THE

RADIO REVIEW

A MONTHLY RECORD OF SCIENTIFIC PROGRESS IN RADIOTELEGRAPHY AND TELEPHONY

VOL. I OCTOBER, 1919 No. 1

Editor:

PROFESSOR G. W. O. HOWE, D.Sc., M.I.E.E.

Assistant Editor:

PHILIP R. COURSEY, B.Sc., A.M.I.E.E.

CONTENTS.

Two Shillings and Sixpence Net

THE
RADIO REVIEW

VOL. I OCTOBER, 1919 NO. 1

On the Goniometric Functions Applicable to Directive Aerials.

BY A. BLONDEL.

INTRODUCTION.

THE principle of the use of two adjacent antennæ to form loop aerials for directional waves has been known some considerable time.* These groups of two aerials have been used since 1902, in their simple form by the author, and in the form of a combination of two pairs of antennæ placed perpendicularly to one another by MM. Bellini and Tosi.

On the other hand, the author has also introduced the use of closed circuits equivalent to two aerials connected by junction wires at their upper and lower points. These separate systems have been put forward as means for determining at the receiving station the direction of the station from which the waves are being received. It has been proposed especially to allow ships to receive signals sent out by these directional stations ("*radiophares*"), such as have already been installed by the Service des Phares Français, between 1911 and 1913, at the instigation of the author. Similar receiving apparatus was also installed about the same time on the Marconi Company's ships.

* The construction of simple frame aerials of two adjacent antennæ, such as are considered here, was described for the first time by the author in 1902 (British Patent 15527, July 11th, 1902); in the same patent is described the use of a closed frame for radio-goniometric purposes,

B

MM. Bellini and Tosi have installed at Boulogne-sur-Mer, at Havre, and other places, fixed radiogoniometric stations capable of telegraphing their bearings to ships at sea.*

The International Convention of London, in 1911, fixed a maximum wave length of 150 metres for signals of this class.

Without wishing to discuss in what follows the respective advantages of the different radiogoniometric systems on land or on ships, it is proposed to indicate the manner in which the phase differences of the electromotive forces induced in the two vertical or nearly vertical parts of the measuring aerial necessitate important corrections, when the dimensions of the loop or frame are not very small compared with the wave length employed. The mathematical relations which indicate these corrections will be called the *goniometrical functions* in the following article.† It is interesting to study them in order to realise the difficulties which attend the use of short wave lengths in radiogoniometric work.

General Definition of Directional Aerials whose Goniometric Functions are to be Examined.

Although the system which is most favoured at present is the closed loop or frame aerial arrangement, I will consider the case of open aerial systems, in order to make this investigation as general as possible.

Aerial systems comprising two adjacent antennæ arranged in

---

and the author has described with some detail in German Patent 237486, January 15th, 1910, and in the descriptions of the apparatus shown by the Service des Phares at the Franco-British Exhibition, 1908, the use of these frames closed by a condenser, and the results obtained in experiments carried out aboard ship with the co-operation of General Ferrié and Commandant Brenot.

In March, 1910, the author took up with Commandant Brenot the study of these closed frames composed of several turns oscillating at their natural frequency, the circuit being closed by a condenser. The dimensions of these frames necessary to secure sufficient sensitiveness were unfortunately too large, but in October, 1915, General Ferrié had the happy inspiration of combining an amplifier with these frames, so as to obtain a considerable increase in the sensitiveness and at the same time to reduce the dimensions of the frame so that it could be easily turned round on a fixed axis. Radio-goniometers with small frames have entered into current practical use since that date, but they are not the object of the present article, which is confined to the previous type of construction.

* More recently M. Bellini has invented a very ingenious system of electrostatic excitation of double aerials.

† The subject of the investigation is limited to the determination of the goniometric functions for continuous and for damped waves; we shall not deal here with the other corrections, often very important, which arise through earth capacity or capacity to neighbouring objects, nor with corrections arising from the construction of the moving part of the radio-goniometers, nor with corrections arising from induced currents in the hull or other metal parts of the vessels, or in any other aerials fixed on the same ship.

the same vertical plane, at a distance $2x$ (less than, or equal to, a half wave length), and brought into resonance (by means of loading inductances or capacities in series) with the frequency of the waves to be received, may be of two different types, according to the mode of connection; these are :—

(1) *Type "D" (Differential)*, in which the inductive effects of the aerials on the receiving circuit are opposed when the aerials are in the plane of the waves. The resultant induced current is a maximum when the plane of the loop coincides with the direction of propagation of the waves and is a minimum when it is perpendicular to that direction.

(2) *Type "S" (Additive)*, in which the inductive effects on the receiving circuit are additive. The positions of maximum and minimum induced current are the inverse of those of the first type.

The loop aerial with several turns can be treated in the same manner as type "D" by multiplying the electromotive forces induced in the two vertical portions of the aerial by the number of turns on the frame.

In order to simplify matters, I will assume that the waves are being propagated along the surface of the sea, and that, in consequence, there is no horizontal component of the E.M.F. vector, such as has been shown by Zenneck to exist in the case of propagation along the ground. We are therefore justified in neglecting all the horizontal connections between the antennæ and, when dealing with oblique parts, considering the vertical component only of the electric force.

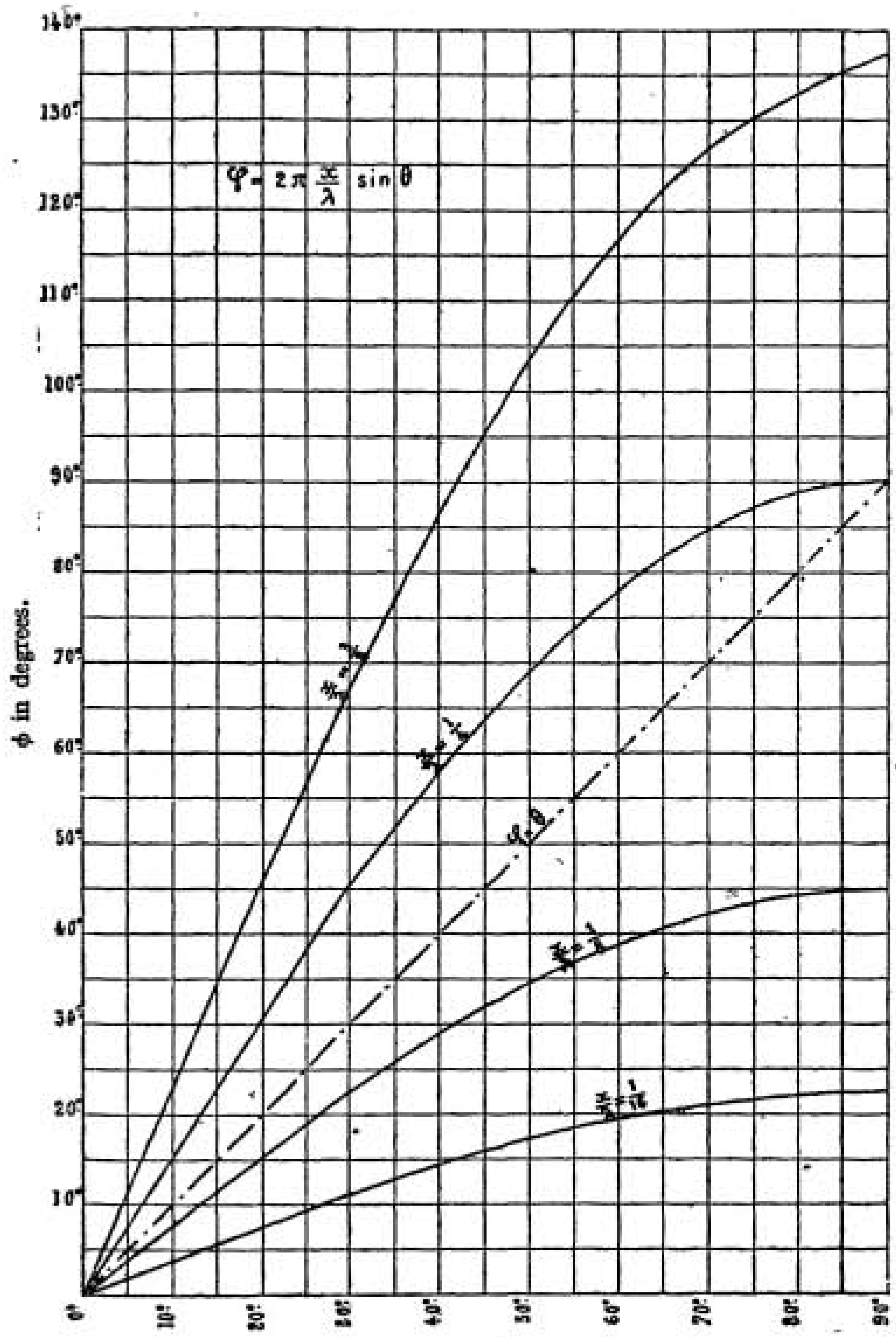
Principle of the Methods.

With the above assumptions it is necessary to distinguish between two methods of determining the direction of the waves, using either of the above types of aerial :—

(1) *The zero method* consists in determining the position of maximum and minimum current as indicated by the detector. The two directions corresponding to the minimum audibility in the telephones are determined, and the angle between them bisected. The accuracy of the measurements diminishes, however, as will be shown later, when the plane of the loop aerial approximates to the direction of propagation of the waves.

B 2

(2) *The comparison method* is based upon the comparison of the currents induced in two or more loop aerials fixed at known angles to one another.* This necessitates a previous knowledge



θ in degrees.

Fig. 1.

of the laws governing the variation of current in the aerial with the direction of the incident waves. For simplicity I shall call this law the "goniometrical function," and represent it by gon θ, where θ is the angle between the plane of the loop and the horizontal line perpendicular to the direction of propagation of the waves.

* *Compare* German patent No. 237456, January 15th, 1919.

I. GONIOMETRICAL FUNCTIONS USING CONTINUOUS WAVES.

If continuous waves of wave length λ are being received and we neglect the transitory effect at the commencement of the signal, it is easy to determine the respective goniometrical functions of the two types of aerial systems. Let $e_0 = E \sin \omega t$ represent the E.M.F. induced in an imaginary simple aerial, placed at the central vertical axis of the loop, and having the same constants as each of the real aerials. This aerial is supposed to act on the detector by means of an imaginary jigger similar to the real jiggers. Let $F(e_0)$ represent the effect on the receiving instrument, F being the function depending on the properties of the detector, in accordance with the most generally accepted hypothesis.

Let the two antennæ of the aerial system be distant x and $-x$ from the imaginary central aerial, and let all the circuit constants be the same, then $F(e_0)$ will be replaced by $F(e_1 - e_2)$ for loops of type D, and by $F(e_1 + e_2)$ for type S loops.

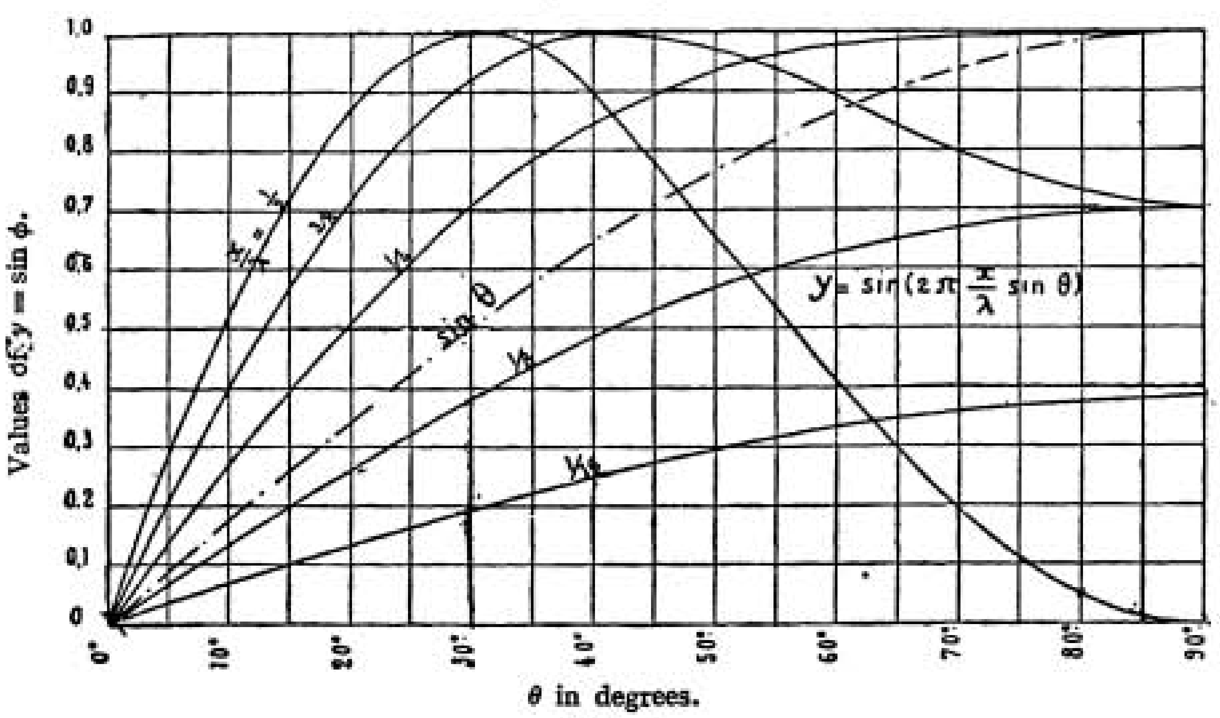


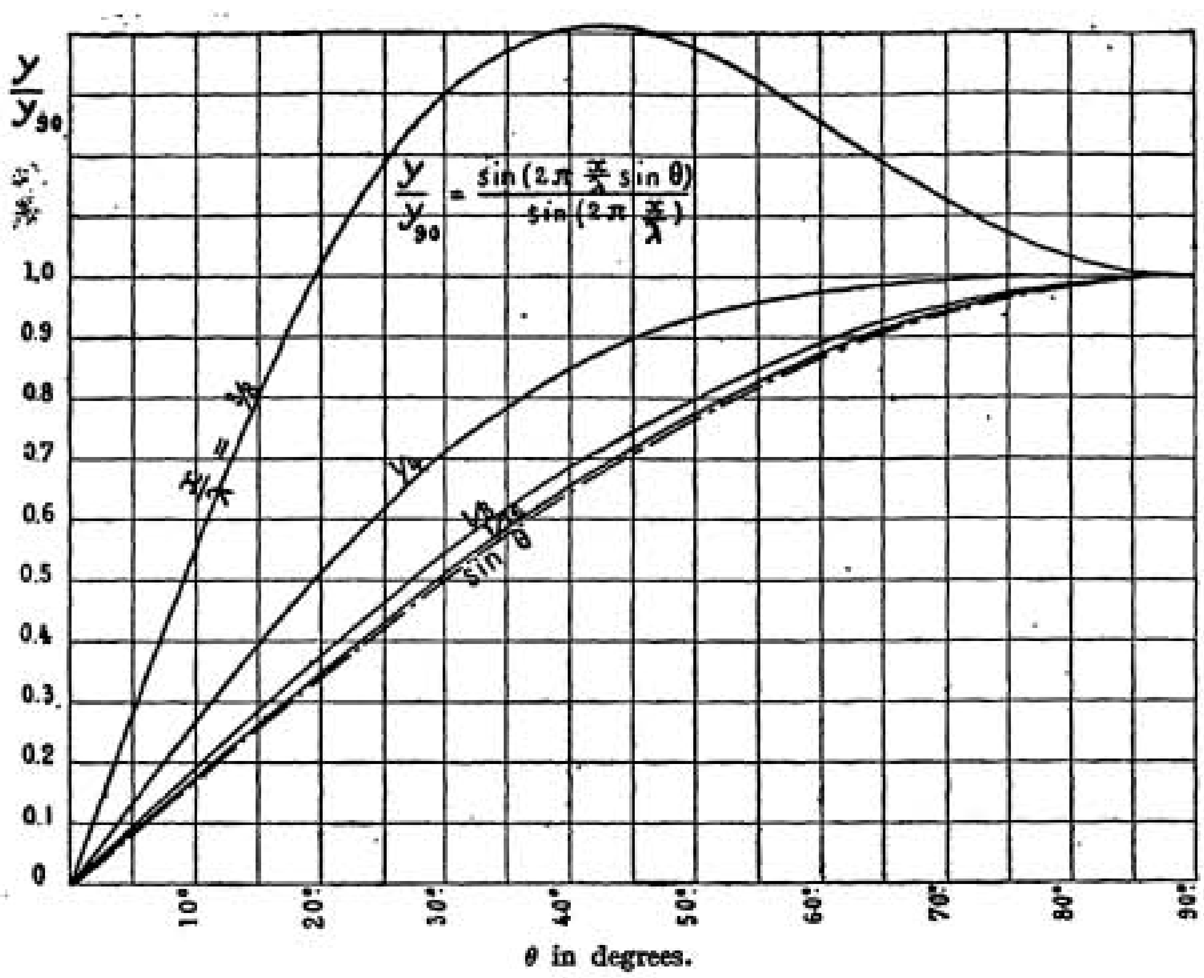
FIG. 2.

Thus putting $\xi = \frac{x \sin \theta}{\lambda}$, and $\phi = \frac{2\pi x \sin \theta}{\lambda}$, we have,

Type D: $e_1 - e_2 = 2e_0 \sin 2\pi\xi = 2e_0 \sin \phi$; . . (1)

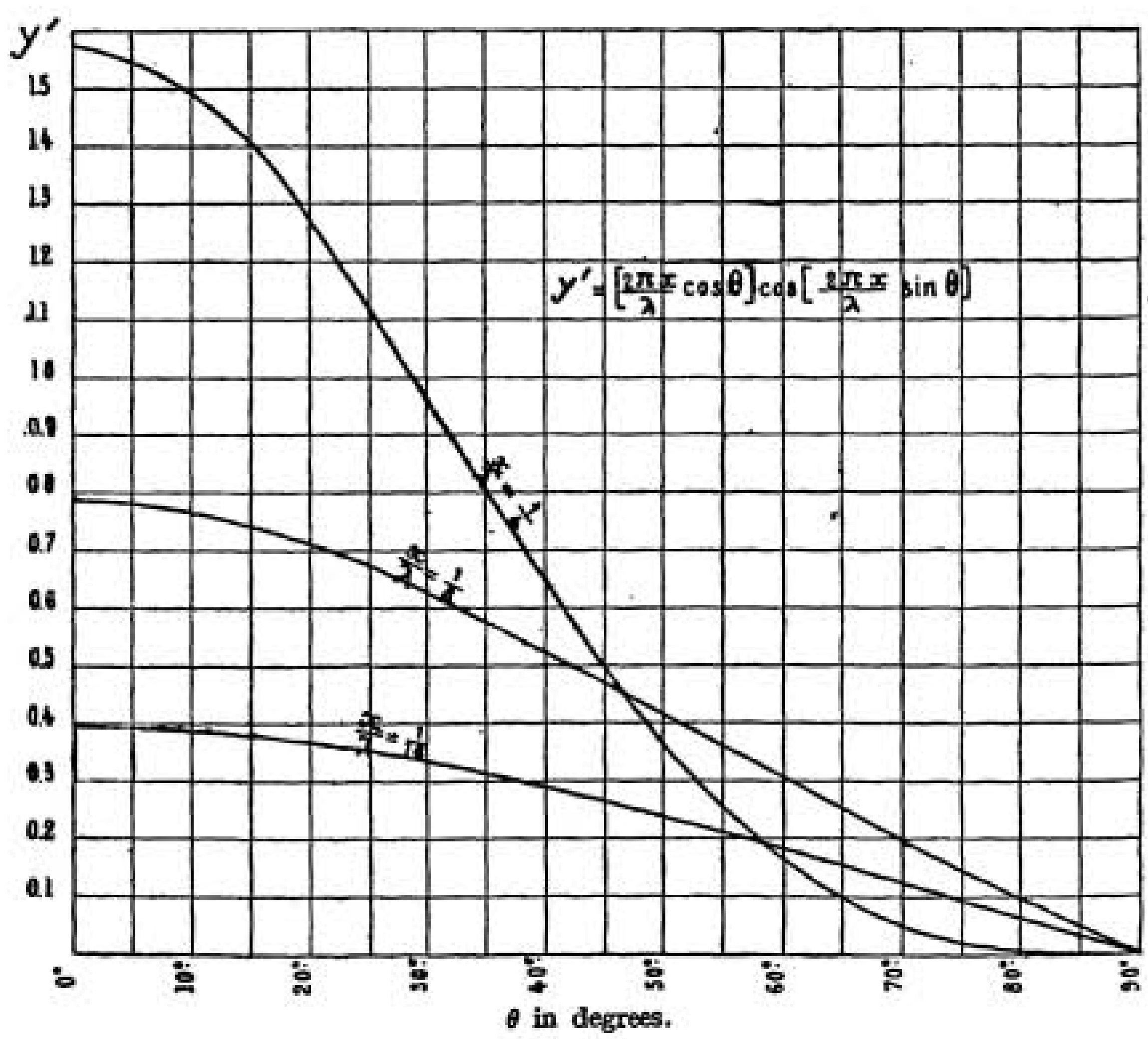
Type S: $e_1 + e_2 = 2e_0 \cos 2\pi\xi = 2e_0 \cos \phi$ . . (2)

The functions gon θ, relating to the two types of loop, are obtained by dividing these expressions by $2e_0$. They are purely geometric functions, independent of the absolute value of the



$\frac{y}{y_{90}}$
$\frac{y}{y_{90}} = \frac{\sin(2\pi\frac{x}{\lambda}\sin\theta)}{\sin(2\pi\frac{x}{\lambda})}$
sin θ
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
10°
20°
30°
40°
50°
60°
70°
80°
90°
θ in degrees.

