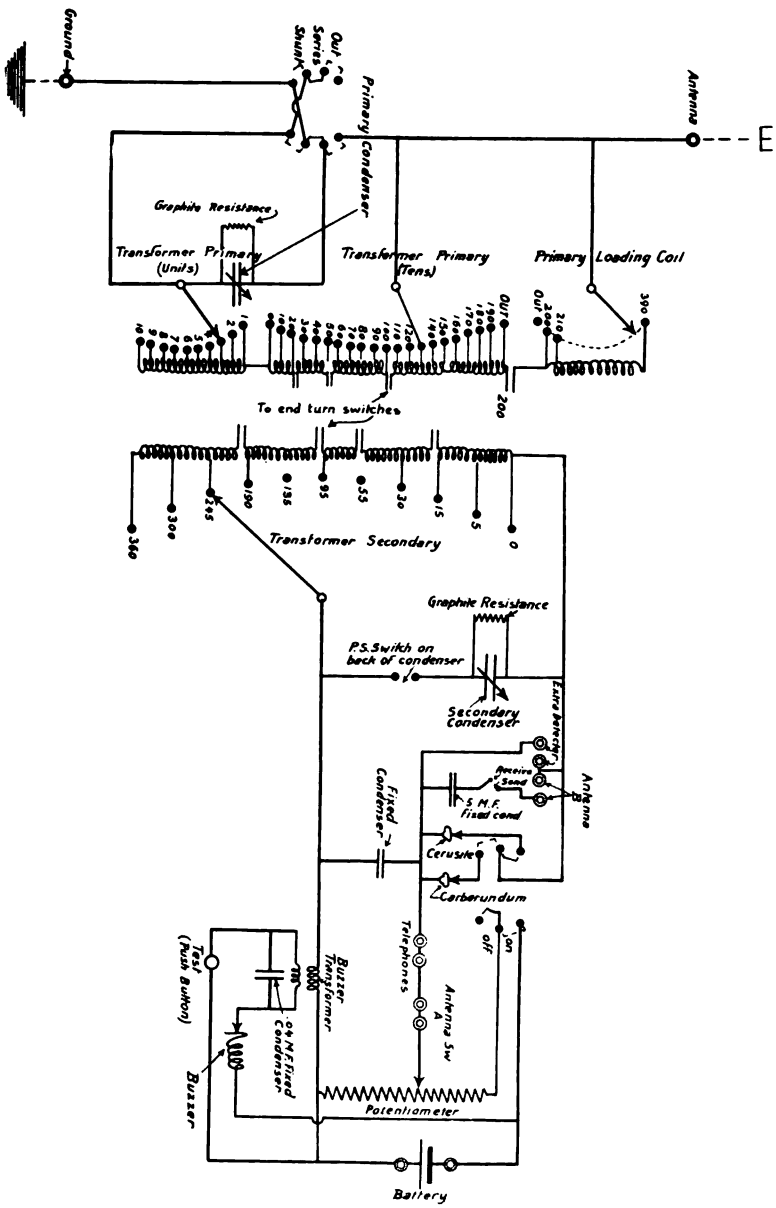


Figure 20

denser case, with attached brackets for holding the inductances F and G. The buzzer, H, the detector, I, and the thermo element, K, (of Figure 26) are also mounted on this case. The variable air condenser is shown in Figure 27, while Figure 28 shows the complete instrument with the galvanometer, L, and the "pick-up" coils, L and M.

This instrument covers a range of wave lengths from 100 to 5,000 meters, and is arranged for measurements of inductance, capacity, and decrement as well as for wave length. A plug containing a known resistance may be inserted in the oscillatory circuit, and the decrement of the instrument itself at any wave length determined. In addition, coils are provided for measuring the wave length of incoming signals, in which case the instrument is employed in much the same way as an ordinary receiver.

We shall now discuss briefly certain matters of design and construction. The alternating current instruments on the power switch boards must be so constructed as to read correctly on wave forms differing widely from the pure sinusoidal type. The alternating current circuits need not be provided with any special protective devices against excess current inasmuch as the characteristic of the generator are such that it is not possible to draw more than the load current. Nevertheless these circuits have been provided with fuses. Fuses are used because it has been found impossible to construct suitable 500 cycle circuit breakers.

The motor of the motor generator set must be provided with closer speed regulation than is common with the usual commercial set, namely from 3 to 5%. The generator is purposely designed to have very poor regulation, so that the voltage drops markedly as the load is applied.

A complete theory of the action of the transformer, with particular consideration to the transient phenomena involved, is beyond the scope of this paper, but will be considered in a later communication. Certain general points in the design are of interest, and will be discussed. In order that the transformer operate properly in connection with a quenched spark transmitter, it is essential that its characteristics shall bear certain relations to the other circuit constants. Figure 23 shows a resonance curve obtained by varying the capacity connected to the secondary, and observing the current in the pri-

Figure 21

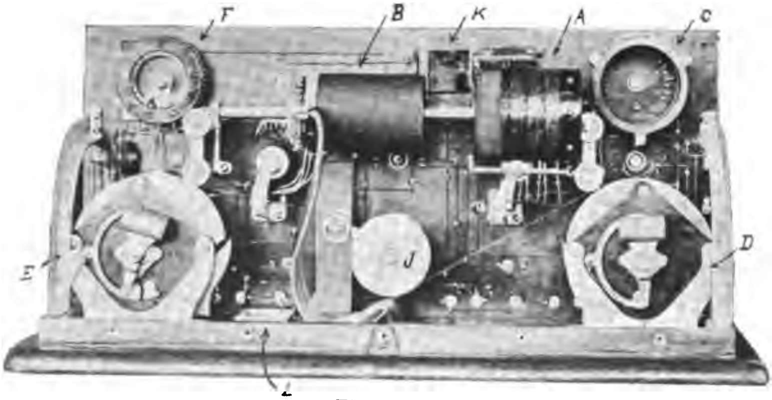


Figure 22

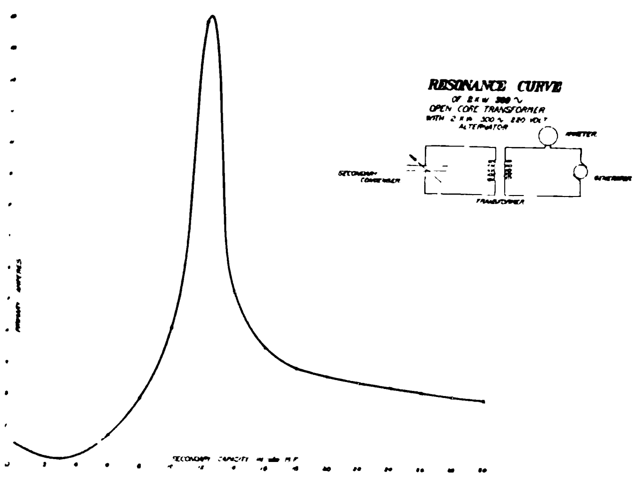


Figure 23

mary circuit. It will be noted that the point of maximum primary current, or "resonance point," is at 0.012 microfarad capacity, while, as previously stated, the capacity used in actual working is 0.016 microfarad. In other words, the natural period of the transformer circuit as a whole, is considerably greater than that of the applied E. M. F. This condition is necessary in order to secure a clear, musical note without critical adjustment. The more nearly the working point approximates to the resonance point, the higher the power factor of the circuit, but the more difficult becomes the adjustment for a clear note. Under the working conditions specified, the average power factor is about 80%.