FIG. 3.

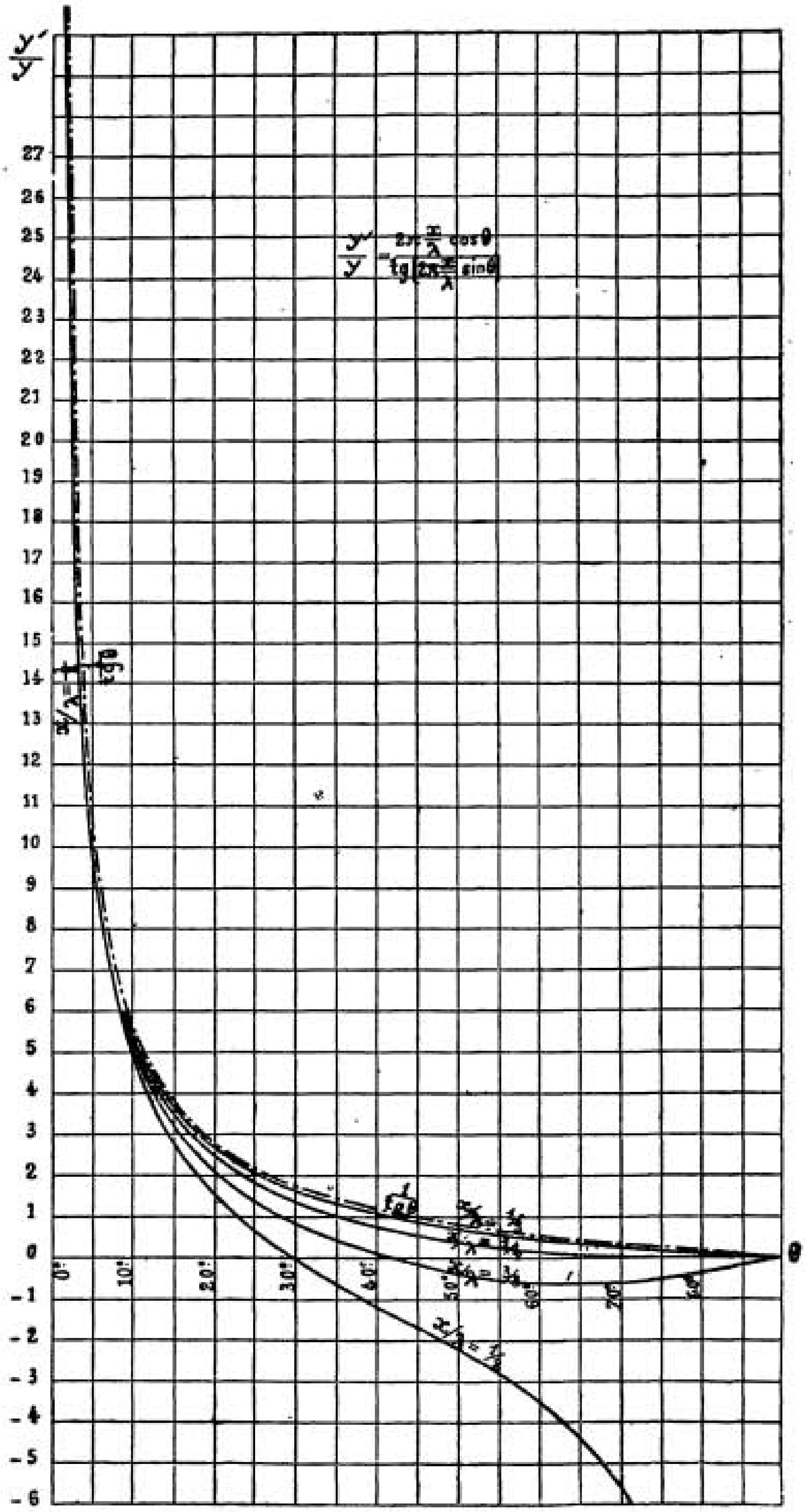


y′
$y' = \left[\frac{2\pi x}{\lambda}\cos\theta\right]\cos\left[\frac{2\pi x}{\lambda}\sin\theta\right]$
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0°
10°
20°
30°
40°
50°
60°
70°
80°
90°
θ in degrees.

FIG. 4.

E.M.F., *i.e.*,

$$\text{gon}_D\ \theta = \sin\phi \quad . \quad . \quad . \quad . \quad . \quad (3)$$
$$\text{gon}_S\ \theta = \cos\phi \quad . \quad . \quad . \quad . \quad . \quad (4)$$



θ in degrees.

Fig. 5.

Figs. 1 to 8 review graphically the properties of the two types (D and S) of aerials.

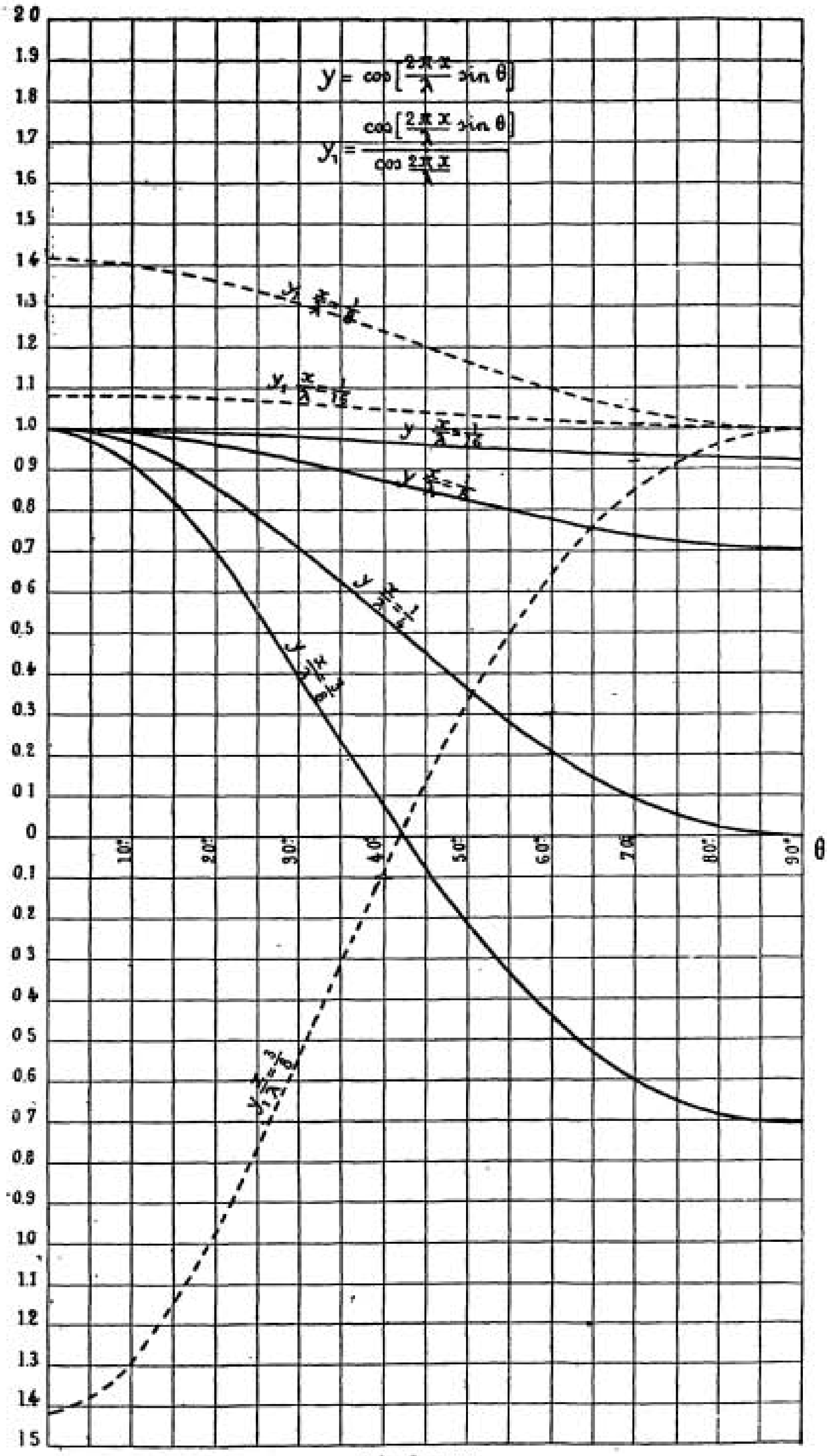


Fig. 6.

Fig. 1 shows the variation of ϕ as a function of θ for different values of the ratio $\frac{x}{\lambda}$; Fig. 2 gives the variation of $\sin \phi$, and Fig. 3 the variation of the ratio of $\sin \phi$ to its value when $\theta = 90°$.

Fig. 4 shows the value of the differential y' of $\sin \phi$, a derivative which gives an idea of the sensitiveness of measurement. When an energy integrating detector is used, the sensitiveness is proportional to $2yy'$, and can be obtained by multiplying together the ordinates of the two preceding curves.

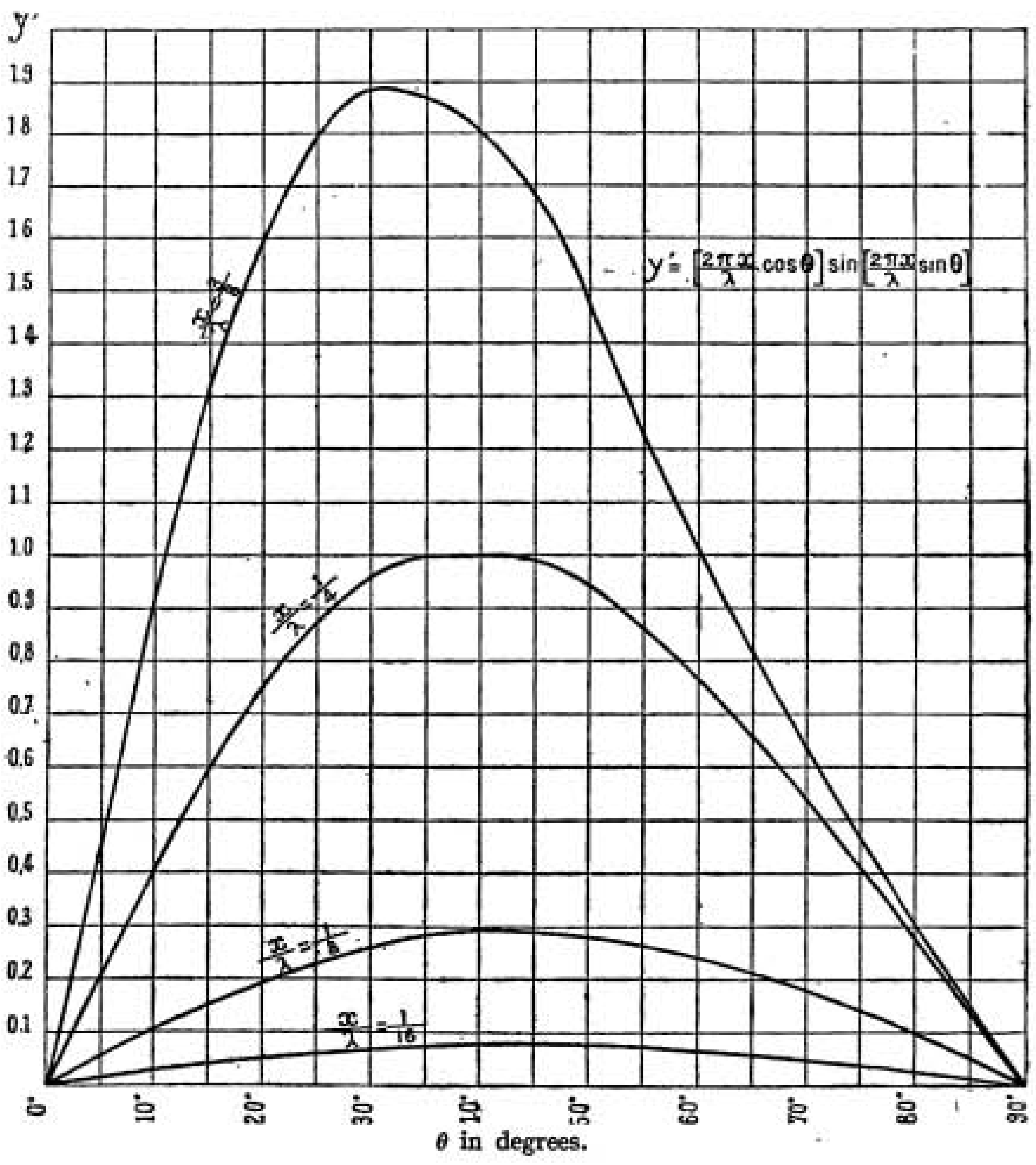
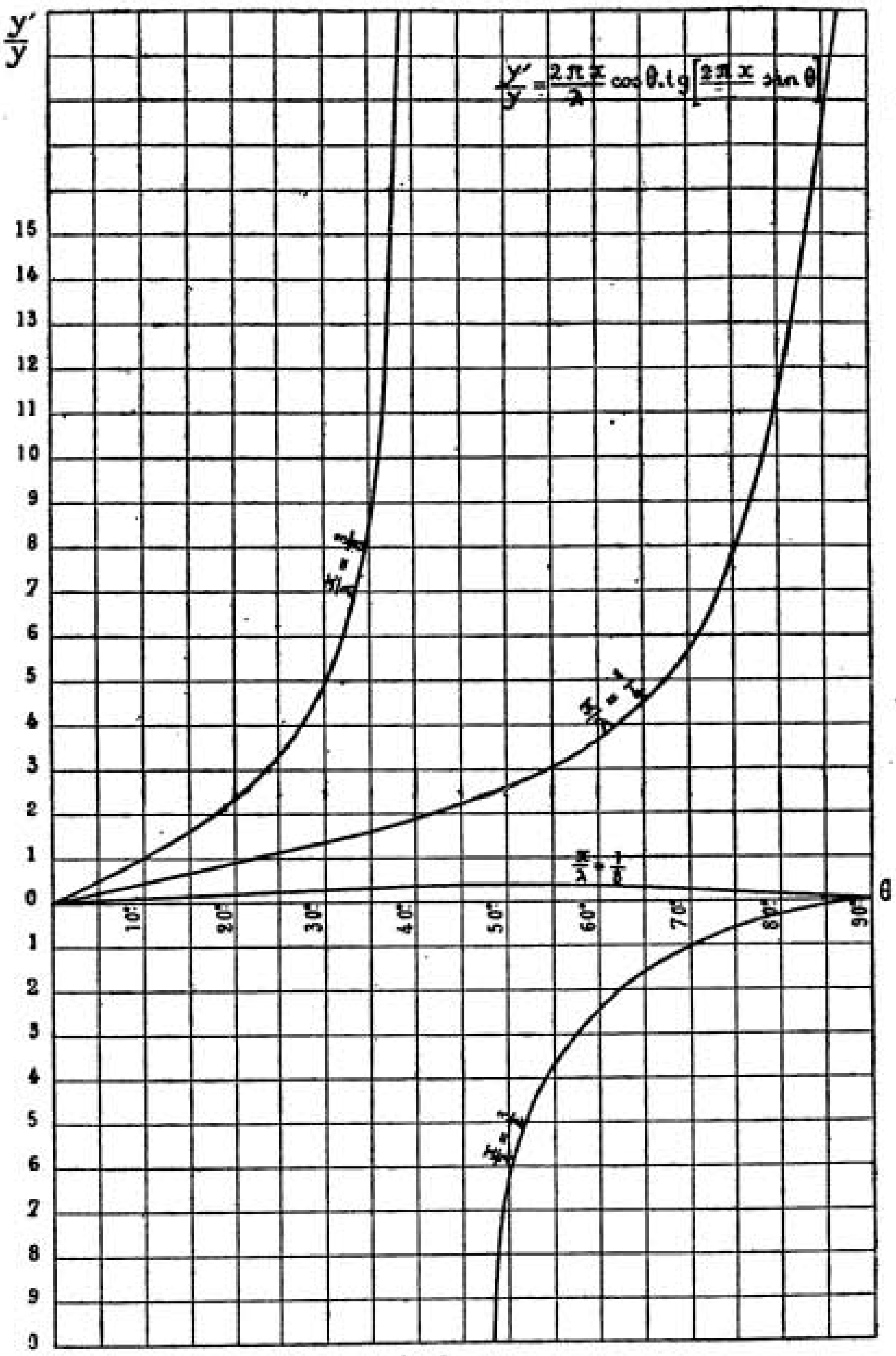


Fig. 7.

Fig. 5 gives the relative sensitiveness ratio, that is, the logarithmic derivative y'/y. For an energy integrating detector this derivative becomes $2y'/y$.

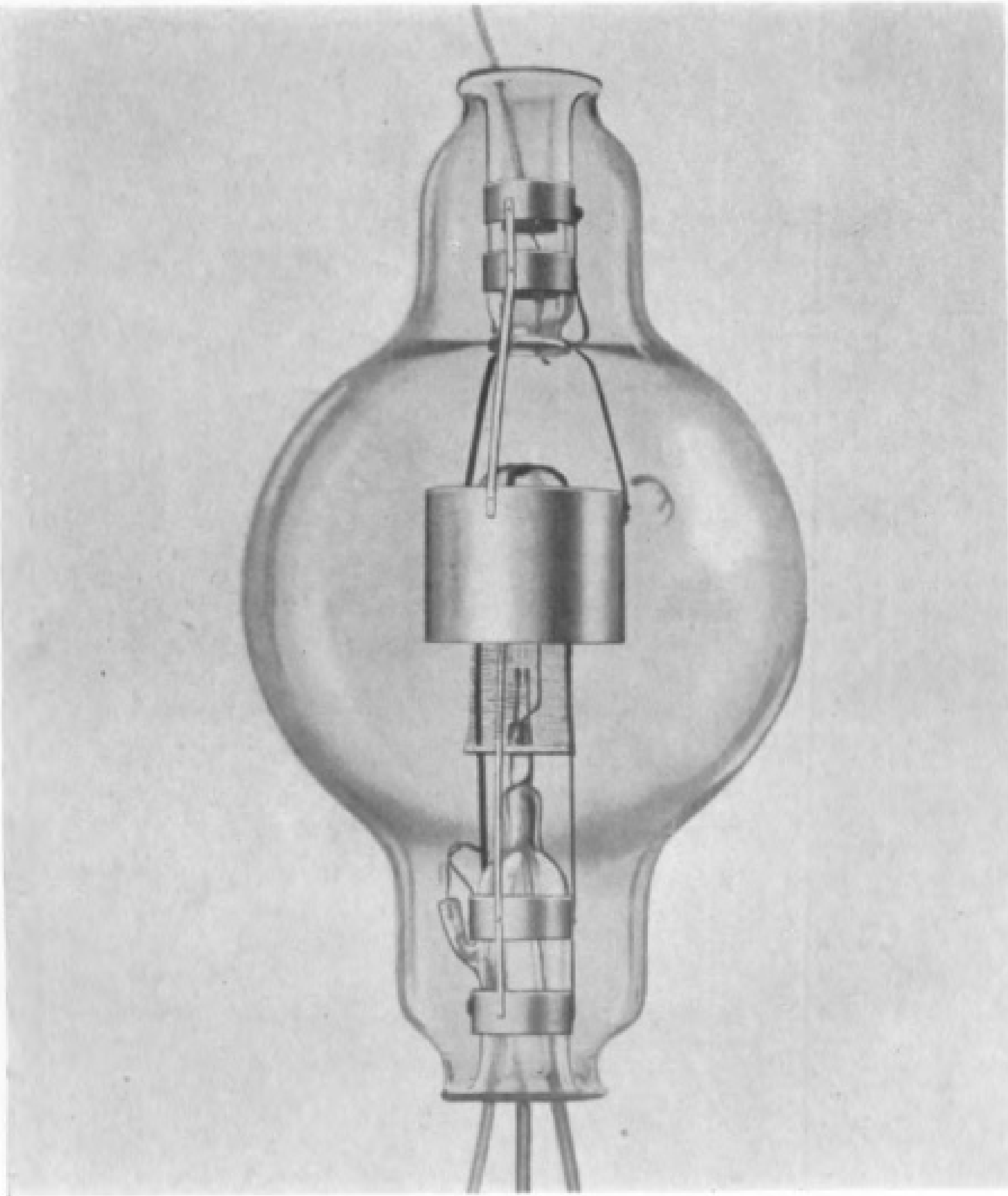
Figs. 6, 7 and 8 give corresponding values of y, y' and y'/y for the case of S type loops. It will be seen from these curves that the properties of the two types of loop aerial are altogether different, and do not show to the advantage of the S type, since in the latter case y' always becomes zero, not only when $\theta = 90°$ but also when $\theta = 0$.



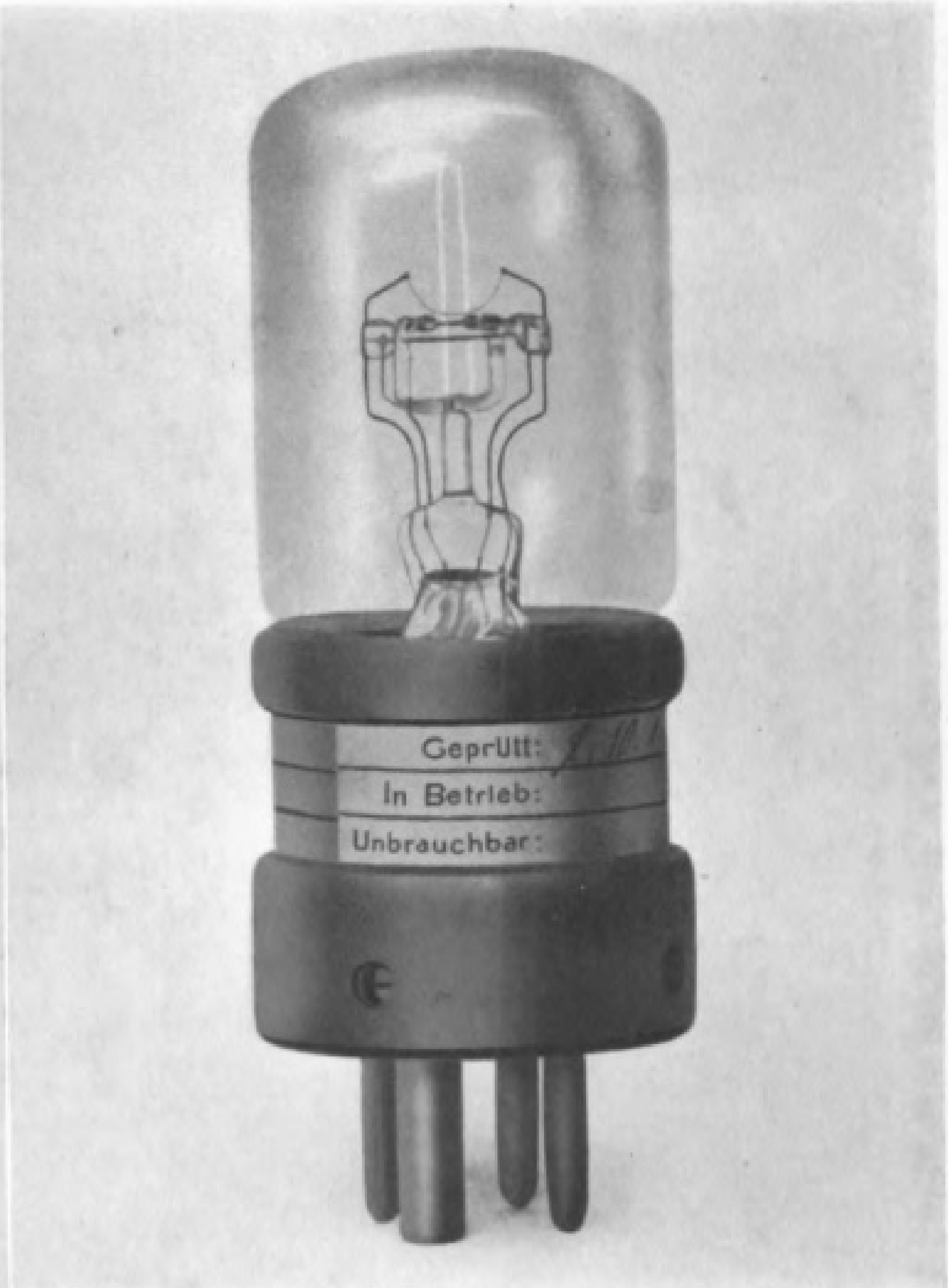
θ in degrees.

FIG. 8.

(To be continued.)

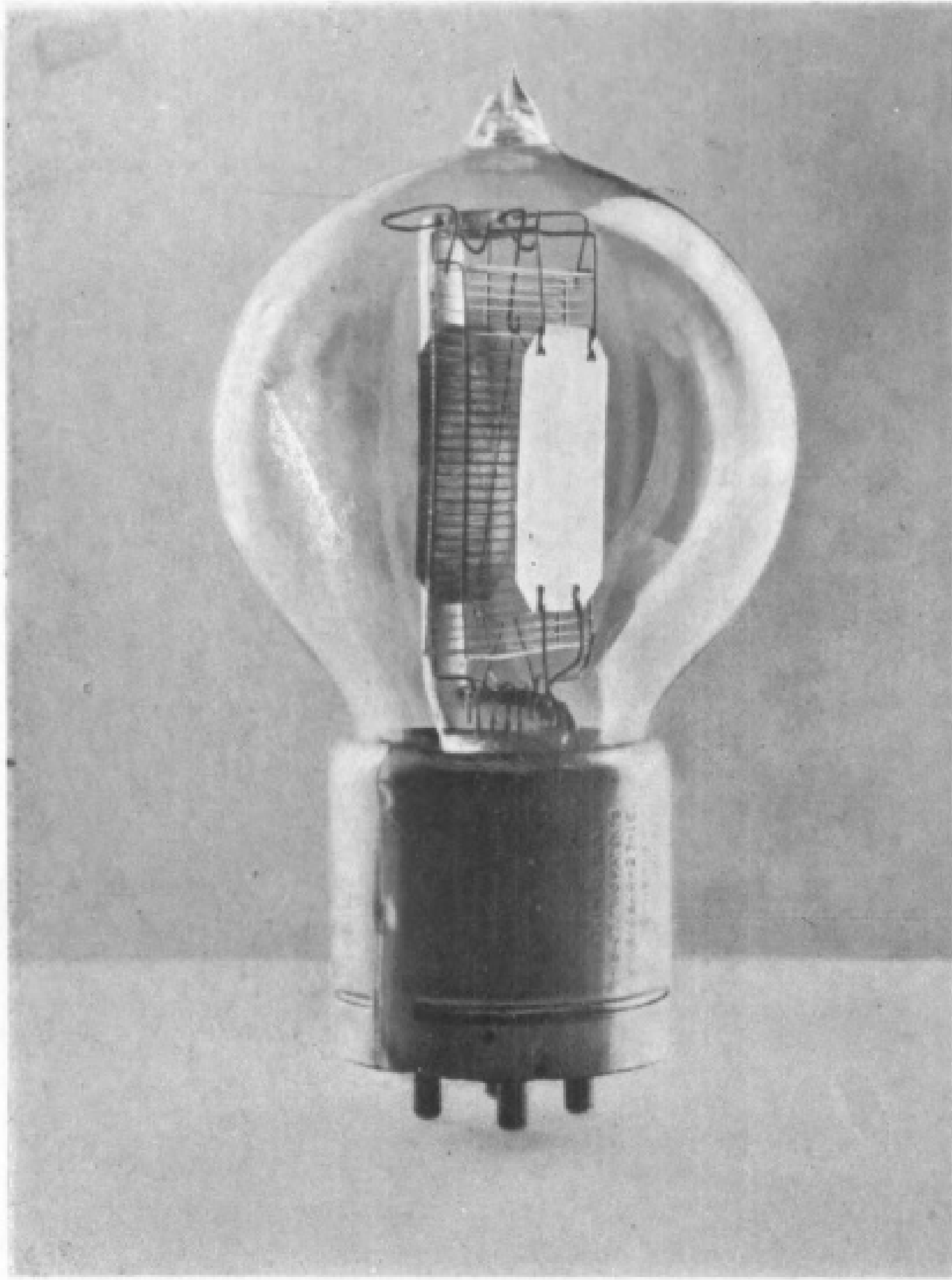


(c) *British.*

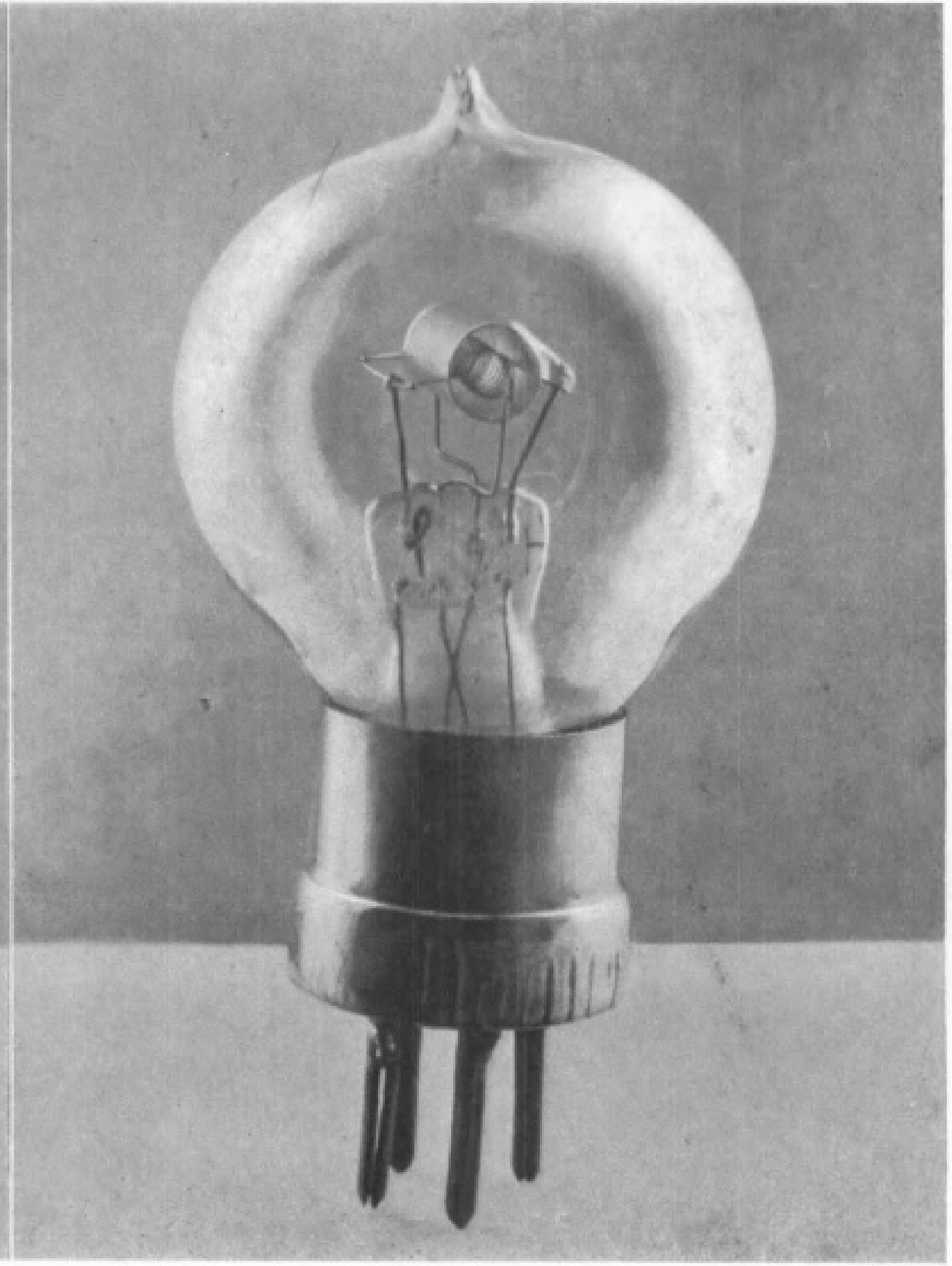


(d) *German.*

TYPICAL MODERN "HARD" TRIODE VALVES.



(a) American.



(b) French.

An Investigation of the

Internal Action of a Triode Valve.

BY W. H. ECCLES, D.Sc., M.I.E.E.

THE most important single instrument in modern wireless practice is the three-electrode thermionic vacuum valve, for it enters into every main division of the subject—it plays a dominant part in the generation of oscillations, the detection of signals and in the amplification of feeble voltages and currents. Its arrival and development have, besides, helped greatly towards the success of apparatus and methods that might otherwise have remained almost failures. It is, therefore, very appropriate that an account of some of its properties, and an attempt to advance our understanding of these properties, should find a place in the first number of a new wireless journal. In order to avoid the repeated use of the long name used above, the instrument will here be called a triode valve, or, more briefly still, a triode; a valve with two electrodes will be called a diode. The term "triode" includes the proprietary articles known as the audion of de Forest, the valve of Round, and the pliotron of Langmuir; the term "diode" covers the original Fleming valve and the kenetron rectifier, for example.

In its most usual forms the triode consists of a heated filament of tungsten, a metal plate or cylinder of refractory metal, and a grid, all enclosed in a very highly exhausted bulb; and in the modes of employment we are to study, the plate or cylinder is maintained at a positive electric potential relative to the filament, while the grid is given voltages considerably smaller than the plate. All the current across the vacuum is carried by electrons produced by evaporation from the heated filament. The filament is nearly always heated by an independent current, but in exceptional types of triode the source of electrons might be a hot plate heated electrically or by a "burning glass"; and, therefore, in general it is better to call the source of electrons the cathode of the tube. The plate or cylinder may be called the anode whatever its shape. The third electrode, which, as already said, is usually a grid between cathode and anode, may really be a conductor of any shape, and need not, even, be situated between anode and cathode; and since its function is to regulate and control the flow of the electrons from cathode to anode, it may in general be called the control electrode. The names anode and cathode come from general electrical terminology, and imply that the current traversing the vacuum appears to enter the vacuum at the plate and leave it at the filament.

The action of the triode depends mainly upon two phenomena, one known as the "space-charge effect" and due to the electric repulsions between free electrons, and one that may be called the "shielding action," exercised by the control electrode over the cathode and the space charge near it. The object of this paper is to study these phenomena and their consequences quantitatively.

THEORY OF THE SPACE CHARGE.

First, let us suppose the cathode and anode to be parallel planes. A sectional view is given in Fig. 1, the distance between the planes being taken as x_a and the distance of a typical plane layer from the cathode being x. We shall suppose the hot cathode to be maintained at zero potential and the plate to be maintained at a potential v_a above the cathode. The electric force in the typical layer will be F directed from anode to cathode, and therefore the mechanical force on an electron in that layer will be towards the anode and of magnitude Fq, where q is the magnitude of the negative charge of the electron. When a steady state has been attained a current i will be crossing each square centimetre of every plane between the anode and cathode and parallel to these. Let the number of electrons per cubic centimetre in the typical layer be n and the velocity of the electrons there towards the anode be u.

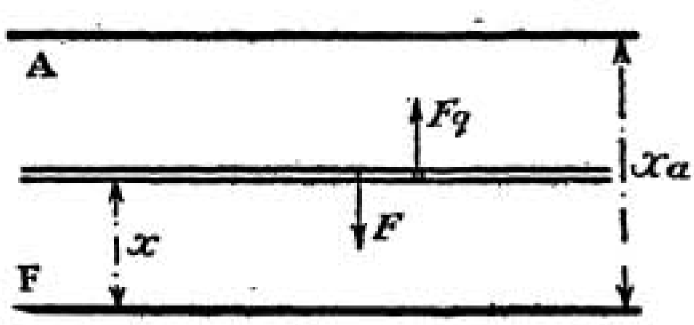


FIG. 1.

It will be noticed that because the positive direction of F has been taken opposite to the direction of increase of x the minus signs that usually appear in front of the differential coefficients are absent from the equations. This is very convenient for the present problem where we are dealing throughout with negative electricity.

The equation connecting the current density i with the potential v at the distance x from the cathode has been given by C. D. Child in the *Physical Review* p. 498 (1911), and by I. Langmuir in the same journal p. 450 (1913). The equation is

$$v = (i/A)^{\frac{2}{3}} x^{\frac{4}{3}},$$

or

$$i = A v^{\frac{3}{2}} / x^2.$$

The value of A in practical units is $2{\cdot}33 \times 10^{-6}$.

In obtaining this solution the velocity of emission of the electrons from the cathode is assumed to be negligible. The electric field at the surface of the cathode must consequently be zero unless the saturation current is being taken. For suppose the current to be well below the saturation value; then more electrons are being emitted than are carried to the anode, and the balance is continually being returned to the cathode. This action takes place because the smallest accumulation of unwanted electrons leads immediately to the creation near the cathode of an electric field which pushes new electrons back again; consequently the accumulation of free electrons is automatically prevented and the electric field has no opportunity of becoming different from zero. If, however, the applied voltage between the plates is greater than that needed to produce the saturation current there will exist at the cathode a positive field that could carry away more electrons than are actually being emitted. This condition of zero field at the cathode, and also that of zero voltage, must be satisfied.