Completely to predetermine mathematically the constants of the transformer is not possible at present, but certain quantities may be easily obtained by the following methods. In designing the primary and core, it is usual to start by assuming some length for the core which has been found appropriate in practice. The flux density chosen generally lies between 6,000 and 15,000 lines per square inch (1,000 to 2,500 lines per sq. cm.). The cross section is usually determined by experience. The following empirical formula connects the number of primary turns with the flux produced in a straight open core, of given dimensions. In this formula ϕ is the total flux produced per ampere-turn in the circular core, L is the length of the core in inches, D the diameter in inches:

$$\Phi = \left(10 + \frac{L}{4D}\right) D$$

Experience has shown that the magnetizing current for best operation should be about one-third of full load current. Having chosen, then, the flux density and the magnetizing current, the number of primary turns is at once obtained. The copper cross-section of the secondary wire is next determined by an approximate knowledge of the current it must carry. A number of secondary sections are then constructed, and by trial, the proper number to be used is found. This method is obviously one of cut-and-try, but we are forced to adopt it because the previous mathematical treatments of the transformer take no account of the periodically recurring transient conditions introduced by the employment of a quenched spark transmitter, and these earlier theories also assume that the transformer is operated at the resonance point. The complete

Figure 24

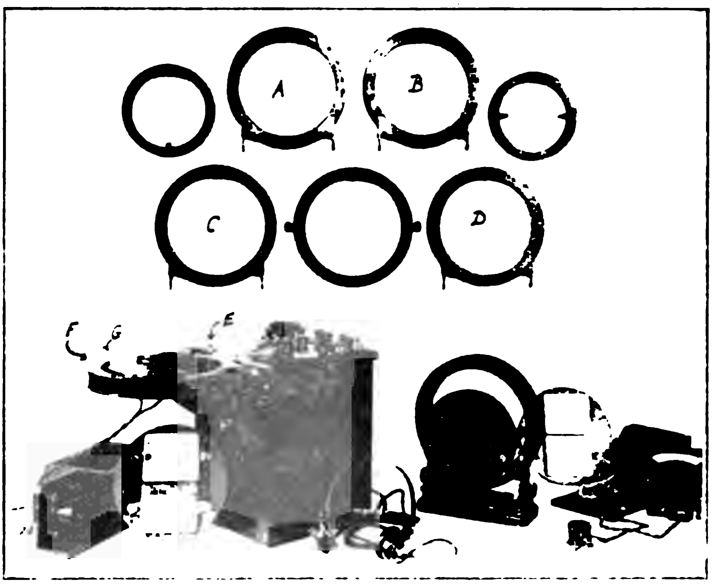


Figure 25

Figure 26

predetermination of secondary voltage and current must therefore await the publication of the full theory. Experience shows that the secondary open circuit voltage is between 0.4 and 0.7 of the condenser or spark gap voltage. It will be found that the product of the secondary open circuit voltage, the secondary current and the power factor is approximately equal to the power input. Since all these quantities except the secondary current may be regarded as known, it is possible to calculate the latter. The last-mentioned relation was first pointed out to me by Mr. Guy Hill, of the United States Naval Radio Service.

The quenched gap exerts a frequently neglected influence on the coupling required for satisfactory operation of the transmitter. The greater the number of sections, and the shorter each section, the closer the coupling which must be used. It is possible therefore to work within a desired range of coupling by properly choosing the number of gap sections.

In the type of receiving set previously described, it has been necessary to cover in one apparatus an extreme range of wave lengths. However, experience shows that such receivers are preferably subdivided into those intended for wave lengths below 1,500 meters, and those designed for wave lengths greater than 1,500 meters. Radically different types of construction are required in the two cases to obtain maximum efficiency. It may also be noted that the efficiency of the modern receiver is far less than that of the transmitter, and that there is room for much improvement in this regard. It appears further, as the result of considerable experiment, that with a given aerial, the receiver must be specially designed for it if maximum efficiency is to be obtained.

The foregoing general remarks concerning quenched spark transmitter design are to be taken as merely indicative of the directions in which future research may be profitably carried on, rather than any complete solution of the problems involved.

DISCUSSION.

ROBERT H. MARRIOTT: On behalf of the INSTITUTE, I wish to thank Mr. Weagant for the interesting and valuable paper he has given us. In reference to the mineral

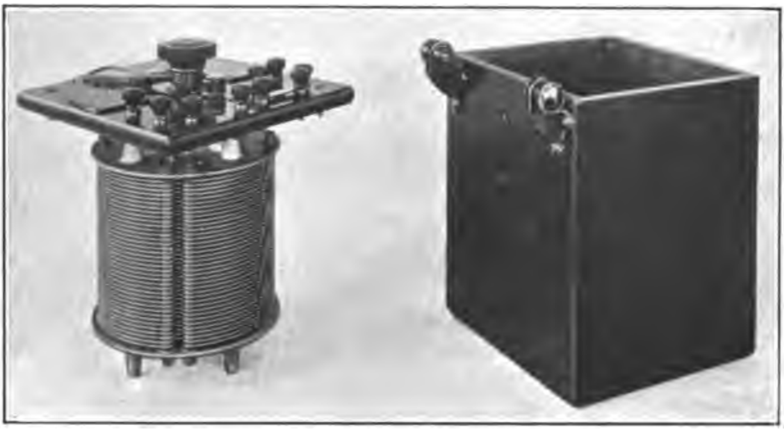


Figure 27

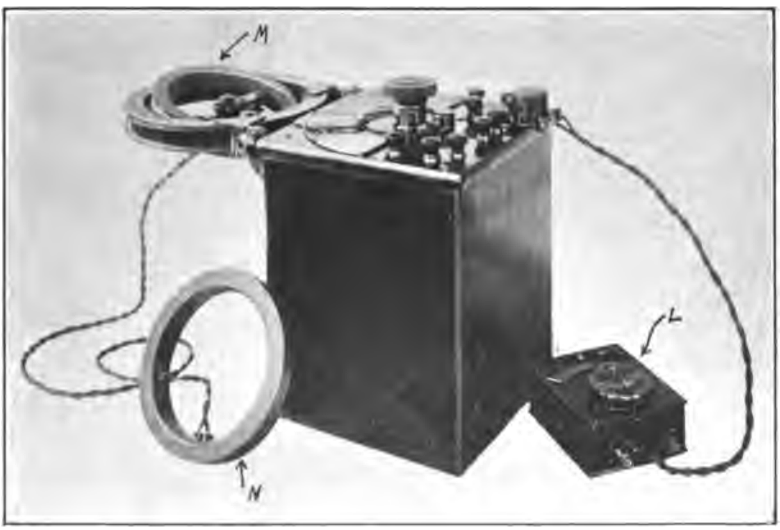


Figure 28

cerusite, which is used in the Marconi detectors, it will be found that the cerusite which is purchasable in the open market is useless for radio work. The deposit of sensitive material is located at a point known only to a Mr. Lyons, who first offered me the American rights to the use of the material. This special deposit of the material is the source of the cerusite now used by the Marconi Company.

EMIL J. SIMON: The INSTITUTE owes Mr. Weagant its thanks for the open and modest way in which he has described his work. The statement that the design of the so-called "resonance transformer" is largely "cut and try" is unfortunately true. I can, however, add to Mr. Weagant's methods a description of a method whereby the secondary of this transformer can also be almost entirely calculated in advance. In the diagram (Figure 29) L_g is the inductance of the generator, L_r that of a supplementary reactance, and L_p that of the primary of the transformer. The inductance of the secondary of the transformer is L_s, its mutual inductance to the primary M, and the transformer capacity load C_2. We use N_g for the frequency of the generator (usually 500 cycles), and N_e for the frequency of the entire circuit shown. The old "secret" which Mr. Weagant has mentioned, namely, that "resonance transformers" are not worked at resonance in cases where a clear note is desired, can then be utilized to advantage. In the case shown by Mr. Weagant, the resonance capacity load for a certain transformer was 0.012 μf., whereas the working capacity was 0.016. That is, the transformer was being used at a frequency about 16% below resonance. In my own work, I usually use between 20 and 25%. If we take 20% as an average value for the percentage difference between the resonance frequency and the working frequency, N_e becomes 400 cycles. In my design, I start by assuming a value for L_p, which has been found appropriate in practice, and then I measure L_g The quantities L_p and L_g must be added geometrically, because the currents in them are not necessarily in the same place. The capacity load, C_2, is probably known from considerations of the desired voltage, frequency, and power. The coupling coefficient for the transformer system is found from the equation

$$k^2 = \frac{M^2}{L_1 \, L_2}$$

where L_1 is the geometrical sum of L_p, L_g, and L_r. The practical problem which confronts us in this design is to obtain a clear pure note, with a given rate of quenching, and with freedom from critical adjustment. In calculating L_2, I use a formula first given by Seibt in the Elektrotechnische Zeitschrift in 1904 in an article on the theory of the resonance transformer, namely,

$$\frac{1}{N_c} = T_c = 2\pi\sqrt{C_2 L_2 (1-k^2)}$$

For an open core transformer, and remembering that we are considering the entire circuit coupling, k may be taken as about 0.8.