We may regard the v, i, x equation as showing the voltage at which an anode placed at the distance x from the cathode must be maintained in order to hold the unsaturated current i constant; or we may say that when we observe a current of density i being carried by electrons between two parallel planes distance x apart we know the voltage between the planes must be as given by the above equation. From the v, i, x equation we may obviously obtain the distribution of F, n and u. We find

$$F = \frac{4}{3} \left(\frac{i}{A}\right)^{\frac{2}{3}} x^{\frac{1}{3}},$$

$$nq = \frac{\kappa}{9\pi} \left(\frac{i}{A}\right)^{\frac{2}{3}} x^{-\frac{2}{3}}$$

$$u = \frac{9\pi}{\kappa} A^{\frac{2}{3}} i^{\frac{1}{3}} x^{\frac{2}{3}},$$

where κ is the electric inductivity of the vacuum.

The distribution of these quantities between the electrodes is given by the curves of Fig. 2, which is not drawn to scale. The total charge in motion at any time between unit area of the plates is obtained by integrating nq with respect to x; it is

$$\frac{\kappa}{3\pi}\left(\frac{i}{A}\right)^{\frac{2}{3}}x^{\frac{1}{3}},$$

and is proportional to the value of the field at the anode. This

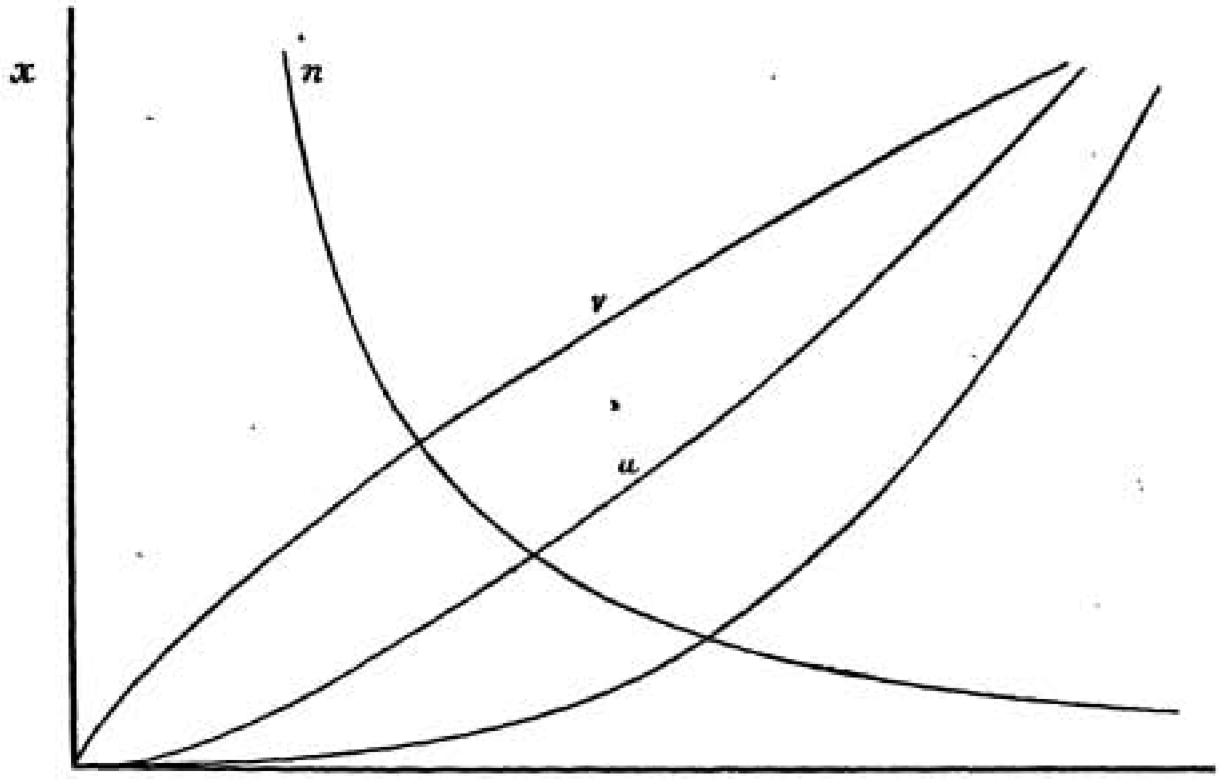


FIG. 2.

is directly evident from the consideration that the Faraday lines leaving unit area of the anode are $\kappa F/4\pi$ in number, and these are all occupied in reaching out, so to speak, to the negative electricity in the space between the plates.

In the preceding paragraphs the electrons are imagined to emerge from the cathode surface with negligible velocity. Let us now remove this limitation, and let us assume that they all leave the cathode with the same velocity u_1. If the current is unsaturated many electrons must be returned to the cathode by virtue of a negative electric field, and this field must be due to an accumulation of electrons at a distance from the cathode. At this place the field must be zero (for accumulation to be possible); and as F changes sign and passes through the zero value some of the electrons will be dragged towards the anode, some will be sent back to the cathode. Since F is the gradient of v it is evident that v is a minimum at this place of zero velocity; we shall call the co-ordinate of this place x_0. Moreover, as the differential equations must still be obeyed, the changes in the old solution must be confined to the introduction of arbitrary constants at permissible places. Inspection of the differentiations shows that we may write $v + v_0 = (i/A)^{\frac{2}{3}}(x - x_0)^{\frac{4}{3}}$,

whence
$$F = \frac{4}{3}\left(\frac{i}{A}\right)^{\frac{2}{3}}(x - x_0)^{\frac{1}{3}}.$$

In these equations we have, as we should,
$$v = -v_0 \text{ at } x = x_0$$
and
$$F = 0 \text{ at } x = x_0,$$
while F is negative when $x < x_0$, and positive when $x > x_0$. Continuing the differentiations as before we obtain
$$nq = \frac{\kappa}{9\pi}\left(\frac{i}{A}\right)^{\frac{2}{3}}(x - x_0)^{-\frac{2}{3}}$$
and
$$u = \frac{9\pi}{\kappa}A^{\frac{2}{3}}i^{\frac{1}{3}}(x - x_0)^{\frac{2}{3}}.$$

When i is held constant we may represent the state of affairs between the electrodes by the curves of Fig. 3.

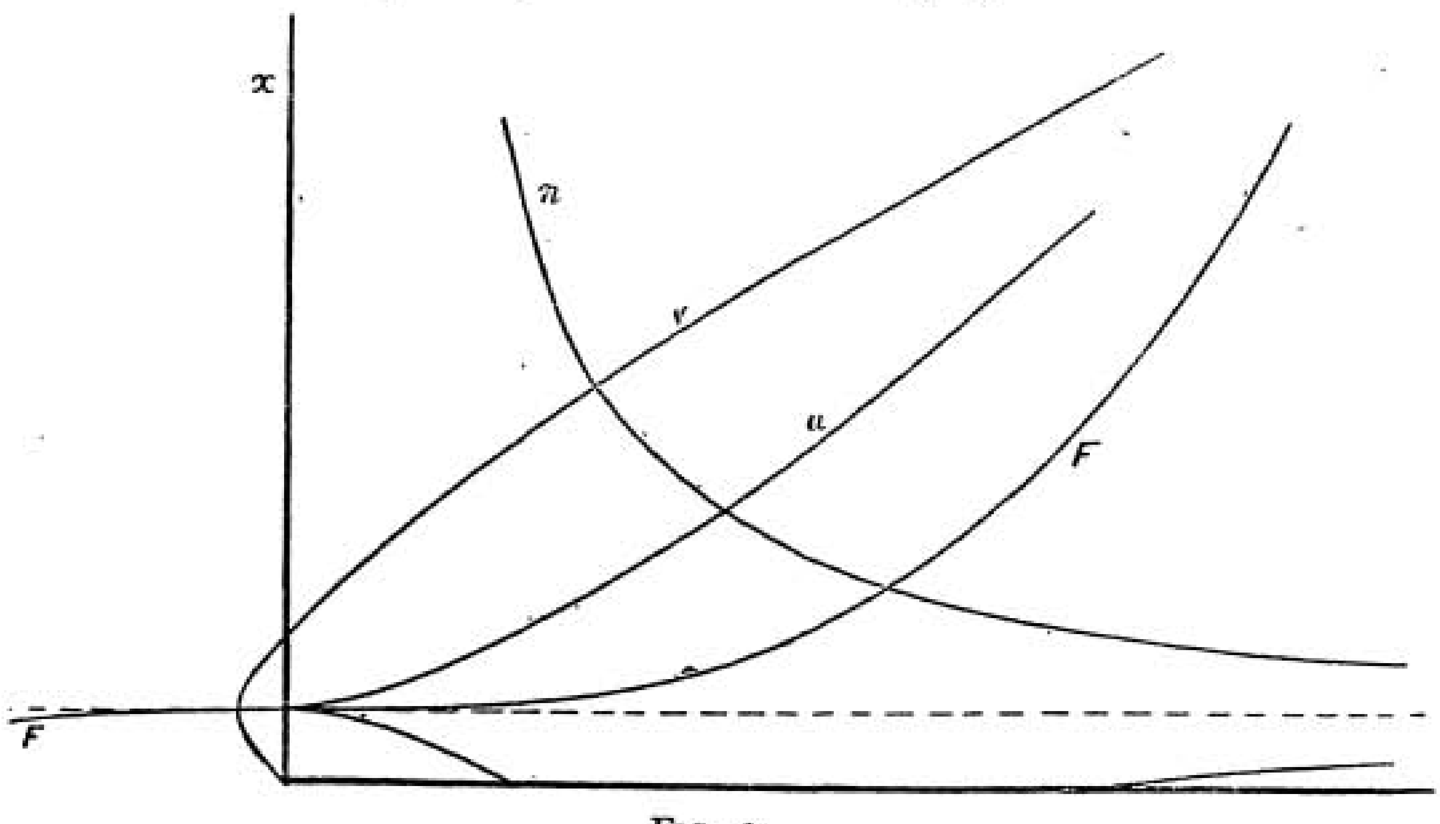


Fig. 3.

The curves may be interpreted as follows: An electron leaving the cathode and moving up the page finds itself in a retarding field by which its initial velocity u_1 is reduced to zero by the time it arrives at x_0. Here the retarding field changes sign and the potential reaches its minimum value v_0. A consequence of the slowing down of the electrons is that their density n increases to a very large value at x_0, the density multiplied by the velocity being, of course, constant because the current constituted by their motion is constant. Some of these accumulated electrons may be assumed to return sooner or later to the cathode, and some pass onwards under the influence of the positive field and rising potential; beyond x_0 the electrons gather speed and become less closely packed, as is seen from the curves of u and n.

We may estimate the magnitude of x_0 by putting v and x zero in the voltage equation above. We thus obtain

$$x_0^2\, i = A v_0^{\frac{3}{2}}.$$

In practical units $A = 2{\cdot}33 \times 10^{-6}$, and it is known that the mean velocity of the electrons emitted from a cathode at a temperature of 2500°K corresponds to about 0·2 volt. Let us assume that i is, in a particular experiment, of magnitude 2 milliamperes. Then

$$x_0 = \left(\frac{2{\cdot}33 \times 10^{6} \times (0{\cdot}2)^{\frac{3}{2}}}{2 \times 10^{-3}}\right)^{\frac{1}{2}} \doteq 10^{-2} \text{ cm}.$$

The distance x_0, which is of order a tenth of a millimetre, may therefore be regarded as small compared with the dimensions of any ordinary thermionic tube. Closer calculation indicates that this is likely to be rather too small than too large; but using the numbers just obtained we have, when $i = 2$ milliamperes,

$$v + 0{\cdot}2 = 74\,(x - 0{\cdot}01)^{\frac{4}{3}}$$
$$F = 99\,(x - 0{\cdot}01)^{\frac{1}{3}}$$

It should be noticed that x_0 is smaller the greater the current.

The formation of a place of accumulation of electrons, and of a place of zero field, at a short distance x_0 from the cathode reduces the case of electrons with finite initial velocity to that of a preceding page in which the initial velocity was taken to be zero. In every case, then, we may sum up the matter by saying that when the current and voltage carried by the space charge are small enough there is a place of zero field; an increase of voltage calls up an increase of current and a corresponding increase of the number of moving electrons, and the electric force due to this new distribution of the charge is just right to restore a layer of zero field. If there are not sufficient electrons to restore zero field the potential gradient becomes positive everywhere and the current is saturated.

It has been assumed in the above discussion that the velocity of emission of the electrons has a definite value u_1 the same for every electron. This is not true, for the evaporated electrons have, in fact, a large range of velocities. The result is that instead of a layer of accumulated electrons of infinitesimal thickness and infinite density at a definite distance x_0 we expect a vaguely defined region of finite thickness and density in which sufficient electrons accumulate to produce the negative electric field needed for repelling the unwanted electrons back into the cathode.

Cathode and Anode Concentric Cylinders.

When the electrodes are of the form discussed in the preceding pages and illustrated in Fig. 1, analysis similar to that employed in the last few paragraphs may be applied to find the distribution of the space charge, but a complete discussion demands more mathematics than is desirable in this paper. Readers may refer to I. Langmuir's paper in the *Physical Review* of November and December, 1913, where it is shown that when the radius of the filament is less than a tenth of the radius of the cylindrical anode the current j per centimetre of the length of the concentric electrodes tends towards a lowest value given by

$$j = \frac{2\sqrt{2}}{9}\sqrt{\frac{q}{m}}.\,\kappa\,\frac{v^{\frac{3}{2}}}{x}$$

as the ratio of the filament radius to the anode radius becomes smaller. Here x is the distance from the axis of the filament and v the potential at that point above that of the filament.

The current density at any point distant x from the axis of the filament is given by

$$i = \frac{j}{2\pi x} = \frac{\sqrt{2}}{9\pi}\sqrt{\frac{q}{m}}\ \kappa\,\frac{v^{\frac{3}{2}}}{x^2}.$$

In practical units the formulæ become

$$j = 14{\cdot}65 \times 10^{-6}\,\frac{v^{\frac{3}{2}}}{x}$$

$$i = 2{\cdot}33 \times 10^{-6}\,\frac{v^{\frac{3}{2}}}{x^2}.$$

When the radius of the cylindrical anode is not very great compared with the radius of the cathode, a correcting factor must be applied to both the last formulæ. The multiplier depends upon the ratio of the anode radius x to the cathode radius r' in the following manner :—

r'/x	0·067	0·10	0·15	0·2	0·3	0·4	0·5	0·6	0·7	0·8	1·0
multiplier	1·02	1·06	1·18	1·32	1·75	2·41	3·61	6·00	10·9	23·3	∞

This table may be applied in order to make rough allowances for the case when, for instance, the cathode is in the form of a curly filament, or is a bundle of parallel filaments.

Theory of the Control Electrode.

Consider three conductors in space, as indicated in Fig. 4, and suppose an electric charge given to each. We shall suppose that the conductor marked 1 is raised to a much higher electric potential than either 2 or 3, and that we wish to inquire how the charge on 2 is connected with the voltages between the three bodies. We know from elementary electrostatic theory that q_2, the charge on conductor 2, is given by

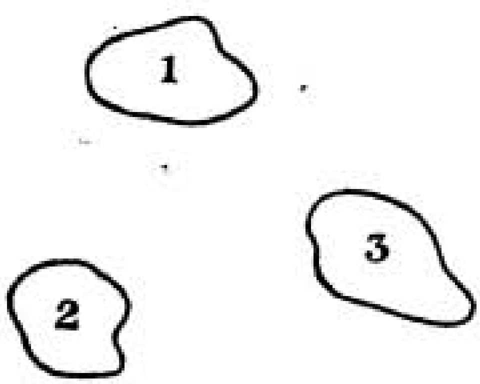


Fig. 4.

$$q_2 = c_{12}v_1 + c_{22}v_2 + c_{23}v_3,$$

where v_1, v_2, v_3 are the absolute electrical potentials of the three conductors, and c_{12}, c_{22}, c_{23} are what are called "capacity co-efficients." Let us suppose that the potential of 1 relative to conductor 2 is maintained by a connecting wire passing from 2 through a battery of voltage e_1 to conductor 1, and that a similar wire and battery of voltage e_3 connects 2 to 3. Then

$$v_1 = e_1 + v_2 \text{ and } v_3 = e_3 + v_2.$$

The connecting wires and batteries are assumed to have capacitance quite negligible compared with that of any one of the conductors 1, 2 or 3. The above equation becomes

$$q_2 = c_{12}e_1 + c_{23}e_3 + (c_{12} + c_{22} + c_{23})v_2.$$

If we take v_2 as the zero of electric potential for our problem, we have

$$q_2 = c_{12}\{e_1 + (c_{23}/c_{12})e_3\}.$$

We shall write g for the ratio c_{23}/c_{12}, and then the equation becomes

$$q_2 = c_{12}(e_1 + ge_3).$$

This equation shows that when e_1 is increased by, say, one volt, the charge q_2 can be maintained at its old value by reducing e_3 to the extent of one g-th part of a volt. In other words, as regards effect on conductor 2, one volt on 3 is worth g volts on 1. The number g may or may not be greater than unity—that depends on the electro-geometrical constants c_{12} and c_{23}, which are sometimes called "mutual capacitances."

In order to make the matter less vague we may take a simple case and perform the necessary calculations. Let the three conductors be spheres of radii r_1, r_2, r_3, separated by distances x, y, z, much greater than the radius of the largest sphere, as represented in Fig. 5. By a very fundamental principle of electrostatics the absolute electric potential of any sphere, say number 1, is made up by algebraic addition of the scalar potential due to the charge on itself, of that due to the charge on 2, and that due to the charge on 3. Therefore

$$v_1 = \frac{q_1}{r_1} + \frac{q_2}{z} + \frac{q_3}{y}.$$

Similarly

$$v_2 = \frac{q_1}{z} + \frac{q_2}{r_2} + \frac{q_3}{x}.$$

$$v_3 = \frac{q_1}{y} + \frac{q_2}{x} + \frac{q_3}{r_3}.$$

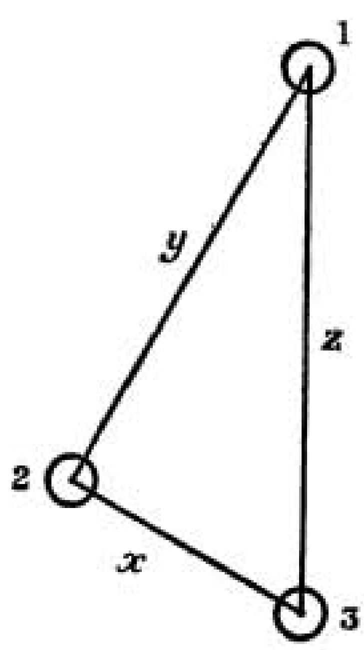


Fig. 5.

On solving these equations for q_2 we find (neglecting a constant factor not needed in our present application) that

$$q_2 \propto -\left(\frac{1}{zr_3} - \frac{1}{xy}\right)v_1 + \left(\frac{1}{r_1r_3} - \frac{1}{y^2}\right)v_2 - \left(\frac{1}{xr_1} - \frac{1}{yz}\right)v_3.$$

The coefficients of v_1, v_2, v_3 are capacity coefficients of the system, and by comparing with the general equation for q_2 above we see that in our present problem

$$g = \left(\frac{1}{xr_1} - \frac{1}{yz}\right) \div \left(\frac{1}{zr_3} - \frac{1}{xy}\right).$$

To prepare for numerical examples take $r_1 = r_3 = r$, that is, let the spheres be of equal radii, then

$$g = \frac{yz - r}{xy - r} \doteqdot \frac{yz}{xy} \doteqdot \frac{z}{x}.$$

This result shows that, when the conductors are small compared with the distances between them, the value of g is equal to the ratio of the distances of 1 and 3 from 2, and is independent of the distance of 1 from 3. For example, if $z = 3x$, as in all the cases of Fig. 6, the value of g is 3, and, therefore, one volt applied between 3 and 2 is worth three volts applied between 1 and 2, as regards effect upon the charge on 2.