ROY A. WEAGANT: I must take complete exception to the expression for T_c given by Mr. Simon. Seibt deduced this equation for a permanent condition; that is, the secondary of the transformer was not connected to any element of rapidly varying resistance such as a spark gap. Operation at the resonant point is also assumed. In our design, it is necessary to provide for the transient conditions.

EMIL J. SIMON: I wish to add that, if k is taken to mean the coupling coefficient between the primary and secondary of the open core transformer, it is given by the expression

$$k^2 = \frac{M^2}{L_p L_s}$$

and that its value is usually from 0.4 to 0.5. It is quite true that, as Mr. Weagant says, we are working under transient conditions. Still, the equation given for T_c is found to hold fairly well in practice, and gives a useful first approximation.

The ratio of turns of secondary to those on primary must be obtained also. We may start by assuming that it is the same as the ratio of secondary to primary electromotive force. As a matter of fact, resonance effects make the ratio of electromotive forces considerably greater than the ratio of number of turns. We first get the (secondary voltage)-(frequency) resonance curve for a transformer of the same general type as the one under consideration, and, knowing the percentage off resonance at which the new transformer is to work, we can observe the correction which must be applied to the electromotive force ratio to obtain the ratio of number of turns.

ROY A. WEAGANT: In working with receiving sets, I have encountered repeatedly a phenomenon for which I can find no explanation. The arrangement of instruments is shown in Figure 30. A is the antenna, B a coupling coil to C. C is a portion of a buzzer exciting circuit. Z is a primary of either receiving set X or receiving set Y; the object being to compare the sensitiveness under working conditions of two receiving sets. It may be found, for example, that the signals on set X are the louder. If, now, coil C is rotated through 180°, so that end 2 is coupled to B instead of end 1, receiving set Y is now found to give stronger signals. In the numerous cases where this effect has been observed, extreme precautions were taken to keep B and C at very considerable distances from X, Y, and Z.

JOHN L. HOGAN, Jr.: The effect may in some way be due to a change in the relative values of magnetic and static coupling between B and C as the latter is rotated. Another curious effect that has been observed in the study of receiving sets is that telephone indication and galvanometer reading do not maintain their relative ratios. For example, it is possible to secure conditions where altering the coupling to the exciting circuit produces practically no change in the strength of the telephone signals, altho the galvanometer reading may change at the same time from a positive to a negative value.

EMIL J. SIMON: Mr. Weagant has mentioned that micarta is used as the support of the spiral tuning inductances. May I ask whether in the intense field of such a spiral, no heating is produced in the micarta, at the end of an eight-hour run?

ROY A WEAGANT: No greater heating was found than when a skeleton coil employing the minimum amount of insulating material was used. Even between the primary and secondary of the transmitting inductive coupler, where there is interposed a double thickness of the micarta, no heating or additional loss was found. Of course, the spiral conductors themselves become slightly warm.

EMIL J. SIMON: I mention this because, while using micarta cores for ordinary helix coils, I found that the tube heated badly, and the construction in question had to be abandoned.

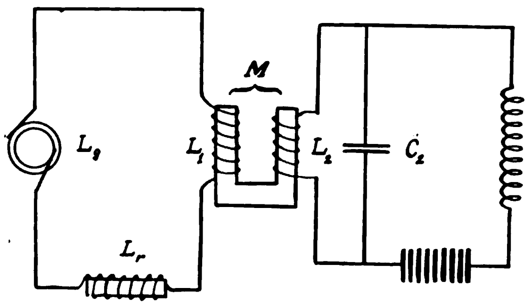


Figure 29

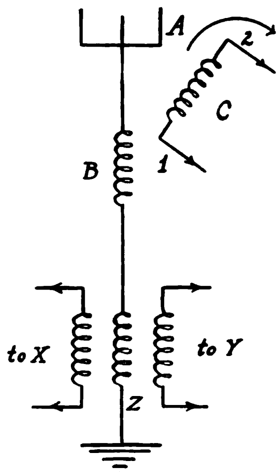


Figure 30

ROY A. WEAGANT: This might be due either to surface leakage over the micarta between uninsulated conductors, or because of actual conductivity of the micarta and consequent eddy current losses.

EMIL J. SIMON: It could not have been surface leakage because the conductors were of litzendraht, very carefully insulated with silk and a weather-proof coating. It may be actual conductivity.

FRANK HINNERS: If the losses are due to conductivity, what effect would increasing the thickness of the tube have on these losses?

ROY A. WEAGANT: It should increase the losses because the greater cross section carries with it diminished resistance and greater currents.

(Printed for Members Only.)

PRELIMINARY REPORT
OF THE
COMMITTEE ON STANDARDIZATION
OF
THE INSTITUTE OF RADIO ENGINEERS
Inc.

DEFINITIONS OF TERMS,
GRAPHICAL AND LITERAL SYMBOLS.

MEMBERSHIP OF THE COMMITTEE.

ROBERT H. MARRIOTT, Chairman, United States Radio Inspector, Department of Commerce, New York, N. Y.

ALFRED N. GOLDSMITH, Ph. D., Secretary, Instructor in Radio Engineering, The College of the City of New York, New York, N. Y.

JOHN L. HOGAN, Jr., Chief of Operating and Erection Department, National Electric Signaling Company, New York, N. Y.

A. E. KENNELLY, M. A., Sc. D., Professor of Electrical Engineering, Harvard University, Cambridge, Mass.

ROY A. WEAGANT, Designing Engineer, Marconi Wireless Telegraph Co. of America, Aldene, N. J.

GREENLEAF W. PICKARD (ex-officio), Chief Engineer, Wireless Specialty Apparatus Company, Boston, Mass.

NEW YORK CITY,

September 10, 1913.

PREFACE.

The early history of new branches of engineering always shows the discouraging spectacle of a confused and ill-defined nomenclature, together with widely different connotations assigned to the literal symbols by the various investigators and authors. Such a state of affairs gives rise to untortunate misunderstandings, or, at best, to a considerable amount of unnecessary labor on the part of the practicing engineer and students of engineering.

The field of radio engineering is far from having escaped the objectionable conditions mentioned above, as is easily seen from reading either theoretical papers on the subject or the reports of the patent lawsuits.

The Committee on Standardization of THE INSTITUTE OF RADIO ENGINEERS was appointed by the Past-President of the Institute, Mr. Robert H. Marriott, and continued by President Greenleaf W. Pickard, for the express purpose of studying the terms and symbols used in the art, selecting and defining the suitable terms, and eliminating the remainder. Its further functions are to develop, and make public, standard methods of testing and rating radio apparatus, and to consider such further matters as would naturally fall within the scope of a Committee on Standardization.

As a result of more than fifty meetings and discussions, the Committee presents to the I. R. E. members and others interested the following definitions and symbols for consideration.

All those interested are requested to send to the Committee, in care of the Secretary, their comments on the following preliminary report. Coöperation of this sort will be welcomed, and will assist the committee in the early publication of a final report.

TO ALL MEMBERS:

The questions given below should be answered, and this page should be torn out and mailed to Alfred N. Goldsmith (former Secretary of Committee on Standardization), The College of the City of New York, New York City. The final action on this Committee Report will be based on the replies received.

1. With the exception of the changes suggested by you below, are you in favor of the acceptance and adoption of this Preliminary Report by the Institute?

....

....

2. If you are not in favor of its acceptance, what are your reasons for its rejection? ....

....

....

3. What criticism of the Report do you make, and what changes in the Report do you suggest?

....

....

....

(Further criticisms and suggestions may be sent on separate sheets.)

....
Signature.

....
Date.

DEFINITIONS OF TERMS.

Acoustic Resonance Device. One which utilizes in its operation mechanical or other resonance to the group frequency of the received impulses. The device most commonly used is a relay.

Air Condenser. One having air as its dielectric.

Alphabet or Code. (See "Code.")

Alternator. A rotating machine which transforms mechanical energy into electrical energy, delivering at its terminals one or more alternating E. M. F.'s. (Single phase or polyphase.)

Alternating Current. One which reverses its direction successively with time, whether periodic or non-periodic. (See also Free Alternating Current, Forced Alternating Current.)

Ammeter. A current measuring instrument indicating in amperes or fractions thereof.

Amplification. The ratio of the useful effect obtained by the employment of the amplifier to the useful effect obtained without that instrument.

Amplifier or Amplifying Relay. One which modifies the effect of a local source of energy in accordance with the variations of received signals, and in general produces a larger indication than could be had from the incoming energy alone.

Angular Velocity of a periodic alternating current in radians per second. 2π times the frequency in cycles per second.

Antenna. A system of conductors designed for radiating or absorbing the energy of electromagnetic waves.

Antenna Resistance. The ohmic resistance in the entire antenna circuit.

The energy consumed in the antenna resistance contributes nothing to the radiation, but produces only heat.

Arc or **Spark.** See "Spark."

Arc Convertor. An arc used for (a) the conversion of alternating to pulsating direct current, or (b) the conversion of direct to alternating or pulsating current.

Arc Converters of Type (b) are classified as follows:

Class (1) Those for which the amplitude of the (approximately) sinusoidal current produced is less than that of the direct current.

Class (2) Those in which the amplitude of the (approximately) sinusoidal current is at least equal to that of the direct current, but in which the direction of the current is never reversed.

Class (3) Those in which the amplitude of the initial portion of the free alternating current is greater than the direct current passing through the converter, and in which the direction of flow of the current is periodically reversed.

Atmospheric Absorption. That portion of the total loss of radiated energy due to atmospheric conductivity, reflection, and refraction.

Atmospherics (Atmospheric Disturbances in the Receiver) may be classified as follows:

(1) Electrical disturbances set up by distant discharges, and

(2) Disturbances caused by contact of charged particles with the antenna, or by the contact of uncharged particles against the antenna and their consequent electrification.

Attenuation. The progressive diminution of intensity as a disturbance advances through a transmitting medium.

Attenuation Radio. The diminution of radiant eletromagnetic energy concurrent with its passage thru a partially absorbing medium.*

Attenuation Coefficient (Radio).* The coefficient which, when multiplied by the distance of radiant transmission through a uniform medium gives the natural logarithm of the attenuation factor in that distance.

Attenuation Factor (Radio). The ratio of the radiant energy received at a distance traversed in an attenuating medium to the initial radiant energy. A numeric.

Audibility (Minimum). The condition in which there is present in the antenna the least power required for an audible

*See footnote on following page.

indication in the receiving telephones, with the particular apparatus employed.

Audibility Factor. The ratio of the telephone current producing the received signals to that producing the least audible signal at the given audio frequency. *

(An audible signal is one which just permits the differentiation of dots and dashes.) The determination of the above ratio should be made by the usual non-inductive shunt-to-telephone method, pending the adoption by the Institute of a more suitable method. The audibility factor is, in general, proportional to the square of the ratio frequency is the antenna and is often stated as the vector $(R_t + R_s)/R_s$ where Rt is the audio frequency impedance of the telephones, and R_t is the impedence of the shunt which, when connected across the telephone terminals, reduces the signal to the point at which dots and dashes can be just distinguished from each other.

Audio Frequencies. The normally audible frequencies lying between 20 and 20,000 cycles per second. (See also Radio Frequencies.)

Brush or Coronal Losses. Those due to leakage convection current through a gaseous medium.

Capacity. That property of a material system by virtue of

*General Considerations for Spherical Wave Distribution.

Assume that energy leaves a source. Because of geometrical considerations of the spread of energy (and depending on the nature of the waves), there will be a normal law of energy diminution with distance. At a distance *s* there will therefore be a normal energy intensity, no absorption of energy in the medium being as yet considered. Therefore (Normal Energy Intensity at Distance *s*) equals the product of (Energy Radiated) and (a Function of *s*). There may be, in addition, a dissipative absorption of energy in the medium. On the assumption that equal thicknesses of a homogeneous medium absorb equal portions of the thereupon incident energy: (Energy Intensity at a Distance *s* taking account of Distance Diminution *and* Medium Absorption) equals the product of (Normal Energy Intensity at distance s as defined above) and (ϵ^{-As}), where A is the attenuation coefficient. The actual energy intensity at distance s will, in general, be a function of (Energy Intensity àt distance *s* taking account of Distance Diminution and Medium Absorption) and other physical conditions (e.g., ground losses, atmospheric reflection and refraction).

which it is capable of storing energy electrostatically.

The capacity of a system is dependent on its geometrical dimensions, its position relative to other conductors, and the dielectric constants of the surrounding media.

Capacity is measured by the ratio of the quantity of electricity stored to the potential difference at which it is stored.

A distinctive property of a capacity is that it permits the passage of electrical energy through it only in the form of displacement currents.

Capacity of An Antenna. Its electrostatic capacity measured relative to the counterpoise or ground.

Capacitive Coupler. An apparatus which electrostatically joins portions of two circuits, and thereby permits the transfer of electrical energy between these circuits thru the action of electric forces.

Capacity Reactance. A measure of that property of a circuit whereby the opposition of inductive reactance to change of an alternating current may be compensated or reversed. It is numerically equal to the reciprocal of the product of angular velocity and capacity in series with the inductance, and is always negative in sign.

Choke Coil, see Reactance Coil or Reactor.

Code (Alphabet). A system of conventional characters designed to represent letters by dots and dashes. The International Morse Code is official.

Coefficient of Coupling (Inductive). The ratio of the mutual inductance of two circuits to the square root of the product of the self-inductance of those circuits.

Coherer. A device sensitive to radio frequency energy, and characterized by (1) a normally high resistance to direct currents at low voltages, (2) a reduction in resistance on the application of an increasing electromotive force, this reduction persisting until eliminated by the application of a restoring or disturbing mechanical force, and (3) the substantial absence of thermo-electric or rectifying action.

Condenser. A material system possessing electrostatic capacity.

Conductive Coupler. An apparatus which magnetically and electrically joins two circuits having a common conductive portion (also known as a Direct Coupler).

Conductance of a conductor is numerically equal to the reciprocal of its ohmic resistance.

Conduction Current. A transfer of electrical energy guided by a conducting medium.

Convection Current. A transfer of electrical energy by separate charged particles, unguided by any material medium.

Counter Electromotive Force exists wherever there is one which opposes any electromotive force that tends to alter the flow of current in a circuit. If the counter electromotive force is due to the presence in the circuit of inductance or capacity or to thermo-electric forces, it may persist after the withdrawal of the electromotive force which was its cause; but in most other cases it persists only so long as the impressed electromotive force.