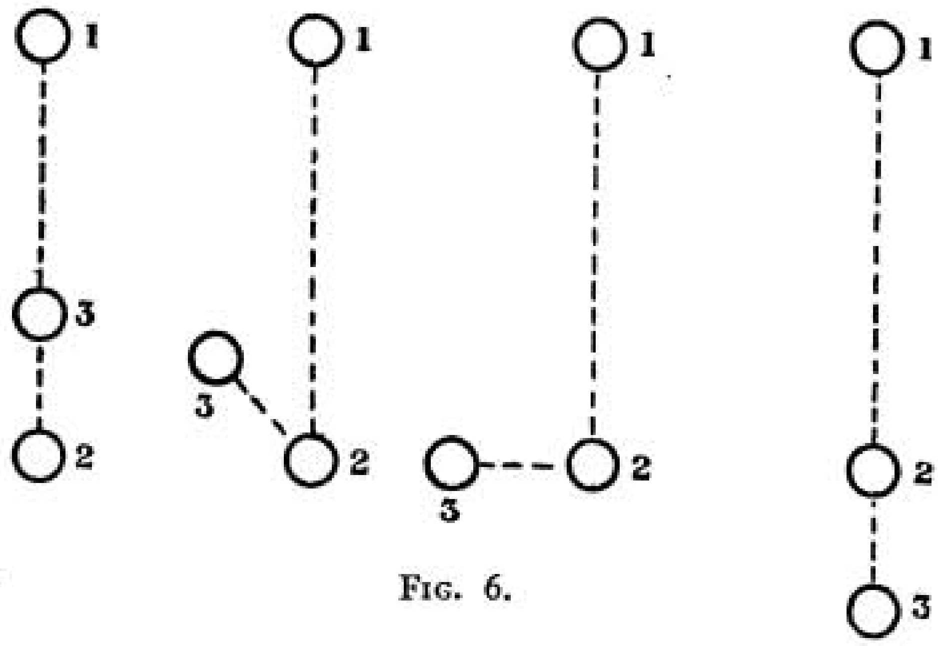


Fig. 6.

In this discussion the conductor 1 is the analogue of the anode of a triode, 2 corresponds to the cathode, and 3 to the control electrode. The charge q_2 on the cathode, being equal to the number of lines of electric force ending on the cathode, may be taken as the measure of the average electric field near the anode. All this applies strictly to a triode when cold; but when the cathode is emitting electrons the presence of the space charge must have an effect—for instance, it is well known that the mutual capacitance between the electrodes of any ordinary triode valve is from two to four times as great when the space charge is present as when it is absent—and but for this effect we could assume at once that the charge q_2 could be taken as a measure of the average electric field near the anode and also of the electron current leaving the cathode. The theory of any control could then be attempted in the manner sketched above. In particular, we could immediately make use of Maxwell's well-known solution for the shielding action of a grid of equal, parallel, evenly-spaced wires placed between and parallel to a plane anode and cathode (Maxwell's "Electricity and Magnetism," p. 248, first edition). The presence of the space charge, especially the dense portion near the filament, compels us, however, to adopt a direct method of calculation in preference to the method of quoting a geometrical formula and endeavouring to adapt it.

(*To be continued.*)

The Radio Review: Its Policy and Aims.

BY THE EDITOR.

ENGLISH-SPEAKING workers in the field of radiotelegraphy have long felt the need of a high class periodical, devoted entirely to the development of this branch of applied science. The literature of the subject is already very extensive, but it is scattered throughout a number of scientific periodicals, and it has been a matter of considerable difficulty for one interested primarily in radiotelegraphy to consult the various papers to which reference is frequently given unless he has convenient access to a good scientific library. The same difficulty is met with in the attempt to keep one's self informed on the current development of the subject in all its many aspects. This want has been increasingly felt during the last few years. The developments connected directly or indirectly with radiotelegraphy and telephony have been so far-reaching, the amount of researeh work in connection therewith has been so great and so fruitful, and the number of people interested in the subject has so increased, that the demand for such a periodical has become imperative.

With the happy termination of the war this demand will undoubtedly become more insistent, and the moment seemed opportune to launch this new venture with every prospect of success.

The sole aim of the RADIO REVIEW will be to record the scientific developments of radiotelegraphy, and of those branches of allied science which are related to that subject.

It is our desire and intention to make the RADIO REVIEW as useful as possible to all interested in radiotelegraphy. For this reason it has been decided to issue it monthly, in order that no delay may be experienced in the publication and dissemination of scientific information.

In addition to original contributions, the magazine will contain a complete digest of the current literature of the subject in all countries, and translations of important papers appearing in other languages. For these to be useful it is important that they be up-to-date, and this will be made possible by the monthly issue.

It is intended to devote a certain amount of space to correspondence, and it is hoped that radio-engineers and scientific workers will take advantage of this opportunity of stating their own views and opinions, and of criticising those of others.

Proceedings of scientific societies in so far as they are concerned with radiotelegraphy will be recorded.

It is hoped that full use will be made of the Radio Review as a medium whereby all workers in the field of radiotelegraphy may communicate the results of their work and their opinions to their fellow workers, and to the ever increasing number of those interested in the subject.

The scope of the Radio Review will be kept as broad as possible. It will seek to cover the whole range of the subject, theoretical and practical, physical and mathematical, electrical and mechanical.

We are undoubtedly approaching a time of great and important developments along all these lines. During the stress of war the theoretical investigation of the physical properties underlying the many devices which were evolved was necessarily postponed. Those best able to carry out such investigations were engaged on far less congenial but more imperative duties. These scientists are now returning to their laboratories with a great many problems needing research and elucidation, and, one may hope, with a Government and public more alive than of old to the necessity of supporting such investigations in every possible way. The coming period of reconstruction should, therefore, see a steady and increasing output of articles and papers recording and discussing the results of this research work.

We must not be satisfied, however, with merely elucidating the secrets of nature; we must utilise the discoveries so made to the fullest possible extent. Before the war we were certainly behind Germany in the practical realisation of new discoveries. The war demonstrated very clearly the folly and danger of allowing another country to take over the conceptions and inventions of British scientists and bring them to practical fruition, forming thereby the bases of new industries and the monopoly which comes from early and well-organised commercial development. It is essential that our manufacturers work hand in hand with our scientists and take up and seek to develop every scientific discovery, whatever the apparent difficulties may be. This will only be possible if manufacturing firms show a higher appreciation of the skilled scientist and of his work than they have in the past.

Nothing has contributed more to the enormous development of many of the highly successful American and German manufacturing concerns than their realisation of the importance of securing a large number of highly-skilled scientists and giving them every facility to carry out research work on an appropriate scale.

As we said above, the Radio Review will cover both the physical and the mathematical side of the subject of radiotelegraphy. No radio-engineer is likely to underestimate the importance of the latter. It is the *sine quâ non* of organised progress in theory and of efficient design in practice. Until a phenomenon has been represented completely by mathematical symbols, its utilisation is dependent on intuition and on the primitive method of trial and error. It is only by their representation by relatively simple mathematical formulæ and curves that the many complex phenomena involved in radiotelegraphy can be comprehended and discussed. It enables one to come to decisions in a few minutes which would otherwise require hours; it enables a man of ordinary attainments to arrive with certainty at a result which would otherwise require the intuitive insight of a genius. We trust, therefore, that non-mathematical readers will appreciate this when articles are published which appear to them to be too mathematical, and remember that the fault, if it be one, is probably not with the writer of the article, but with the phenomena, which are so complex that such treatment is essential to their elucidation.

Radio-engineering involves many problems which are not electrical. In so far as they are not peculiar to radiotelegraphy, or to apparatus and machines specially adapted to radiotelegraphy, they do not come within the scope of the Radio Review. There are many mechanical problems, however, involved in the design of masts, guys, aerials, alternators, transmitting mechanisms, etc., which may properly be deemed to come within the scope of the Radio Review, and which we hope to see discussed in its pages.

In conclusion, we wish to say that we shall welcome any suggestions which may be forthcoming with regard to possible improvements in the magazine. Its success will depend upon the whole-hearted support of radio-engineers and scientists and all those interested in the scientific development of radiotelegraphy and telephony.

G. W. O. HOWE.

The British Association Meeting at Bournemouth

Papers and Discussions of Radio Interest

SECTION A.

REPORT OF THE COMMITTEE ON RADIOTELEGRAPHIC INVESTIGATIONS.

During the past twelve months the war-time restrictions on wireless telegraphy have continued in operation. A few statistical records from British Colonial Radio Stations have been sent regularly to the Committee, and occasional information from other parts of the world has been received.

In connection with the solar eclipse of May 29th the Committee arranged for the carrying out of experiments on the effect of the eclipse on signals transmitted across the central line. The British Admiralty stations at Ascension and Azores transmitted continuously during the transit of the umbra across the Atlantic Ocean. Observing stations north of the Equator were for the most part asked to listen to Ascension for at least an hour round about the time when the umbra passed between themselves and Ascension; observers south of the Equator were asked for the most part to listen to the Azores. Certain selected stations north of the Equator were asked to listen to the Azores, so as to afford check observations upon the variations which might be observed in signals passing across the central line of the eclipse, and, similarly, selected stations south of the central line were asked to listen to Ascension. The American station at Sayville also transmitted a programme during a portion of the period of the eclipse, and arrangements were made for special experiments between Darien and the Falkland Islands, and between an Egyptian station and a South African station.

The main portion of the experiment hinged upon Ascension. The umbral cone passed from west to east, and was expected to affect in succession the strength in which signals were received at such stations as Demerara, Jamaica, the stations on the coast of the United States and Canada, stations in Ireland, England, France, Italy, in the Mediterranean and Egypt.

The following is a brief account of the preliminary reduction of the statistics received from various parts of the world :—

The shadow of the moon struck the earth first at dawn on the coast of South America, and swept across the continent in the course of half an hour, at first with enormous velocity, but losing speed as the Atlantic Ocean was approached. About the middle of the Atlantic Ocean, and near the Equator, the speed of the shadow was about one-third of a mile per second. On crossing the African Continent from the Gulf of Guinea to the Mozambique Channel the speed gradually increased, and the eclipse finished at sunset near Madagascar. The effects of the moving shadow were investigated under three heads:—

(1) Strays;
(2) Signals not crossing the denser parts of the shadow;
(3) Signals crossing through or near the umbra.

Strays.

These were bad on the day of the eclipse and on the preceding day in Europe, North America and in temperate latitudes on the Atlantic Ocean. They were very few in Central and South America and in the central equatorial Atlantic. In Central America the conditions were exceptional meteorologically, the day having less rain than nearly every day of the preceding three weeks. The preliminary survey of the results recorded throughout the part of the globe reaching from Constantinople to Rio Janeiro suggests that there was no outstanding occurrence in regard to frequency or intensity of strays that could be directly ascribed to the passage of the shadow.

Signals Not Traversing the Dense Shadow.

Many observations were made in Northern Europe and America on the signals from the Azores, which were arc signals of 4,700 metres wave length. The observing points extended from Berlin, through Holland, France, Italy, Spain and Great Britain, to stations near the Atlantic coast of the United States. There were no unusual variations in the strength of the signals from the Azores.

Another class of experiment comes under this heading. It was suggested by the effect sometimes observed at sunset or sunrise in which the twilight band, when on one side of a transmitting station, appears to strengthen, as if by reflection, the waves received at a station on the other side of the transmitting station. In order to test whether such reflections occurred during an eclipse, certain stations on the south of the central line of the eclipse were asked to listen to Ascension, which was also south of the central line. The stations at Durban and Port Nolloth (South-West Africa) found no trace of the effect, and, in fact, the former concluded that the signals from Ascension were rather worse after the eclipse began. An analogous experiment on the northern side was carried out by one of the Malta stations, and also at Rosyth, listening to Cairo, with similar conclusions.

Effect on Signals passing Across the Central Line.

Arrangements were made for the transmission of signals from the Darien Station of the Panama Canal zone, and several stations in South America attempted to receive the signals. The report from the Falkland Islands has not yet come to hand, and the other stations in South America did not succeed in picking up the signals. The only observations made on the earlier stages of the eclipse are those of Demerara listening to Ascension. Fluctuations in signal strength are reported, but no steady increase or decrease in strength. Ships at sea within the penumbra report a strengthening of all signals during the eclipse. The most striking results were obtained at some of the stations in France, Malta and Teneriffe. At Meudon and at Rousillon (near Lyons), the signals from Ascension were received practically only while the eclipse was in progress. Both Malta and Teneriffe found that the eclipse produced a great improvement in the strength of signals. On the other hand, Durban was unable to pick up Cairo, though this is usually possible; but Aden was picked up with greater intensity than normal. On the whole the records show that the improvement in signal strength reached its highest value long before the umbra intervened between the stations, and this value persisted after the umbra had passed; that is to say, if ionising processes are the cause of the change in the strength of signals, the results indicate that the processes are practically fully accomplished in a given region of the air before the arrival of the umbra at that place, so that there appears to be nothing left for the umbra to do in the few minutes of complete shadow it brings.

The thanks of the Committee are due especially to the Admiralty for arranging that their stations at Ascension and the Azores, and at Cairo, should transmit the necessary signals; and also to the American Government for making similar arrangements regarding Sayville and Darien. Thanks are due also to the American, French and Italian Governments, the Admiralty, the War Office, the Air Ministry and Marconi's Wireless Telegraph Co., Ltd., for undertaking observations and recording the variations in signal strength.

Discussion on Thermionic Valves.

W. H. ECCLES, "The Three-Electrode Thermionic Vacuum Tube and the Revolution in Wireless Telegraphy."

During the war dark hints reached the civilian that a revolution was taking place in wireless telegraphy, the principal agent in which was reported to be an instrument called a "valve," a "lamp," or a "tube." This instrument seemed to have risen suddenly into a predominant position among all the apparatus of the wireless experimenter and operator, and appeared to be of use in every corner of his outfit. The complete name of the instrument is the three-electrode thermionic vacuum tube. It must be emphasised that it is the three-electrode valve, and not the valve with two electrodes, that has been responsible for the overthrowing of the old methods and apparatus. That it has been a veritable revolution can be seen by comparing the common practice in wireless telegraphy of 1914 with that of 1919. In 1914 practically all the most powerful transmitting stations in the world generated waves by sparks, and signals were received at nearly all stations by means of crystal detectors or magnetic detectors. The spark method of generating waves involved the use of very large antennæ for spanning great distances; and at receiving stations which wished to listen to stations more than even 100 miles away very large aerial structures were customary. But if we look at the state of affairs to-day we find most of the high-power stations for long-distance transmission are "continuous wave" stations, that is, they produce uniform uninterrupted waves instead of a series of short gushes made by sparks; while at the receiving end new modes of detecting these continuous waves appropriate to, and taking advantage of, their uniformity in character have been introduced. This is where the three-electrode tube, in various adaptations, enters the arena. Taken together, the improvements at both ends of the span have made possible the use of smaller antennæ at transmitting stations, and have almost removed the necessity for any antenna at all at receiving stations. For example, under reasonable weather conditions, it is quite easy to listen to the messages coming from stations on the other side of the Atlantic by using a receiving circuit of which the receptive element is a small coil of wire, three or four feet square. Thus, so far as receiving goes, it is possible to intercept practically all the great stations on one half of the globe by means of apparatus contained wholly in one room, or even in a cupboard. This does not mean that the use of an antenna for reception is abolished; on the contrary, when these highly magnifying methods are put into operation with large antennæ for the purposes of reception, the range over which signals can be received is extended very far beyond what it was in 1913, and, in consequence, it is possible, under reasonably good weather conditions, to receive at the antipodes the signals from a modern high-power station. In accomplishing this the magnifications in use amount to several hundred-thousand-fold. All this is the work of a thing which looks like an ordinary electric light bulb with a few extra pieces of metal in it—the three-electrode tube. This is not all the story, for, when the tube is made in large sizes, it can be used for producing alternating current of high frequency and of considerable power, and then it can be employed for transmitting electric waves. Moreover, by giving another aspect to its functions, the triode can be used for modulating the alternating current just spoken of, and so for impressing upon the waves the human voice. In this way speech has been transmitted freely across the Atlantic, being received, it need hardly be said, at the distant end by the aid of other of the protean properties of the ubiquitous three-electrode tube.

In passing, it is worth remarking that the process of thermionic evaporation is really a method of obtaining electricity from matter without the use of moving parts—that is, without machinery. Possibly it may lead to the long-sought-for method of obtaining electricity and power direct from fuel without steam boilers or engines or dynamos. In other words, the electric engines of the future may be based upon thermionic processes deriving their energy direct from coal. Before that time comes, substances may have been discovered from which the emission of electricity takes place more easily than it does from the refractory metals we most frequently employ in the filaments of three-electrode tubes. It is known already, for instance, that some of the earthy oxides are greatly superior to platinum or tungsten in this property of emission of electricity. A new condition of matter, or a new substance, may be involved here and awaiting investigation.

The development of the three-electrode tube from fundamental ideas can be traced a long way back. The use of auxiliary electrodes in order to influence the current passing between two main electrodes in a vacuum tube has often been proposed, and had to some extent been applied before the method of obtaining the electrons from a hot filament was introduced into wireless telegraphy. Even after the use of the third electrode had been combined with the use of a thermal source of electrons many minds and hands were needed, and many years elapsed before the researchers themselves realised how useful the contrivance was destined to become.

As has already been hinted, the three-electrode tube (which will in future be called briefly a "triode") has found applications in every branch of wireless telegraphy and telephony, as will be shown shortly. There is no doubt it will prove equally useful in other branches of applied electricity and also as a tool in the hands of the experimental physicist. For instance, one fundamental property of the triode is that an electrical influence in one circuit may, by acting upon the control electrode, be made to exert effects in another circuit without suffering appreciable reaction; which implies that practically no energy is absorbed by the control electrode, not even so much as would be used up in setting a galvanometer needle into motion. This property alone should make the instrument welcome as a tool in the physical laboratory.

Then, again, the combination of triodes in cascade so as to obtain very large magnification opens up new regions of research by aid of the ear, and sanguine persons even anticipate that we shall some day hear the clatter of the collision of individual atoms with one another. Besides this, there is the fact that the triode provides a very convenient means of generating oscillations of exceedingly high frequency, which opens illimitable fields of measurement upon the properties of matter and of electric waves.

Amplifiers using several triodes have been made in thousands during the war for use in earth telegraphy, in submarine listening, in telegraphy by certain invisible rays or by electromagnetic induction, as well as for use in wireless telegraph stations. Besides this, it is possible to build amplifiers for work at ten or twenty vibrations per second, using a vibration galvanometer as the indicating instrument. The sensitiveness of some apparatus developed in my laboratory during the war is such that it is possible to detect with certainty alternating current corresponding to one ten-thousand-millionth part of a volt at the input side. Magnifications of the order twenty thousand times are here involved. This tempts one to revive old dreams of trans-oceanic telegraphy by means of alternating currents delivered into the sea at the ends of long cables. Calculation shows that by aid of a cable fifty miles long on each side of the Atlantic Ocean, capable of delivering about forty amperes alternating current of frequency 20 $\sim$, telegraphic communication ought to be possible by aid of the three-electrode tube.