Counterpoise. A system of electrical conductors forming one plate of a condenser, the other plate of which is the ground. For alternating current, it may be used to replace a direct connection to ground.

Coupler. See Capacitive Coupler and Inductive Coupler.

Coupling. See Coefficient of Coupling (Inductive).

Critical Resistance of an oscillating circuit. Twice the square root of the ratio of the inductance of that circuit to the capacity of that circuit, both expressed in practical units. This term applies only to circuits capable of carrying free alternating currents.

Current. The time rate of transfer of electrical quantity.

Current. See also Convection Current, Conduction Current, Displacement Current, Alternating Current, R.M.S. Value.

Damping of a Circuit. The diminution of E.M. F. and current in that circuit resulting from the withdrawal of electrical energy.

Damping Factor of a simple circuit. The ratio of the effective resistance of that circuit to twice the effective inductance. (The reciprocal of a time.) This term applies only to circuits capable of carrying free alternating currents.

Decrement. See Linear and Logarithmic Decrement.

Detector. That portion of the receiving apparatus which, connected to a circuit carrying currents of radio-frequency, and in conjunction with a self-contained or separate indicator, translates the radio frequency energy into a form suitable for operation of the indicator. This translation may be effected either by the conversion of the radio frequency energy, or by means of the control of local energy by the energy received.

Dielectric. A medium that may be regarded as incapable of electric conduction, i.e., an insulator.

Dielectric Constant (or Specific Inductive Capacity) of a medium. The ratio of the capacity of a condensor having that medium as a dielectric to the capacity of a condenser having a vacuum dielectric but otherwise identical. (The dielectric constant of air is substantially unity, and therefore, for all practical purposes, air may be used in place of the vacuum in the comparison condenser.)

Dielectric Hysteresis. That lagging property of a dielectric which is measured by the energy lost when the rising and falling (displacement current)-(voltage) characteristics (dynamic) are not identical.

Dielectric Hysteretic Constant of a given dialectric. The value of the dielectric hysteresis per cycle per unit of potential gradient applied to the dielectric.

Dielectric Lag. That property of a dielectric which is evidenced by a dissimilarity, and general time lag, of the impressed (potential difference)-(time) curve as compared with resulting (displacement current)-(time) curve for a condenser having that dielectric.

Dielectric Strength. A measure of the ability of a dielectric to withstand without rupture the application of a difference of potential.

Diplex Operation involves either the simultaneous reception, or the simultaneous transmission, of two messages at one and the same station.

Discharger. An element of varying resistance in a circuit containing inductance, capacity, or both. Examples are spark gaps, commutators, arcs, etc.

Displacement Current. The electrical condition within a dielectric region of varying electric stress. It produces the same external electric and magnetic effects as the equivalent conduction current.

Duplex Operation involves simultaneously both transmission *and* reception at one and the same station.

Dynamic Characteristic of an Arc Converter, for a given frequency and between given extremes of impressed E.M.F. and resultant current through the arc. The relation given by the curve obtained when the impressed E.M.F. is plotted against the resultant current, both E.M.F. and current varying at the given frequency.

Dynamic Characteristic of a Dielectric for a given potential gradient applied to a given dielectric at a given frequency. The curve obtained when displacement current is plotted against the sinusoidally varying difference of potential.

Eddy Currents. Those induced in conducting masses by external varying magnetic fields, the location of these currents being primarily determined by the position of the fields and not by the configuration of the conducting mass. (That is, the conducting mass is not specially arranged to provide perfectly well-defined circuits.) Such parasitic currents are also called Foucault currents.

Effective Capacity of An Antenna. That capacity which, connected in series with an inductance of appropriate value, will give a circuit whose reactance for all practical purposes is equivalent to that of the antenna throughout the working range of frequencies. The effective capacity of an antenna is, in general, less than the electrostatic capacity of the antenna, and depends on the potential distribution along the antenna.

Effective Resistance of a Spark. The ratio of the heat produced in that spark in a complete free alternating current group to the square of the R.M.S. value of the current during that time.

Efficiency of any element of a system, or of that system. The ratio of the available and useful output to the input, both measured in the same units.

Electric Charge. Quantity of electricity, definitely situated.

Electrical Potential at any point is measured by the work done in carrying a unit charge of electricity from infinity to the point considered. (See Electromotive Force.)

Electric Stress. The cause of the electrically strained condition in the medium between two regions which are at different potentials

Electromagnetic Wave. A progressive disturbance characterized by the existence on the wave front of electric and magnetic forces acting in directions which are perpendicular to each other and to the direction of propagation of the wave.

Electromotive Force. The force which tends to displace electricity, and is proportional to the difference of potential between the two points considered.

Forced Alternating Current. One produced in any circuit by the application of an alternating electromotive force. See also Free Alternating Current.

Form Factor of an open oscillator. The ratio of the average value of the R.M.S. currents measured at all points along that oscillator to the greatest of these R. M. S. currents. For a given R.M.S. current at a current antinode in the oscillator, the field intensity at distant points is proportional to the form factor.

Free Alternating Current. That produced by an isolated electrical displacement in a circuit having capacity, inductance, and *less* than the critical resistance. See also Forced Alternating Current.

Frequency. See Audio Frequency and Radio Frequency.

Frequency Meter. An instrument which indicates the audio frequency of a source of electrical power.

Gas Rectifier. A body of ionised gas having unilateral conductivity, together with means for utilizing this property.

Group Frequency. The number of distinguishable alternating current groups occurring per second in an electrical circuit.

Note 1. The group referred to above is, in general, mainly a free alternating current which is substantially damped to extinction before the beginning of the following group or train.

Note 2. The pitch of the note in the receiving station is, in general, determined by the group frequency at the transmitting station.

Note 3. The term Group Frequency replaces the term "Spark Frequency."

Hysteresis. See Dielectric Hysteresis and Magnetic Hysteresis.

Hot Wire Ammeter. An ammeter dependent for its indications upon the changes in dimensions of an element which is changed in temperature by the passage through it of a current.

Impedance. Total opposition to current flow in a circuit in which the current is varying, and is numerically equal to the square root of the sum of the squares of the ohmic resistance and the total reactance of the circuit.

Impulse Excitation. The term applied to a method of producing free alternating currents of relatively small damping by means of the actual or equivalent removal of a source of highly damped free alternating currents from the coupled secondary circuit. As a special case, the primary current may be very highly damped, but in all cases there must be, in effect, a suppression of reaction between the circuits.

Impulse excitation is obtained in the secondary of two coupled circuits of decrements d_1 and d_2, coupling coefficient k, provided that **either**

(a) k^2 is small compared with $(d_1 d_2 / \pi^2)$, when the primary contains no spark gap, or

(b) thru the use in the primary of a spark discharger the resistance of which increases with time or diminished electromotive force, and the partial fulfillment of condition (a) above.

Note: Under the conditions of impulse excitation:

(1) The decrement of the free alternating current in the secondary circuit is appreciably that of the secondary circuit.

(2) The reaction of the secondary circuit on the primary, at least in so far as the production of the coupling frequencies is concerned, is negligible.

Inductance. That property of a material system by virtue of which it is capable of storing energy electromagnetically.

The inductance of a system is dependent upon its geometrical dimensions and the permeability of the surrounding media. In hysteresis-free circuits, inductance is measured by the ratio of the energy stored in the magnetic field surrounding a current-carrying conductor to the square of the current in that conductor, for stationary conditions. In any circuit, it may be measured by the interlinkage with the system itself of magnetic lines of force due to unit current passing through the system. An alternative method involves the measurement of the counter electromotive force at the terminals of the given conductor when the current through the conductor changes at the rate of one unit of current per second. In hysteresis-free circuits these three methods of measurement yield identical results.

Inductance. See also Mutual Inductance and Self Inductance.

Inductive Coupler. An apparatus which magnetically joins portion of two circuits.

Inductive Reactance. A measure of the opposition to an alternating current produced by the presence of inductance in a circuit, and is numerically equal to the product of the Angular Velocity and the Inductance in the circuit.

Key. A switch arranged for rapidity of manual operation.

Line of Force. A curve described in an electric or magnetic field such that the electric or magnetic force is at all points of that curve tangentially directed to it.

Linear Decrement of a circuit containing a resistance element equivalent to a spark: The difference of successive current amplitudes in the same direction divided by the larger of these amplitudes. (In circuits containing such an element, not the ratio of successive current amplitudes, but their difference is constant, and characteristic of the damping.)

Logarithmic Decrement of a circuit containing inductance, capacity, and constant resistance is one half the ratio of the electrical energy withdrawn from that circuit during a cycle to the total energy present in that circuit at the beginning of the cycle. It also equals the natural logarithm of the ratio of successive current amplitudes in the *same* direction. Note: Logarithmic decrements are standard for a complete period or *cycle.*

Magnetic Field Intensity. The flux density of magnetic lines of force produced by a magnetomotive force in air (or in a vacuum).

Magnetic Force at a point. The force acting on a unit magnetic pole placed at that point. It is numerically equal to the field intensity in a medium of unit permeability.

Magnetic Hystersis. That property of a magnetic medium which is measured by the energy losses, when the rising and falling (magnetomotive force)-(induction), i. e. (H-B), dynamic characteristics are not identical.

Magnetic Hysteretic Constant for a given material. The value of the magnetic hysteresis per cycle per unit induction for that medium.

Magnetic Induction. The magnetic flux density in a magnetic medium.

Magnetomotive Force. A force tending to produce a magnetic flux.

Microphone. An electrical contact, the resistence of which is directly and materially altered by slight mechanical disturbances.

Mutual Inductance of two circuits, each on the other, is that portion of the inductance of one due to the magnetic field common to both.

Oscillograph. A device for continuously indicating the wave form of a varying electrical quantity, e.g., voltage, current, power, etc.

Oscillating Circuit. One in which free alternating currents exist. It therefore contains less than the critical resistance.

Note: *Forced* alternating currents may be produced in circuits containing *any* combination of inductance, capacity and resistance, and resonant effects may be produced in any circuit if all three of the electrical quantities above mentioned are present.

Oscillations. See Alternating Currents, Free and Forced.

Permeability of a medium. The ratio of the magnetic flux density produced in that medium by a given magnetomotive force to the magnetic flux density produced by the same magnetomotive force in vacuum (or for practical purposes, in air).

Potential. See Electric Potential.

Radiation Resistance is the difference between the apparent total antenna resistance and the sum of all resistances which give rise to measurable dissipative energy losses, at a given wave length. This quantity is to be distinguished from antenna resistance.

Radio Communication. The radio transmission of intelligible signals.

Radio Frequencies. Those above 20,000 cycles per second. See also Audio Frequencies.

It is not implied that radiation cannot be secured lower frequencies and the distinction from audio frequencies is merely one of convenence.

Radio Frequency Resistance of a conductor. The ratio of the heating in watts to the square of the R.M.S. current in the conductor.

Radiogram. A message sent by radio communication.

Radio Telegraphy and Radio Telephony. Further divisions of radio communication. It is proposed that the term "wireless" shall be entirely eliminated, as inaccurate and inappropriate.

Reactance, (Total of a Circuit) is measured by the algebraic sum of the capacity reactance and the inductive reactance. See also Capacity Reactance and Inductive Reactance.

Reactance Coil or **Reactor.** A form of stationary induction apparatus used to supply reactance or produce phase displacement. (It is essentially an inductive resistor.)

Rectifier. A device which, when supplied with alternating current deliver unidirectional current.

Relay Key. An electrically operated key or switch.

Reluctance of a magnetic path determines the magnetic flux produced by a given magnetomotive force, and is numerically equal to the ratio of the second of these quantities to the first.

Resistance. The measure of that property of a conductor by the action of which electrical energy is transformed into heat in that conductor. It is numerically equal to the ratio of the heat energy liberated per second, measured in watts, to the square of the current in the circuit, for stationary conditions; it is also equal to the ratio of the applied electromotive force to the resulting current, both being constant.

Resonance to an Alternating Current at a given frequency. That circuit condition in which the inductive reactance at that frequency is numerically equal to the capacity reactance at that frequency; that is, the apparent reactance is zero.

Resonance Curve gives the relation between circuit energy, current, or voltage at various frequencies of excitation as a function of those frequencies.

A Standard Wave Length Resonance Curve. One wherein the abscissas are ratios of specified wave lengths to the resonant wave length, and the ordinates are ratios of the energy (or square of the current) at corresponding specified wave lengths to the energy (or square of the current) at the resonant wave length. The scale of ordinates and abscissas shall be equal.

A Standard Frequency Resonance Curve. One wherein the abscissae are ratios of specified frequencies to the resonant frequency, and the ordinates are ratios of the energy (or square of the current) at corresponding specified frequencies to the energy (or square of the current) at the resonant frequency. The scales of ordinates and abscissae shall be equal.

A Standard Resonance Curve, unless otherwise specified, is assumed to be a standard wave length resonance curve.

Resonance: See Sharpness of Resonance.

R. M. S. (Root-Mean-Square) Value of a current or electromotive force: the square root of the mean value of the squares of the instantaneous values of the current or electromotive force for any given number of cycles. The R. M. S. value of an alternating current is also the value of that direct current which produces an equal heating effect when flowing for the same time.

Selecting. The process of adjusting an element driven by a plurality of simultaneous impulses, until the ratio of desired response to undesired response is a maximum.

Selectivity of a driven element is a maximum when its damping is a minimum consistent with the use of the given indicator.

Self Inductance of a circuit. That portion of the inductance which is due to the magnetic field produced by the current in that circuit. See also Inductance.

Sharpness of Resonance of a circuit of logarithmic decrement d_2 coupled to one of decrement d_1 is defined as

$$2\pi / (d_1 + d_2).$$

It is a measure of the steepness of the resonance curve obtained from the secondary circuit. It is also a measure of the amount of detuning necessary to secure a halved-squared-current value, at very loose couplings. In circuits having linear decrements, d_1 and d_2 must be taken at the average value of the logarithmic decrements.

Skin Effect of varying currents. The non-uniform current density thru the cross section of the conductor.

Space Waves. Electromagnetic waves in a homogeneous insulator. Their distinguishing characteristic is that their energy varies inversely with the square of the distance from the source for distances great in comparison with the wave length, neglecting absorption.

Spark (or Arc) A body of ionised (and therefore conducting) gas which permits and accompanies a disruptive electric discharge. There is no sharp line of demarcation between arcs and sparks. See also Effective Resistance of a Spark.

Static Characteristic of an Arc. The relation given by the curve plotted between the impressed electromotive force and the resultant current thru the arc for substantially stationary conditions.

Surface Density of Electrification at any point of a surface is the charge of electricity per unit area at that point.

Surface Waves. Electric waves which follow the surface of a conductor.

Their distinguishing characteristics are

(a) That if they radiate over a plane sheet, at considerable distances their energy varies inversely with the distance, neglecting medium absorption, and

(b) That they are subject to medium absorption, that is, dissipation of their energy thru its conversion into heat in the guiding conductor.

Sustained Radiation consists of electromagnetic waves of constant amplitude (such as are emitted from an antenna in which flows a forced alternating current).

Transformer. A stationary induction apparatus which changes electric energy in a primary coil into electric energy in a secondary coil thru the medium of magnetic energy. As applied in radio engineering, it should refer exclusively to the so-called "power transformer."

Tuning. The process of securing the maximum indication by adjusting the time period of a driven element. (In transmitter or receiver.)