Perhaps the uniform generation of electrical oscillations in a circuit by aid of a triode is one of the most striking and fascinating of its applications.

Not that there is anything visible, for, in fact, rather special apparatus is required to tell that oscillation is taking place, and the interest excited is, therefore, scientific.

It is usually found on analysing an oscillator that the maintenance of the oscillations largely depends upon the interaction of two portions of the circuit on each other. If it be arranged that these two parts can be separated so as to interact less strongly the oscillation becomes weaker. There is a critical setting where oscillations are just not maintained, and the system is poised in suspense, so to speak. When it is in this condition, a very feeble stimulus, if properly timed, can provoke the system into vibration; the resulting display is energetic to an extent out of all proportion to the initial stimulus. Evidently enormous magnification is possible in this manner with a single triode. Its most important application is in wireless telegraphy, and many ships are equipped with this type of receiver. By its aid spark signals can be read at distances that are amazing compared with the old records.

If any one tries the experiment just indicated to find what order of magnification is obtained by the sub-generative method, he will discover that, on passing gradually from this adjustment to the oscillating condition, other phenomena arise. If the incoming oscillations which he is trying to magnify are unceasing and uniform, and of nearly the same audible frequency as that natural to the oscillator, he will find that a throbbing appears in the formerly steady musical note of the telephone. The throb appears only when the input current is really being introduced into the oscillating system, and is more marked the greater the original strength of the current that is to be magnified; but the input necessary to produce a perceptible amount of throbbing is exceedingly small. It would seem that the input current, when it reaches the grid, becomes magnified, first by the more ordinary processes of the triode, and then combines with the local oscillations to produce what the musician calls "beats," and then the beats are themselves magnified by circuits of the triode.

As carried out in wireless, the operator at a receiving station sets his apparatus near the wave length he desires to receive, and then causes his triode to sustain his circuits in oscillation. The waves from the distant station, acting upon his antenna, produce minute currents in the antenna which are transformed so as to apply an electromotive force to the grid of the triode. The result is an audible note in the operator's telephone each time the key of the transmitting station is depressed, provided, of course, the frequency of the receiver is near enough to that of the incoming waves. He can adjust the local frequency at will, and make it very near to the waves or very different from them; these adjustments alter the pitch of the beat note, and he chooses the more agreeable and efficient setting for the reception in hand. This process of receiving continuous wave signals on an oscillating circuit is called autoheterodyne or, sometimes, endodyne reception. Circuits can be designed in which a change of capacity of about one-thousandth part of the electrostatic unit can be detected; and in such circuits the change of capacity produced, for instance, by substituting coal gas for air in a condenser, is measurable with facility.

C. L. FORTESCUE.—The interest in the thermionic valve lies partly in its application and partly in the underlying physics of its action.

The application is mostly concerned with the use of the valve as a finished article in combination with various electrical circuits. The problems encountered are similar to, or often merely variations of, the ordinary problems of electrical engineering, and, as such, are essentially matters for discussion at the meetings of Section G of the Association. When the engineer begins his work, the valve is a piece of electrical apparatus having certain definite electrical properties which it is his duty to make use of to the best effect.

To the physicist, however, the main interest lies in the valve itself, and to a large extent the keenness of this interest is due to the fact that there is no widely used piece of electrical apparatus depending so directly on the most recent research work on the structure of matter. It is probable that there is no other sphere where research work has had such a combination of immediate practical value and intense theoretical interest.

Several papers dealing with the application are being read before the Association. In these papers the advantages of the valves for the various purposes for which they are used are fully explained. Results are obtainable by means of the valves which cannot be obtained by any other device—or, at any rate, not with equal facility. It must not be assumed, however, that the valve has reached finality; that further improvement and development is not to be expected. This is very far from being the case. The valve is, in fact, still in childhood, a somewhat precocious childhood possibly, but certainly little more than that.

At the moment the popular cry is for Research and more Research. Research of the organised and industrial nature; and Research of the unorganised and spasmodic type, as carried out by the inspired genius.

In the valve there are fields of research for both these types, fields which are possibly more of interest to the physicist in consequence of the new information which may be forthcoming than in consequence of any improvement to the valves that may be effected. It seems highly appropriate, therefore, to consider before this Section some of the possible lines which this research might take.

The filament of the valve, being the source of free electrons upon which the whole action depends, may reasonably be the first part to be dealt with. As far as the available information goes at present, the process of emitting free electrons appears to be somewhat as follows:—The filament is a conductor, and moving in the interstices between the atoms are a large number of electrons which are free in the sense that they can move with relatively little constraint amongst the atoms, but are not free in the sense that they can be dragged away from the conductor either in air or in a vacuum with electric fields of ordinary magnitude. The fields in the inter-atomic spaces are very intense, and although they more or less balance out inside the conductor—so allowing the electrons to move along the conductor with some freedom under weak fields—they effectively prevent electrons from being drawn away from the boundary surfaces. The average kinetic energy of the electrons is apparently the same as that of a molecule of a gas at the same temperature. As the temperature is increased the mean energy increases according to the usual gaseous laws. Some electrons at some periods have, momentarily, energy far in excess of this average. Hence, as the temperature is increased, a state is reached where an appreciable proportion of the electrons near the surface become possessed of sufficient energy to break away from the attractions of the surface atoms, and so become free electrons in the sense that they can be drawn away by the application of electric fields of quite ordinary magnitude. At any particular temperature it is probable that the distribution of energy is the usual Maxwell distribution. So if a definite energy is required to enable the electrons to break away from the surface, it follows that, as the temperature is raised, the number of electrons escaping increases very rapidly. The full theoretical treatment may be found in Professor O. W. Richardson's monograph, "The Emission of Electricity from Hot Bodies."

In practice, the hot conductor now most largely used is a filament of tungsten heated by passing a current through it, but it is by no means an ideal source. It is very liable to damage during the exhausting process, and it is highly inefficient. The electrons that break through the boundary appear to require energy corresponding to about four and a half volts. Now, with an ordinary filament, an optimistic estimate of the watts required to heat the filament for an emission of one ampere of free electrons is 100. This ampere of electrons absorbs energy at the rate of about four and a half watts, the remaining ninety-five and a half being radiated as ether waves or conducted down the filament supports—principally the former with the large valves. The efficiency of the filament is thus about 4½ per cent., and it immediately becomes a matter for consideration as to whether this cannot be improved upon.

Numerous possibilities suggest themselves; first and foremost, is tungsten the best material? It is well known that surface contamination of the filaments will reduce the emission for a given temperature. On the other hand, the addition of certain oxides similar to those used in the Nernst filament will greatly increase the emission. Is it, therefore, not possible to find some alloy of tungsten, or some mixture of tungsten and oxides, having an efficiency far above that of the filaments now in use? Possibly some entirely different substance could be used where the energy required for an electron to break through the boundary is much less than the four and a half volts of tungsten. It is well known that a lime-coated filament will give, for a time, a large emission at a surface temperature in the neighbourhood of 1,000° C., whereas, for tungsten to give the same emission, a temperature in the neighbourhood of 2,000° C. is required. Could not the improvement be carried further with careful investigation?

The oxide-coated filaments used up to date are fragile, and more liable to damage during exhaust than are the tungsten ones. The cause of this damage is, undoubtedly, the bombardment of the surface by positive gaseous ions. What is the nature of this damage? Is it purely mechanical, consisting of atoms or groups of atoms being, as it were, chipped off? Apparently this is the case, and apparently the conditions are unstable in that the chipped area emits more freely, and so attracts more positive ions. Cannot this damage due to bombardment be overcome?

Many of the lime-coated platinum filaments lose their power of emitting electrons after a time. There is some evidence of the surface developing a cracked appearance like that of dried mud. The surface layers, though at a high temperature, have probably little of the heating current passing through them when the cracks have developed. Has this anything to do with the falling-off of the emission, or is the deterioration connected with impurities in the lime, which are gradually evaporated away or broken up chemically?

Then, again, if research shows that the energy limit cannot be very much reduced, is it possible to use still higher temperatures? The efficiency of the tungsten filament increases with increase of temperature, owing to the increase of the number of electrons possessing sufficient energy to break away being more rapid than the increase of the energy radiated. Presumably, the same holds for all substances. If a higher temperature is to be used, carbon seems to be the only possibility. That being so, is it impossible that means should be devised of making a carbon filament that does not lose its adhesion at temperatures higher than those at which tungsten is used at present? If such a filament could be constructed, it would revolutionise the lamp industry!

The use of a filament heated by passing a current through it is in itself objectionable in that it means that different parts of the emitting surface are at different potentials. This difference of potential may have an appreciable effect on the characteristic curves of the small low-voltage valves. Some form of separate heating suggests itself, but the difficulties to be overcome in order to secure a high efficiency and a cheap construction are very great.

Any method of freeing the electrons by thermal agitation has the further disadvantage that the electrons are emitted with varying velocities. This causes a rounding off of the corners of the characteristic curves, and materially affects the action of the valves when used for limiting or as sensitive rectifying detectors.

Possibly there may be alternatives to the method of thermal agitation.

Photo-electric methods suggest themselves, but at present the emission currents are small, and the over-all efficiency is much less than that of the thermal method. Moreover, the electrons are still, apparently, emitted with varying velocities.

Finally, there is the question, "If the electrons have to be given energy corresponding to from two to five volts, is it in any way possible to give them this energy without so accelerating them that a far greater amount of energy is radiated?" That is to say, is not the process a fundamentally inefficient one; at any rate, at the temperatures at which the materials known to-day can be used. It would appear that this problem should be amenable to mathematical treatment.

Passing on to the grid electrode, several questions present themselves.

An extremely important one in the small receiving valves is that of the contact potential between filament and grid. It is believed that this point is being touched upon more fully by others taking part in this discussion.

Then there is the combined mathematical and mechanical question of the best form of the grid electrode. Numerous forms of this electrode have been described in patent specifications and elsewhere; notably in a specification of the Western Electric Company.

Some of these forms are possibly amenable to approximate mathematical treatment, and, if they have the additional virtue of mechanical simplicity, the results would be of value.

At the positive electrode the outstanding problem is that of the occluded gas. In point of fact, it is not the positive electrode only that is involved. During exhaustion, and when in use, gas may be liberated from any of the electrodes or from the inner surface of the containing envelope. With a high-vacuum high-voltage valve, where the gas pressures are in the neighbourhood of one ten-thousandth of a millimetre of mercury or less, a very minute quantity of gas will lead to appreciable ionisation effects, with the consequent instability and rapid destruction of the filament.

The term " occlusion " is used to describe the various ways in which gases may be retained in matter in the liquid and solid state. In the present instance the interest lies in the retention of the gas in the solids. Three clearly distinguishable processes appear to be involved, viz.:—

(*a*) There may be minute blowholes, or the remains of blowholes, where some gas has been entrapped when the solid last passed from the liquid to the solid state. This gas might have come from the atmosphere of the furnace, but more probably it was gas which was originally in solution in the liquid.

(*b*) The solid may consist in part of actual chemical compounds which decompose and liberate gas under heat treatment or under electron bombardment.

(*c*) There are the allied phenomena of surface absorption, solid solution in the crystals of the solids, and the retention of the gases in the amorphous intercrystalline layers.

The first two of these three possibilities are not, probably, of serious import. Preliminary heat and vacuum treatment will remove most of the gas ever likely to be liberated in these ways from the metal portions of the valves, and there does not seem to be any evidence to show that gas is liberated from the glass from either of these causes. It is the phenomena of the third category that present the difficulties.

The problem is either to remove these gases or to treat the surface so that the gas cannot escape whilst the valve is in use.

The present procedure is of the sledge-hammer type, and merely consists of exposing the valve to a higher temperature and a heavier bombardment whilst the valve is connected to the pump than it will ever experience in actual use. The gas coming out under these conditions is pumped away, and it is piously hoped that so long as the working conditions are less stringent no further gas will be evolved.

Presumably the absorbed surface layer will be removed by this treatment. The extent to which the gas is removed from the crystals and the inter-crystalline layers is doubtful. Presumably it is a question of time. If so, *i.e.*, if diffusion in the solid is appreciable, why does not some of this gas find its way to the outer surface, if an exhausted valve is left cold for, say, a month? Valves are occasionally observed to "go soft" if left in this way. Usually this is attributed to a minute leak, but there is no conclusive proof that this is the case. An examination of the spectrum of the gas in such a valve should settle this point, but no such examination appears to have been carried out up to date. It is well known that if the gas has been thoroughly removed from the electrodes of a valve, and if air is readmitted, then gas is reabsorbed by the electrodes. But unless the electrodes have been re-exposed to the air for a lengthy period, the absorbed gas is quite easily removed. Presumably it is the outer absorption layer that is involved in this case. But the question immediately arises, "For how long can the metal be exposed before the gas becomes difficult to remove again?"

The examination of the gases given out after the exhaustion was completed is a matter of intense general interest to physicists, and has brought out certain results which require a good deal of explaining. Two methods have been used, viz.:—

(1) Spectrum analysis. The valve was overloaded and the "blue glow" examined by means of a spectroscope. Many characteristic lines were observed, and many gases, such as Ar and CO, were clearly identified. Some of the spectra were, however, unusual.

(2) Ionisation potential. The grid and the positive electrode were connected together, and the voltage between them and the filament—the latter being negative—was gradually raised, careful observation of the current being made. The curves of current and voltage were then plotted. These curves follow Langmuir's 3/2 power law up to certain clearly defined points where ionisation sets in. These points are indications of the nature of the gas present. But the voltages at which ionisation sets in are quite different from the usually accepted ionisation voltages. One gas has not yet been identified, and still goes by the name of "electrode gas."

It is hoped that others taking part in this discussion will enter into this question more fully. Why are the spectra unusual? Why are the ionisation potentials abnormal? What is the "electrode gas"?

Many interesting phenomena are observed with the traces of residual gases always present even in the hardest of tubes. After running for some time with a given electron current to the positive electrode and a given voltage, a steady value for the pressure of the residual gas may be reached. If now the voltage is increased, but not sufficiently to overheat the positive electrode, the tube will harden, *i.e.*, some of the residual gas will be absorbed. On the other hand, if the voltage is reduced, and particularly if the filament is simply heated without any voltage being applied to the positive electrode, the amount of residual gas will increase.

These effects are well known to radiologists and various suggestions are put forward in explanation. But from the point of view of the development of the high-power valves, the whole problem requires careful investigation.

The fact that an increasing voltage at the positive electrode hardens the valve leads to the conclusion that the effects are due to the action of the ionised gas. At these voltages the ions are positive, and their observed disappearance must be due to their being driven into the hot filament, or into the walls of the containing vessel. If they are driven into the filament, how are they retained with the filament at 2,000° C.? Is any chemical action involved, or is it the same process as the occlusion in the positive electrode? Or is it only the walls of the containing vessel that absorb the ions?

A suggestion has been put forward by Dr. G. B. Bryan, of the Physics Laboratory, at R.N. College, Greenwich, that the occlusion of the gases and the emission of positive ions from metallic surfaces at moderate temperatures are closely related. He visualises the process as follows: Some proportion of the gas to which the electrodes are exposed will probably be ionised hydrogen. A positive hydrogen ion is a very small heavy projectile with considerable powers of penetration. On striking the surface of a solid it will pass through the outer surface and pick up an electron, so becoming neutral. Now, however, it is a large body entrapped in among the atoms of the metal and unable to escape under ordinary conditions. But at moderate temperatures the electrons may be shed again, and the positive ion, being no longer encumbered by the outlying electron, can escape, so constituting the positive emission. One peculiar fact has frequently been observed by Dr. Bryan when exhausting a valve, viz., that a small liberation of occluded gas will give rise to a greater tendency to arcing than the introduction of a much greater quantity of ordinary air. If the gas liberated from the electrodes is already ionised, the observation is immediately explained.

This theory is a very interesting one, and is one on which some light could be thrown by the entire removal of all traces of hydrogen. At present, however, it has never seemed possible to do this, as such extremely small quantities are involved; and possibly other ionised gases may be entrapped in the same way. If it is the outer electron that is lost, this would seem to be quite possible.

Many interesting questions arise in connection with the outer envelope. Glass is almost universally used owing to the fact that it is the only material combining high insulating properties with ease of making vacuum-tight joints with conducting wires or strips. But glass has many disadvantages, particularly for the large power valves. It is a brittle material liable to failure under mechanical shock. But worse than that is the liability to cracking when subjected to change of temperature.

Again, like metals, glass has the property of occluding large quantities of gas, which it gives up when heated. This has to be eliminated as far as possible, by "cooking" during the exhausting process. For small valves not liable to appreciable heating in use this presents no serious difficulties; but with high-power valves, where the bulb gets really hot when in use, there is always the risk of more gas being liberated.

The relatively low temperature at which glass of the ordinary kind softens makes it impossible to heat up the metal electrodes by external means to the temperature necessary for the removal from them of the occluded gas.

With certain kinds of glass, too, slight chemical action not infrequently takes place at the seals when subjected to high temperatures, which may lead to the seals ceasing to be vacuum tight.

Finally, a disadvantage with glass for use with power valves where the positive electrode is at a bright red or yellow heat is that it is opaque to the infra-red radiation. If it would allow this energy to pass through, the heating of the bulb could be much reduced and the size and expense would be correspondingly less.

One obvious alternative to glass is fused silica. The trouble of cracking due to temperature change does not exist. There is no difficulty, apparently, in working up to the high temperatures. The great problem of sealing in the conducting wires remains, however, an uncertainty. Many methods have been suggested, but, as far as is known, none of them have been used on a large scale with high vacuum apparatus subjected to considerable changes of temperature.

De Forest, in an American patent specification (No. 100959/1917), has described a valve made up of a double metallic container, with mercury to assist in securing vacuum-tight joints. With this arrangement the leads to the grid and filament electrodes are thoroughly insulated from the outer metallic container, which is used as the positive electrode.

Here, again, is the difficulty of the vacuum-tight joint. At high power the smallest trace of mercury vapour leads to disintegration of the filament from the heavy bombardment with positive mercury ions.

If a really flexible cement could be devised that would secure a vacuum-tight joint between two materials of different co-efficients of expansion, and which would withstand temperatures up to, say, 300° C., a design of power valve on the general lines of De Forest's patent would be possible. Once this was accomplished, and once the difficulty of occluded gas was overcome, all limits to the output of the transmitting valves used for wireless telegraphy and telephony, other than that of power available, would be removed. No longer would it be necessary to put up with the unsatisfactory and tricky arcs where high powers are required, and a valve giving an output of 500 k.w. would become quite feasible. It is interesting to note that such a valve would require a free-electron emission of some thirty or forty amperes—and it is only a few months ago that the habit of measuring free-electron currents in microamperes was given up!

All the foregoing remarks have presupposed a valve of the same general type as that now in existence. The function of a valve is essentially that of a relay, and its fundamental advantage lies in the fact that its moving parts consist of free electrons. The three-electrode tube is one way of making use of the electron stream so as to get the relay action. Is it the only way? In Hull's dynatron the electron stream is used in a different manner, and, for some purposes, may have advantages over the ordinary three-electrode type. This is one alternative. Are there no others?

With the power valves the present method of operation gives an efficiency —neglecting the filament watts—of about 75 per cent. under the best conditions. Is there no way of improving this?

B. S. GOSSLING.—A considerable number of physical phenomena, besides the actual thermionic emission and the effects of the mutual repulsion of the emitted electrons, are observed to enter into the action of the valve. These include the Maxwell distribution of velocities amongst the electrons, the contact potential between the filament and the grid, the composite electric field produced near the filament by the grid and anode, and by the difference of potential between the two ends of the filament, and also the orbits described by the electrons in the neighbourhood of the grid wires. The pressure of the residual gas present is usually reduced to a point (*e.g.*, 0·0001 mm.) where the ionisation produces little effect on the space current.