Waves: See Surface Waves and Space Waves.

Wave Length. The shortest distance between two points in a sustained plane wave group or train such that magnitude and rate of change of magnitude of the disturbances at those points are completely identical. In general, it is twice the distance between a point of zero disturbance and the next point of zero disturbance. Wave length should always be expressed in meters.

Wave Meter. A radio frequency measuring instrument calibrated to read wave lengths.

LITERAL SYMBOLS.

1. (Symbols arranged alphabetically).

Units used should be those of PRACTICAL SYSTEM, e. g., the volt, ampere, ohm, henry, farad, etc., and their multiples and submultiples. The inductances and capacities in radio frequency circuits should be normally expressed in microhenrys and microfarads respectively.

a	Damping Factor (that is, R/2L) (Time reciprocal)
A	Attenuation Coefficient (Distance Reciprocal)
A_f	Audibility Factor
b	Linear Decrement (Numeric)
B	Magnetic Induction
c	Capacity (at audio frequencies) (Farads)
C	Capacity (at radio frequencies) (Farads)
C_d	Distributed Capacity (Farads)
d	Logarithmic Decrement (that is, RT/2L) (Numeric)
e	Instantaneous Value of Voltage. May also be used for E. M. F. of individual cells of a battery or accumulator, etc.) (Volts)
E	R. M. S. Value of Voltage (Volts)
E_m	Maximum Value of Voltage, (Amplitude) (Volts)
E_R	Resonance Voltage (Volts)
EFF	Efficiency (Numeric)
h	Effective Height of Antenna (Meters)
ht	Actual height (e. g. of antenna) (Meters)
H	Magnetic Force (Gilberts per cm.)
i	Instantaneous Value of Current (Amperes)
I	R. M. S. Value of Current (Amperes)
I_m	Maximum Value of Current (Amplitude) (Amperes)
I_R	Resonance Current (Amperes)
I_r	Received Current (Amperes)
I_s	Transmitting (Atenna) Current
j	$\sqrt{-1}$
k	Coefficient of Inductive Coupling (that is, $\frac{M}{\sqrt{L_1 L_2}}$) (Numeric)
K	Dielectric Constant (Specific Inductive Capacity)
k_c	Coefficient of Capacity Coupling (Numeric)
l	Inductance (at audio frequencies) (Henrys)
L	Inductance (at radio frequencies) (Henrys)
L_d	Distributed Inductance (Henrys)

M	Coefficient of Mutual Inductance (Henrys)
n	Frequency, in complete cycles
N	Group Frequency (e. g., sparks per second)
p	Instantaneous Value of Power (Watts)
P	Mean Value of Power (Watts)
PF	Power Factor (Numeric)
Q	Quantity of Electricity (Coulombs)
r	Resistance (at audio frequencies) (Ohms)
R	Resistance (at radio frequencies) (Ohms)
R_a	Apparent Total Antenna Resistance (Ohms)
R_f	Radiation Resistance (Ohms)
s	Distance (between stations, e. g.) (Km.)
t	Time (as a variable) (Seconds)
T	Period of one Cycle or Complete Oscillation (Seconds)
W	Energy (Joules, or Watt-hours)
W_e	Electrical Energy (Joules, or Watt-hours)
W_m	Magnetic Energy (Joules, or Watt-hours)
X	Reactance. (When X is positive, it denotes preponderance of inductive reactance, and when X is negative it denotes preponderance of capacity reactance.) Reactance always equals $2\pi nL—(1—/2\pi nC)$
Z	Impedance (It is the square root of the sums of the squares of the resistance and the reactance of a circuit.) R + $jL\omega$ represents inductive impedance and R - $(j/C\omega)$ represents impedance containing capacity reactance component. (Ohms) $Z = \sqrt{R^2 + \left(L\omega - \frac{1}{\omega C}\right)^2}$
α	Form Factor (of antennae) (Numeric)
μ	Permeability
μa	Microampere
μv	Microvolt
μw	Microwatt
μh	Microhenry
μf	Microfarad

(In general, the prefix μ shall indicate "Micro," and the letter "m," used as a prefix, shall indicate "milli.")

λ	Wave Length (Meters)
ϕ	Magnetic Flux (Maxwells)
ω	Angular Velocity, that is 2π times the frequency (Radians per second.)

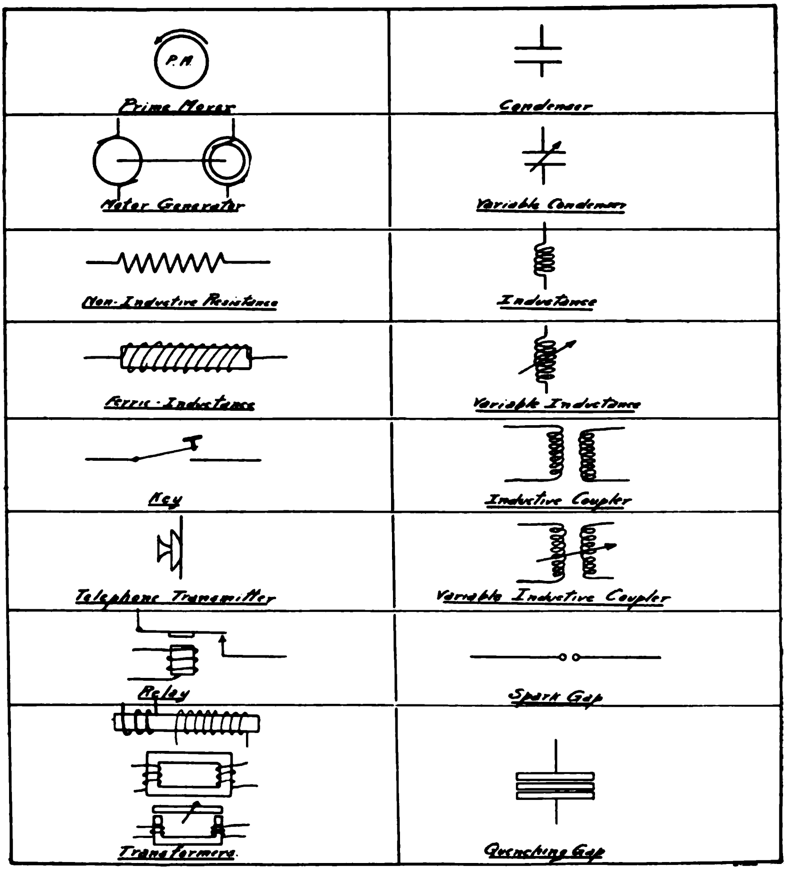
LITERAL SYMBOLS.

2. (*Arranged alphabetically according to the terms symbolized*).

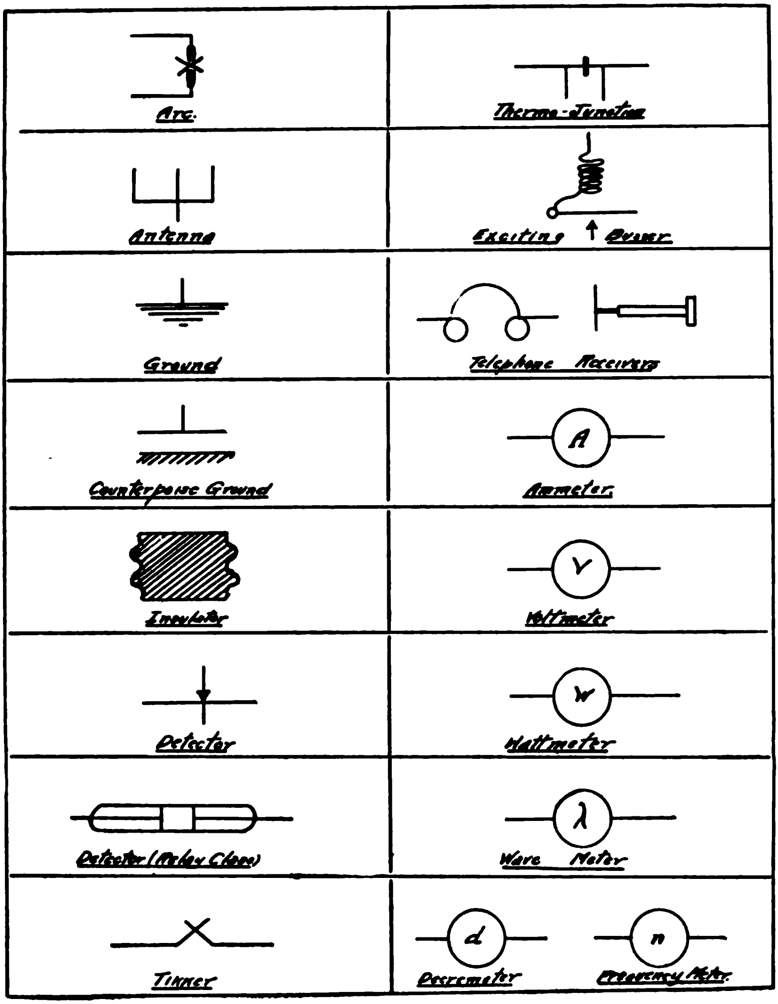
ht	Actual Height (e. g. of antenna) (Meters)
ω	Angular Velocity, that is 2π times the frequency. (Radians per second.)
R_a	Apparent Total Antenna Resistance (Ohms)
A	Attenuation Coefficient (Distance reciprocal)
A_f	Audibility Factor
c	Capacity (at audio frequencies) (Farads)
C	Capacity (at radio frequencies) (Farads)
k_c	Coefficient of Capacity Coupling (Numeric)
k	Coefficient of Inductive Coupling (that is, $\frac{M}{\sqrt{L_1 L_2}}$) (Numeric)
M	Coefficient of Mutual Inductance (Henrys)
a	Damping Factor, (that is, R/2L) (Time reciprocal)
K	Dielectric Constant (Specific Inductive Capacity)
s	Distance (between stations, e. g.) (Km.)
C_d	Distributed Capacity (Farads)
L_d	Distributed Inductance (Inductance)
h	Effective Heights of Antenna (Meters)
EFF	Efficiency (Numeric)
W_e	Electrical Energy (Joules, or Watt-hours)
W	Energy (Joules, or Watt-hours)
δ	Form Factor (of antennae) (Numeric)
n	Frequency, in complete cycles
N	Group Frequency (e. g., sparks per second)
Z	Impedance (It is the square root of the sums of the squares of the resistance and the reactance of a circuit). R + jLω represents inductive impedance and R- (j/Cω) represents impedance containing a capacity reactance component. (Ohms) $Z = \sqrt{R^2 + \left(L\omega - \frac{1}{\omega C}\right)^2}$
i	Instantaneous Value of Current (Amperes)
p	Instantaneous Value of Power (Watts)
e	Instantaneous Value of Voltage (May also be used for E. M. F. of individual cells of a battery or accumulator, etc.) (Volts)

l	Inductance (at audio frequencies) (Henrys)
L	Inductance (at radio frequencies)
b	Linear Decrement (Numeric)
d	Logarithmic Decrement (that is RT/2L) (Numeric)
W_m	Magnetic Energy (Joules, or Watt-hours)
ϕ	Magnetic Flux (Maxwells)
H	Magnetic Force (Gilberts per cm.)
B	Magnetic Induction
I_m	Maximum Value of Current (Amplitude), (Amperes)
E_m	Maximum Value of Voltage (Amplitude), (Volts)
P	Mean Value of Power (Watts)
μa	Microampere
μf	Microfarad
μh	Microhenry
μv	Microvolt
μw	Microwatt
T	Period of one Cycle or Complete Oscillation (Seconds)
μ	Permeability
PF	Power Factor (Numeric)
Q	Quantity of Electricity (Coulombs)
R_f	Radiation Factor (Ohms)
X	Reactance. (When X is positive, it denotes preponderance of inductive reactance, and when X is negative it denotes preponderance of capacity reactance.) Reactance always equals $2\pi nL—(1/2\pi nC)$
r	Resistance (at audio frequencies) (Ohms)
R	Resistance (at radio frequencies) (Ohms)
I_r	Received Current (Amperes)
I_R	Resonance Current (Amperes)
E_R	Resonance Voltage (Volts)
I	R. M. S. Value of Current (Amperes)
E	R. M. S. Value of Voltage (Volts)
j	Square root of minus one ($\sqrt{-1}$)
t	Time (as a variable) (Seconds)
I_s	Transmitting (Antenna) Current
λ	Wave Length (Meters)

GRAPHICAL SYMBOLS.



GRAPHICAL SYMBOLS.



TESTS AND RATING.

The Committee on Standardization has further planned a series of preliminary recommendations relating to testing and rating apparatus for radio transmission. This work is in progress, and will be further reported in the future. The two following rules are, however, of sufficient importance to warrant submitting them to the radio engineering profession for immediate criticism and suggestion.

1. All radio transmitting sets shall be rated in actual power output measured in the antenna.

The Committee is aware of some of the theoretical and practical difficulties involved in making a measurement of the actual power output in an antenna, but is convinced that they are far from sufficient to justify discarding this unquestionably just method of rating. The group or audio frequency of the note of the station should be stated as well, (except for sustained wave sets, where that characteristic should be mentioned).

2. The over-all efficiency of a radio transmitting station shall be the quotient of the actual power* output measured in the antenna to the power* input supplied to the first piece of electrical machinery which is definitely a part of the radio equipment.

* Or the corresponding total energy, as explained below.

Examples of the application of this rule are the following: (a) A ship station. Direct current is supplied from the ship's mains to a motor generator set, which furnishes alternating current to the high tension transformer of the radio set. The ratio of power in the antenna to power supplied to the motor of the motor generator set and to the auxiliary radio equipment (e. g., blower motors, rotary gap motors) is the over-all efficiency.

(b) An auxiliary ship station. Storage batteries are charged from the ship's mains, and operate a motor generator set or an induction coil. The over-all efficiciency is the ratio of the kilowatt-hours supplied to the storage battery for a full charge to the kilowatt- hours delivered by the antenna circuit during the complete time of discharge. The energy ratio, rather than the power ratio, is here required, because of the method of storing energy in such batteries. It may be conveniently measured by the ratio of (kilowatt-hours on discharge of the storage battery to kilowatt-hours on charge) multiplied by the ratio of (power delivered in the antenna to power supplied by the storage battery to the radio equipment.) This method is closely approximate.

(c) A land station. High voltage alternating current (2,200 volts, for example) is supplied to the station from local power mains. This is stepped down to operate a motor generator set which supplies current of the definite type desired for the station. The over-all efficiency is the ratio of the power output of the antenna to the power supplied by the step-down transformer. If the step down transformer feeds other electrical machinery or apparatus not a part of the radio equipment, (e. g., lamps), the power supplied to such apparatus shall be subtracted from the total power supplied by the step-down transformer when calculating the over-all efficiency. If the motor generator in question is used to charge storage batteries which operate the station, an energy ratio, somewhat as in case (b) above, must be taken instead of the power ratio.

(d) A land station. A large steam engine operates directly or indirectly an audio or radio frequency alternator which supplies current to the radio station exclusively. The over-all efficiency is the ratio of the power output in the antenna to the brake kilowatts of the engine driving the alternator.

(e) A land station. A steam or gasoline engine drives a high voltage direct current generator which feeds directly or indirectly arcs or special gap discharges in the station. The ratio of the antenna power to the brake kilowatts of the engine is the over-all efficiency, (under similar conditions to those of (c) above.)