Test observations on very large numbers of valves were made during the war, the final rate of production of valves having been about 500,000 per annum. These observations indicate the range of probable variation of the various factors, confirm earlier purely scientific work, and provide a basis for further investigations.

In the valves handling higher powers the important phenomena are few and simple. Complete prior information, theoretical and numerical, as to these being available, the necessity for experiment was in large measure avoided and development much accelerated.

Dr. WHIDDINGTON opened his remarks by alluding to the difficulty of adding much in a few minutes to what had already been given so admirably by the three previous speeches. He thought, however, that it might be useful to draw attention to a few of the possibilities of the valve in the physical laboratory. Taking, for example, the well-known typical oscillating circuit alluded to by Professor Eccles, it could be shown, theoretically, that it was only when the mutual induction M between grid and anode coils was greater than $\frac{1}{k}\left(\frac{L}{\rho} + RC\right)$ that the oscillations of period $2\pi\sqrt{LC}$, natural to the circuit, were initiated and sustained.

In this formula L, C and R were the usual constants of the periodic circuit, ρ was the valve resistance, and k the amplification factor of the valve. This gives at once a method of determining the value of M between two coils, for if one is connected between grid and filament, the other between anode and filament, and a condenser, C, placed across the anode coil and adjusted till oscillations are just not sustained, then (very nearly) $M = \frac{RC}{k}$. Captain Turner had produced a relay valve on this principle.

M was, in his arrangement, just less than $\frac{RC}{k}$. A signal incident on the system upset the balance and produced oscillations, thereby slightly increasing k and making the oscillations permanent; the relay, in fact, was not self-restoring, and had to be restored to quiescence mechanically, as, for example, by a Post-Office relay in the anode circuit. But from the above formula it is clear that, if a wire of positive temperature resistance coefficient be included in the oscillating circuit, then, as soon as oscillations are produced, the wire gets hot and its resistance rises, if a suitable choice has been made, to such a value as to extinguish the oscillations and make the relay self-restoring.

Professor Eccles had pointed out the extreme sensitiveness of heterodyne reception at wireless frequencies, giving as an example the effect of passing coal gas in place of air between the plates of the air condenser used in his experiments. Dr. Whiddington said that in addition he had demonstrated the change of resistance with temperature of conducting wires, the conductivity of flames, the permeability of liquids, etc., and he thought that many interesting quantitative investigations along these lines could be usefully carried out.

Sir OLIVER LODGE and *Dr. W. MAKOWER* briefly discussed the use of radioactive processes in valves; and *Mr. S. G. BROWN* referred to recent experiments with lime-coated cathodes.

Wireless in the Royal Flying Corps.

By MAJOR T. VINCENT SMITH, R.A.F., M.C., M.I.E.E.

This paper dealt with wireless in what was the military wing of the R.F.C. on the Western Front during the first three years of the war, and detailed the history of this work up to the time of the amalgamation of the R.N.A.S. and R.F.C. into the Royal Air Force.

It showed the state of knowledge at the beginning of the war, and the gradual progress made in the building up of an immense organisation. The experiences of early days, the difficulties which arose, and how they were overcome were described in detail. Improvements in apparatus, methods, organisation, and their effect upon operations were shown, and the technical means whereby the enemy was beaten were discussed.

The important work of the R.F.C. in co-operation with artillery, infantry and cavalry would have been practically impossible without wireless. The introduction of thermionic valves for reception, transmission, inter-aeroplane telephony and directional wireless were touched upon, though the war ended before their influence had time seriously to effect the final operations.

The story of wireless in the R.F.C. is a collection of details, each one small in itself, but the combined whole shows how the many difficulties inseparable from an ever-increasing demand were overcome in a way which earned the respect of the enemy.

A Wireless Method of Measuring the Ratio e/m.

By R. WHIDDINGTON, M.A., D.Sc.

This paper deals with the use of a valve to measure the ratio of charge to mass for electrons and ions. It will be given in full in our next issue.

Diffraction of Electric Waves.

By PROFESSOR G. N. WATSON, F.R.S.

This paper will be dealt with in the November issue of the Radio Review.

SECTION G.

Directional Wireless, with Special Reference to Aircraft.

By CAPTAIN J. ROBINSON, R.A.F., M.Sc.

This paper, read before Section G of the British Association Meeting at Bournemouth, is merely a brief summary of more technical papers by the same author, which we are publishing in full in succeeding issues of the Radio Review.

The following is an abstract of the paper as presented at the meeting :—

(1) The ordinary methods of navigation which are used for ships at sea are not sufficient for aircraft, as the conditions as regards drift are of an entirely different order. It is thus necessary to use some other means for determining position in the air. Drift is of a very large magnitude in the air, and by night, or in fogs, it is very often impossible to apply dead reckoning methods. The use of wireless bearings is the most hopeful method of progress, as bearings can be obtained with considerable accuracy.

The systems for determining bearings that were known at the beginning of the war were :—

(*a*) The single coil method. When such a coil is rotated about a vertical axis the intensity of the wireless signal varies from zero to maximum, being zero when the plane of the coil is at right angles to the direction of the incoming waves.

(*b*) The Bellini-Tosi system. This system used two fixed loop-aerials at right angles to each other, the moving part being a small coil rotating between two coils at right angles, which are in the circuits of the two fixed aerials.

(*c*) The Telefunken clock.

(2) There are two distinct methods of employing wireless bearings in order to determine position :—

(*a*) By the first method the machine transmits, and the direction-finding stations are on the ground. Each direction-finding station finds the bearing on the moving object and communicates its bearing to a central station. There the position of the moving object is worked out from the various bearings and re-transmitted to it.

(*b*) By the second method the moving object, either aircraft or ship, has its own direction-finding apparatus, and finds bearings on fixed transmitting stations.

As regards aircraft, method (*a*) was used largely by the Germans. This method has considerable drawbacks, the first being that, in case of war, when the aircraft transmits to ask for its position, this is also disclosed to the enemy.

Secondly, only very few aircraft can be dealt with, as a considerable amount of transmission is required for a single aircraft to find its position. In consequence it was decided to attempt to use method (*b*) in the British Air Service.

(3) Royal Air Force system. In attempting to apply direction-finding systems to aircraft it was found that considerable modifications to the known systems had to be applied. The single coil and Bellini-Tosi systems are what are called minimum systems, *i.e.*, in order to determine the bearing one finds the minimum by swinging the coil through this position until the signal is heard on both sides. On aircraft, as there is considerable extraneous noise, the region of this minimum is widened, and, in consequence, the accuracy of the system diminishes. It is necessary to use a system where signals can be heard whilst the bearing is taken. The system devised is to use two coils at right angles, which can be rotated together on a vertical axis. One coil alone is used first, and the system rotated to be somewhere near the maximum of this single coil. Then the second coil is introduced, and its effect added to or subtracted from those of the first coil. If the first coil is correctly on its maximum, then the second coil will be on its minimum, and thus there is no change of intensity on adding or subtracting the effects of this coil by a reversing switch. This method enables bearings to be taken whilst the signal is heard, and it is easy to see that it can be applied to any system which has hitherto been a minimum system. Having devised this system, there were other problems to be solved.

(*a*) One was to obtain efficient strength of signals. It was uncertain as to whether loops could be obtained of sufficient size to give loud enough signals to hear over the noise of the engine.

(*b*) The Bellini-Tosi system was considered to be too complicated, as at that time it was necessary to tune the two aerials to exactly the same frequency, and unless this system is very carefully installed fairly large errors are introduced.

(4) It was hence decided to use the rotating aerial system. This was done in two ways.

(*a*) The wing coil system. In this case the aerials are fixed rigidly to the aeroplane, which has to be rotated in order to determine the bearing. This system is particularly useful in the case of flying towards an objective where there is a wireless station. One particular example is where a wireless station exists at the aerodrome, and the machine can thus return home by merely heading to this wireless station.

(*b*) The rotating coil system. In this case the rotating coils are placed in the fuselage, and are rotated independently of the machine. This is particularly useful on the larger type of aeroplane, and enables position to be determined whenever a sufficient number of transmitting beacon stations can be heard.

(5) Considerable difficulties had to be overcome to bring the R.A.F. system to a stage of perfection.

(*a*) The extraneous noises on an aeroplane are considerable, but, besides, there is a far greater disturbing influence in the electrical disturbance due to the magneto. This produces considerable noise in the telephones, and cannot be overcome by amplifications of signal strength. It is necessary to cut out this electrical disturbance. The cause of this disturbance was traced to the emission of very short waves by the magneto, the wave length being of the order of from five to thirty metres. It is possible to use short wave stoppers to cut out these waves, but by far the most efficient method of eliminating this disturbance is to screen the whole magneto system.

(*b*) When using the fuselage coil system it was found that corrections had to be applied for the deviation produced by the metal work of the aircraft. These corrections can be determined by swinging the aircraft in a similar way to the swinging of a ship to adjust the compass.

(6) In addition to the preceding difficulties there is another trouble in the variation of bearings produced by atmospheric influence. The extent of these variations is not large, possibly never more than about 3° when using waves of 2,000 metres and upwards. The problem of this variation is one that should be investigated at an early date. The R.A.F. system of D.F. gives means for recording these variations very accurately. The sensitiveness of this system is under control, and depends on the ratio of the area-turns of the two coils. It is possible to design coils so that the system is sensitive to $\frac{1}{4}$°. This is the case when the minimum coil has its area-turns about eight times those of the maximum coil. With such a system it is easy to conceive an automatic arrangement, so that the variations in bearings can be automatically recorded.

(7) Excellent results have been obtained with the R.A.F. system of wireless navigation. A large number of flights have been made, and it has been found that the mean error of bearing is $1\frac{3}{4}$° when using beacon stations whose distance varies from 20 to 500 miles. Under these circumstances, when three beacon stations are available, the mean error in determination of position was found to be seven miles.

Flights have been made purely by wireless navigation. One particular flight was made from Biggin Hill to Paris, and back from Paris to Brighton. In both of these flights the machine was above the clouds most of the time.

Position was determined by wireless bearings, and the course was set or altered from these determinations. The navigator was in a position so that he could not look out of the aeroplane, and he was able to determine the force and direction of the wind and to forecast the time of arrival at his destination within two minutes.

The Three-Electrode Thermionic Valve as an Alternating Current Generator.

By PROFESSOR C. L. FORTESCUE.

A Method of Using Two Triode Valves in Parallel for Generating Oscillations.

By W. H. ECCLES, D.Sc., and F. W. JORDAN, B.Sc.

A Trigger Relay Utilising Three-Electrode Thermionic Vacuum Tubes.

By W. H. ECCLES, D.Sc., and F. W. JORDAN, B.Sc.

The above papers will be dealt with in the November issue.

The Wireless Society of London.

We understand that the above Society shortly hopes to resume its activities. A committee meeting, under the presidency of Mr. A. A. Campbell Swinton, F.R.S., was held on July 24th, and further preliminary meetings are now being arranged. The Society is open to all interested in the study and furtherance of wireless telegraphy. The new secretary is Mr. L. McMichael, 30, West End Lane, West Hampstead, N.W. 6.

The services of the Advisory Committee of this Society are again being accepted by the Post Office in connection with the issue of Experimental Licences for Radio work.

Review of Radio Literature

1. Abstracts of Articles.

Note.—*It is intended to devote the space in this section of the* Radio Review *to as complete a review as possible of the published literature of radiotelegraphy and telephony, and kindred matters. The more important of these papers and articles will be given in abstract, while, for the remainder, references will be given, accompanied by one or two lines to indicate the contents of the article. In this way it is hoped to obtain a complete monthly record of the progress of the science, and of the latest developments and inventions relating thereto, that should be of considerable value to all research workers and students of the subject.*

1. On the Absolute Measurement of the Time Period of H.F. Oscillations. By H. Abraham and E. Bloch. (*Comptes Rendus*, 168, p. 1105, June, 1919. *Rev. Gen. de l'Elec.*, 5, p. 855, Abstract.)

The precise determination of the wave length of high frequency electric oscillations is of great importance for the calibration of wavemeters and for all H.F. measurements. The use of standard inductances and condensers to construct a circuit of known wave length does not permit of an accuracy greater than 1 per cent. The method described by the author involves the direct comparison with a tuning fork standardised by comparison with a standard clock. A source of electric oscillations rich in harmonics is then adjusted (by the method of beats) to have the same fundamental frequency as the fork, while one of its higher harmonics is then compared with the high frequency oscillations. Special arrangements of three electrode valves are used for the comparison source of oscillations, giving harmonics up to 200—300 times the fundamental frequency. The accuracy obtainable is claimed to be closer than 0·1 per cent.

2. Electrical Oscillations in Antennas and Inductance Coils. By J. M. Miller. (*Proceedings Inst. Radio Engineers*, 7, pp. 299—326, June, 1919.)

The author applies the theory of circuits having uniformly distributed electrical characteristics to the problem of the electrical oscillations in aerials and inductance coils. A number of errors in the interpretation of previous applications of the theory are pointed out, and the effective inductance, capacity and resistance of aerials are calculated, with and without series loading coils or condensers. Putting C_1 = capacity of aerial per unit length, L_1 = inductance per unit length, R_1 = resistance per unit length, l = length, $C_o = C_1 l$, $L_o = L_1 l$, and $R_o = R_1 l$, it is shown that the effective static or low frequency resistance, inductance and capacity are given respectively by $R_e = \frac{R_o}{3}$; $L_e = \frac{L_o}{3}$; $C_e = C_o$. At the frequency of the fundamental of the aerial these become $R_e = \frac{R_o}{2}$; $L_e = \frac{L_o}{2}$; $C_e = \frac{8}{\pi^2}C_o$.

It is further shown that for most practical cases the aerial can be represented by its "static" inductance $\frac{L_o}{3}$, with its "static" capacity C_o in series, and the frequency of the oscillations with a loading coil L in the lead-in can be computed by the ordinary formula applicable to circuits with lumped constants, *i.e.*, the wave length in metres is given by $\lambda = 1885\sqrt{\left(L + \frac{L_o}{3}\right)C_o}$. When L/L_o is greater than 0·5, the error obtained by the use of the above approximation is less than $1\frac{3}{4}$ per cent., while in the extreme case of no loading coil in series the error rises to 10 per cent. Similarly, for an inductance coil it is shown that the effective "self-capacity" $C_e = \frac{C_o}{3}$, so that the wave length of oscillation of the coil with a capacity C across its terminals is given by $\lambda = 1885\sqrt{L_o\left(C + \frac{C_o}{3}\right)}$.

The frequency variation of the effective resistance of an aerial is then considered. Measurements are described and curves given, which indicate that antenna resistance is largely due to imperfect dielectrics in the field of the aerial, and emphasis is placed on the necessity of avoiding such dielectrics in regions of strong electrostatic field.

3. Quantitative Experiments with Coil Antennæ in Radio-telegraphy. By L. W. Austin. (*Journal of the Washington Academy of Sciences*, 9, p. 335, June, 1919.)

Theoretical transmission formulæ for frame aerials are given in this paper. Fundamentally the following formula is assumed for ordinary aerial to aerial transmission :

$$I_r = 120\pi \frac{I_s h_s h_r}{\lambda d R} \text{ (meters and ohms).}$$

The replacement of either or both aerials by a frame necessitates the substitution of the expression $N \, . \, H \, . \, 2\pi \frac{L}{\lambda} \cos\theta$ for the height of the aerial in the above formula.

Let N = number of turns on frame, H = height of frame, L = length, λ = wave length, θ = angle between plane of coil and the direction of the incoming waves. The following formulæ are then derived. Frame sending aerial to antenna at receiver :

$$I_r = 2369 \frac{I_s N_s H_s L_s h_r}{\lambda^2 d R} \cos\theta_s.$$

Antenna sending and frame receiving:

$$I_r = 2369 \frac{I_s h_s N_r H_r L_r}{\lambda^2 d R} \cos \theta_r.$$

Frame sending and frame receiving:

$$I_r = 14880 \frac{I_s H_s N_s L_s H_r L_r N_r}{\lambda^3 d R} \cos \theta_s \cos \theta_r.$$

If $\theta = 0$, the "effective height" of an ordinary aerial equivalent to the frame is:

$$h = 2\pi \frac{\text{Area} \times \text{Turns}}{\lambda}.$$

Experiments are mentioned showing measurements ranging up to 24 per cent. from the calculated figures—these errors are partly due to the action of the frame and its leads as an ordinary plain receiving aerial. A very good agreement is found between the formula and the measurements when sending on the frame aerial and receiving on an antenna.

4. RADIO TRANSMISSION FORMULÆ FOR ANTENNA AND COIL AERIALS. By J. H. Dellinger. (*Journal, Franklin Institute*, 188, pp. 95—96, July, 1919. *Telegraph and Telephone Age*, p. 370, August 1st, 1919, Abstract.)

Transmission formulæ are given applicable to communication with ordinary and frame aerials. Originally derived from theoretical considerations, they have been verified experimentally in a number of cases investigated by the U.S. Signal Corps. A flat-top type of aerial is considered, and a rectangular frame.

Antenna to antenna:

$$I_r = \frac{188\, h_s h_r I_s}{R \lambda d}.$$

Antenna to frame coil:

$$I_r = \frac{1884\, h_s h_r N_r I_s}{R \lambda^2 d}.$$

Frame to antenna:

$$I_r = \frac{1884\, h_s l_s h_r N_s I_s}{R \lambda^2 d}.$$

Frame to frame:

$$I_r = \frac{7450\, h_s l_s h_r l_r N_s N_r I_s}{R \lambda^3 d}.$$

Where h = Height of aerial or frame; l = Horizontal length; N = Number of turns of wire on frame; I = Current — amperes; λ = Wave length; d = Distance apart of transmitter and receiver; R = Resistance of receiving aerial circuit.

Subscripts s and r refer to sending and receiving respectively.

5. SENSITIVE APPARATUS FOR THE MEASUREMENT OF ALTERNATING CURRENTS. By H. Abraham, E. Bloch and L. Bloch. (*Comptes Rendus*, 169, pp. 59—62, July, 1919.)

The need of suitable apparatus for the measurements of feeble alternating currents and potentials is emphasised in this communication. An arrangement is described consisting of an indicating direct-current milli-ammeter or micro-ammeter, used in conjunction with one or two 3-electrode amplifying valves and one detecting valve. It may be used for currents of radio or low frequencies, and will indicate potentials of the order of one millivolt, while the effective resistance of the apparatus when used as a voltmeter is extremely high.

6. THE PRODUCTION AND MEASUREMENT OF SHORT CONTINUOUS ELECTROMAGNETIC WAVES. By Balth Van der Pol, D.Sc. (*Philosophical Magazine*, 38, p. 90, July, 1919.)

7. RADIO TRANSMITTING SETS ON THE N.C. TYPE SEAPLANES. (*Telegraph and Telephone Age*, pp. 330—331, July 1st, 1919. *Electrical Review*, 85, p. 233, August, 1919, Abstract.)

These 550-watt transmitting sets, as employed on the N.C. type seaplanes used for the American trans-Atlantic flight, possess some novel features.

The complete transmitter, with the exception of the sending key, and the aerial ammeter and tuning coil, is mounted in the stream-line casing enclosing the 1,000 ∼ alternator (Fig. 1). The generator, of the inductor type, delivers 135—150 volts at 5,000 r.p.m., dropping to 100 volts at full load. The stator has four D.C. poles, into each of which are cut four slots for the A.C. winding. The rotor has twelve teeth, and acts as the inductor. The D.C. armature winding for exciting the field is wound in the slots between the rotor teeth. Two rotary gaps of twelve and eight teeth are mounted on the same shaft, enabling spark frequencies of 1,000 or 666 to be used as desired. The transformer has a step-up ratio of 34 : 1, and the mica dielectric oscillation circuit condenser has a capacity of 0·01 mfd. Wave lengths of 335, 375 and 425 metres may be used with a trailing wire aerial 250 feet long. A feature of the aerial tuning inductance is the provision of a copper ring to screen the magnetic field from the turn under the contact,

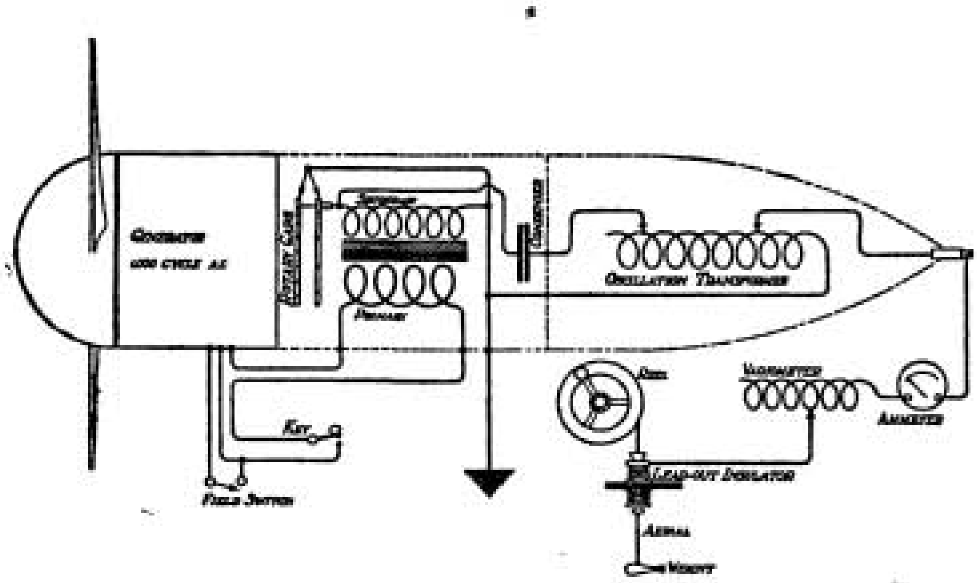


FIG. 1.

thus preventing sparking when passing over from one turn to the next. Normal range = 300—400 miles, but the sets were heard for 1,200 miles during the trans-Atlantic flight.

8. "On the Electrical Operation and Mechanical Design of an Impulse-Excitation, Multi-Spark Group Radio Transmitter." Further discussion by S. Cohen. (*Proceedings Inst. Radio Engineers*, 7, p. 327, June, 1919.)

This additional discussion on the original paper by B. Washington with this title, deals with further experiments on impulse transmitters, and the use of tungsten-tungsten and copper-amalgamated copper electrodes in alcohol. The former gap is suitable for radiotelephony.

9. Apparatus for Producing High-Frequency Oscillations. By I. Shoenberg and Marconi's Wireless Telegraph Company. (*British Patent* 126146. May, 1918.)

With a view to utilising the qth harmonic of a high-frequency alternator, the ratio of breadth of rotor teeth to their pitch is made equal to $q/2 \times$ an odd integer greater than unity. In a case utilising the 5th harmonic, rejection circuits tuned to the fundamental and 3rd harmonic frequencies are joined in the main circuit to cut out the unwanted frequencies.

10. On the Poulsen Arc and Its Theory. Supplementary note by P. O. Pedersen. (*Proceedings Inst. Radio Engineers*, 7, pp. 293—297, June, 1919.)

A continuation of an earlier paper discussing production of sustained oscillations of the first or second types by Poulsen arcs. The effect of too strong or too weak magnetic fields is considered.

11. Electric Oscillation Generators. By N. Lea. (*British Patent* 128383. June, 1918.)

An electric oscillation generator adapted for standardising oscillatory circuits, or for use as a wave meter. An ordinary type of three-electrode-valve oscillation circuit is described, having tuned anode and untuned grid circuits, with telephones in the anode circuit. The filament battery is used to supply the anode circuit voltage, as well as for lighting the filament.

12. The Current-Voltage Characteristics of High-Voltage Thermionic Rectifiers. By C. L. Fortescue. (*Proceedings Physical Society of London*, 31, pp. 319—337, August, 1919.)

This paper deals in detail with the design of circuit arrangements for high-voltage valve rectifiers. If I_0 is the direct current output current, V_0 = direct current output voltage, a = fractional permissible variation in V_0 (usually $< 0{\cdot}1$), θ = the phase angle of the alternating current supply when the applied alternating current voltage becomes equal to the output voltage V_0, f = frequency, C = condenser capacity required, then

$$C = \frac{I_o}{V_o} \cdot \frac{1}{af} \cdot \frac{\pi + 2\theta}{2\pi} \text{ . for a single-valve rectifier, or}$$

$$C = \frac{I_o}{V_o} \cdot \frac{1}{af} \cdot \frac{\theta}{\pi} \text{ for a two-valve rectifier.}$$

Expressions and curves are also given for the transformer current, and the efficiency of the whole arrangement.

13. WIRELESS TELEPHONE TRANSMITTERS. General Electric Company (U.S.A.). (*British Patent* 127325. April, 1917.)

An arrangement of valves for wireless telephone transmission is described. A number of valves are used in parallel, fed from common filament and anode batteries. Fig. 2 shows one connection scheme. V_1 V_2 are two oscillating valves in parallel fed from the filament battery B_o, grid battery B_1 and anode battery B_2. The oscillation circuit comprises the inductances L_2 L_3, and the aerial circuit capacity plus the valve grid-plate capacity. The transformer T_1 couples the control microphone M to the grid circuit, and T_2 provides a return coupling between the plate and grid circuits. This return coupling is for the speech frequencies only, and both transformers may have iron cores, as indicated.

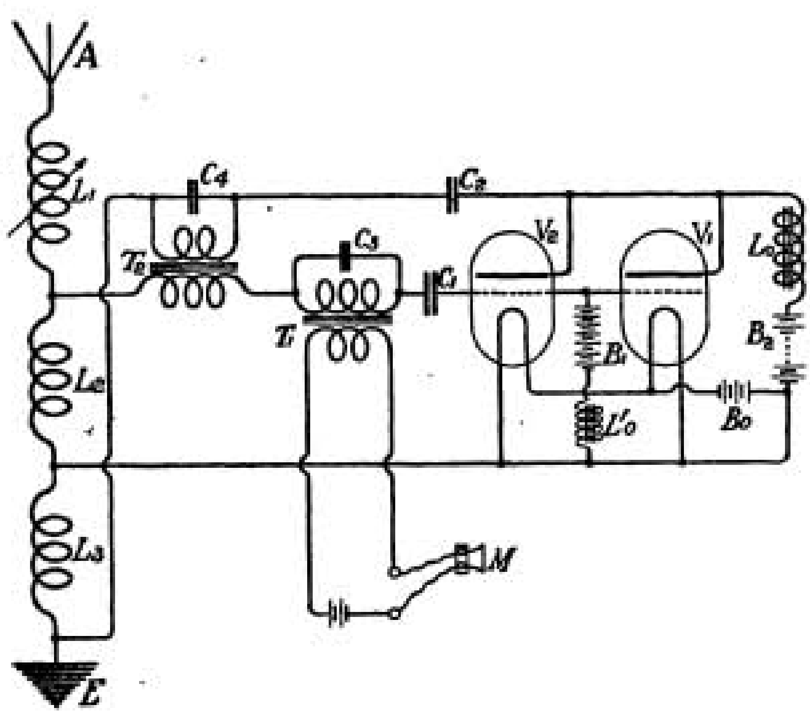


FIG. 2.

14. WIRELESS TELEPHONY. Société Française Radio Électrique. (*British Patent* 127008. January, 1917.)

Details are given of a modulation arrangement for controlling the output from oscillation valves. The particular feature is the provision of a shunt between the grid and the filament, which is controlled by the transmitting microphone. In order to secure a sufficiently high impedance in this shunt, an inductance is placed in series with the microphone, and a tuning condenser across both microphone and inductance. The combined shunt is tuned to the oscillation frequency.

15. WIRELESS TELEPHONE TRANSMITTER FOR SEAPLANES. (*Telegraph and Telephone Age*, pp. 342—346, July 16th, 1919.)

A description, with circuit diagrams, of the wireless telephone installations developed for use in seaplanes by the American Marconi Company. The transmitter comprises two valves, one for oscillation generator, and one for speech modulator, capable of working on 1,600 or 600 metres wave length.

Speech transmission range = 150 miles. Telegraph signalling can be effected by means of a buzzer in the grid circuit of the modulator valve.

16. Vacuum Tubes. By M. Peri and J. Biguet. (*British Patent* 126658. October, 1915.) *

This patent, only just issued, although applied for in 1915, deals with the constructional details of three-electrode valves of the "French" type.

17. A New Electron Tube. By P. Donle. (*Radio Amateur News*, 1, p. 14, July, 1919.)

The valve described in this communication has the anode on the outside of the glass, with the usual spiral grid surrounding the filament in a vacuum. Best results were obtained with a silver anode. Curves of conductivity of the glass at various temperatures are given, and a characteristic curve of the complete valve.

18. Reception through Static and Interference. By R. A. Weagant. (*Proceedings Inst. Radio Engineers*, 7, p. 207, June, 1919. *Electrician*, 83, pp. 84, 110, 180, August, 1919, Abstract.)

One of the greatest troubles in the operation of wireless receivers of all

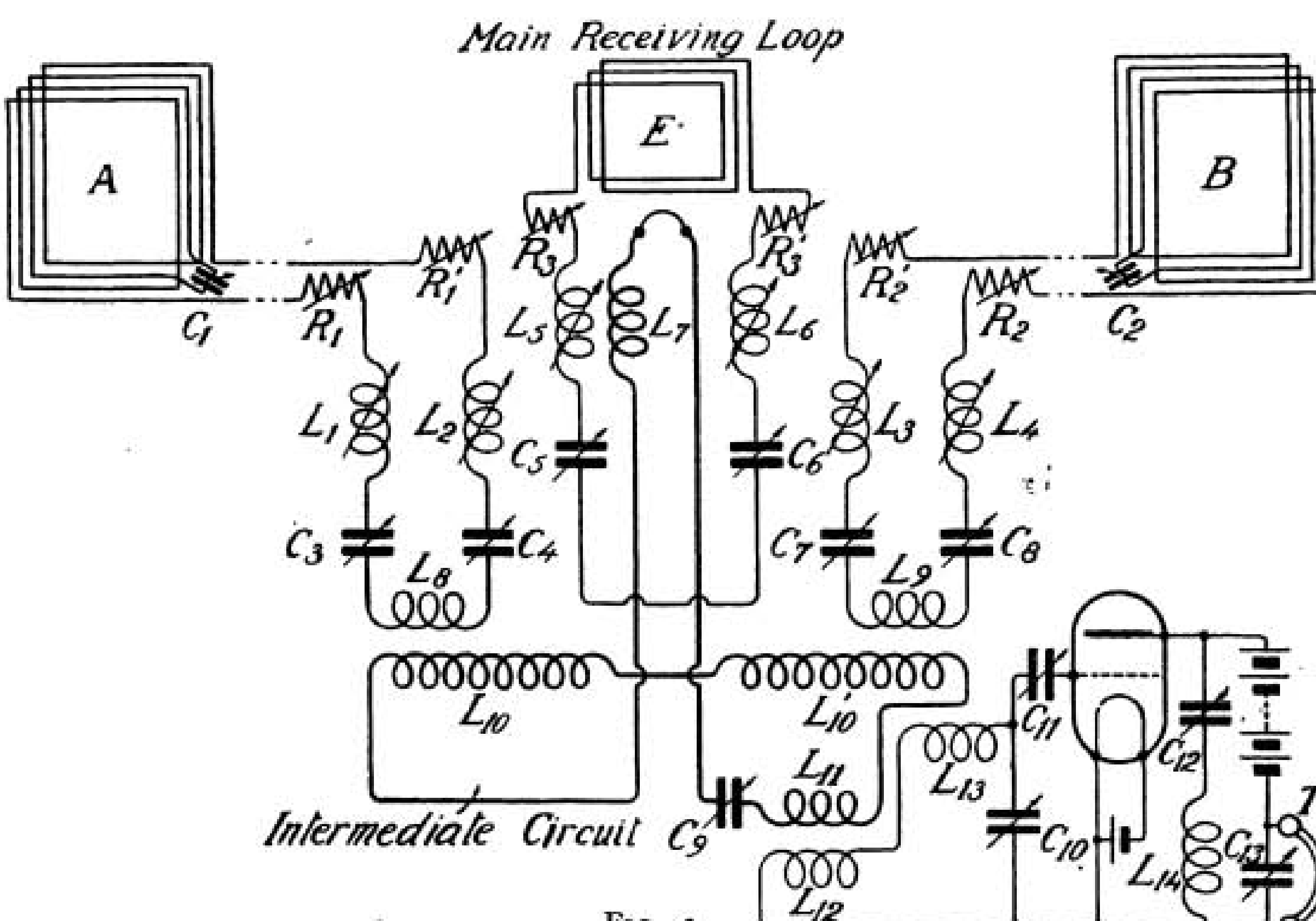


Fig. 3.

* The publication of a large number of radio patents has suffered considerable delay under war-time conditions. Some of these are now being issued, and they will be dealt with as available.

types is the disturbance arising from the reception of atmospherics, strays, or X's. In this paper the author discusses the effects produced by the various classes of X's (grinders, clicks and hisses), and a series of researches is described bearing on the directive effect obtained with the various classes of X's. Clicks originating in fairly definitely positioned thunderstorms show a decided direction of propagation, but the grinder type of X appeared to have no definite direction determinable by ordinary direction-finding apparatus. The theory is put forward that the direction of propagation of atmospheric impulses of the grinder class is not horizontal, but vertical—

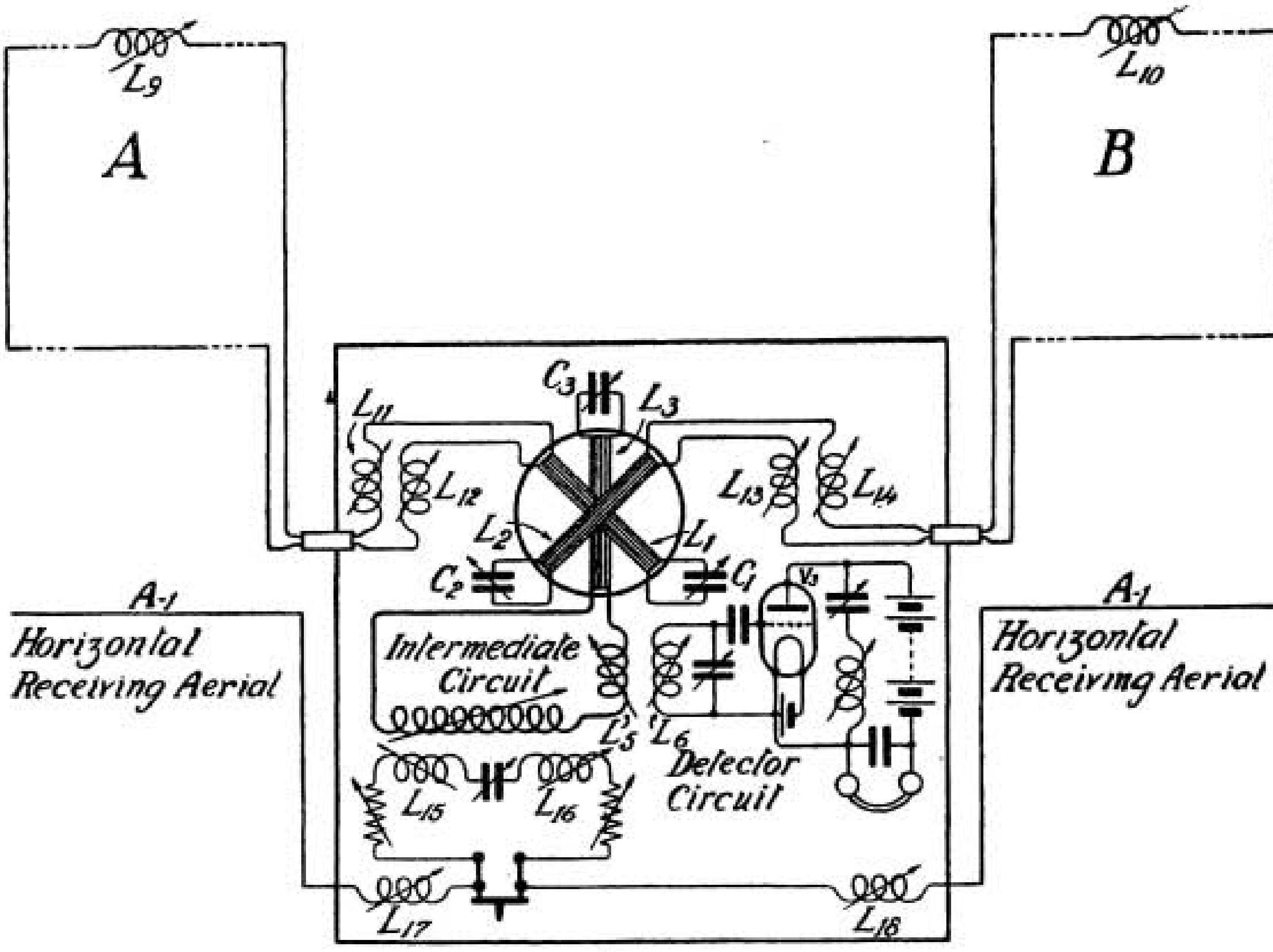


FIG. 4.

perpendicular to the earth's surface at the station—and that they behave as heterogeneously polarised waves, originating either overhead or underfoot.

Various experimental evidence collected during the research work is claimed to support this theory. One method adopted to take advantage of the above theory is indicated in Fig. 3. Two vertical loop aerials, *A* and *B*, are employed, spaced apart, with their plane in the line joining the receiving and transmitting stations, and connected up to a common radiogoniometer at the receiving station, which is placed midway between the two loops. Each loop circuit is provided with independent tuning inductances, L_1, L_2 and L_3, L_4. Coils L_8, L_9 form the fixed coils of the goniometer, while the moving coil, L_{10}, is coupled to the detector circuit through L_{11}, L_{12}. In order to secure the best results the centres of the loops *A* and *B* should be spaced one-half wave length apart, although smaller distances may also be used. Assuming this spacing, the currents set up in the two loop circuits are evidently of opposite phase, so that, by properly combining them through the goniometer, the impulses from the two loops become additive. Evidently, when this is the case, the currents induced in the two loops by the X's are in opposition, and so cancel out, since there is no appreciable phase difference between them. The resistances R_1, R_2, R_1', R_2' serve to equalise the decrements of the two circuits, to ensure a proper cancelling out of the X's.

Atmospherics of the "grinder" type are eliminated by this method.

To eliminate clicks as well as grinders, a similar principle is adopted, but in this case the spaced double loops are used to form a source of atmospherics of adjustable frequency and damping that may be used to oppose and cancel out the atmospherics received with the signal on the main receiving loop aerial (*E* in Fig. 3). Another scheme for this arrangement is indicated in Fig. 4, which shows a low horizontal aerial used for the main reception instead of a third loop. *A* and *B* are the two loops, which are connected so as to collect the atmospherics, but no signal, although tuned to the same frequency. Long low loops are preferred for these, running out as loops directly from the station to the extreme end, instead of being square loops connected by long lead-in wires, as indicated in Fig. 3. Inductances L_9, L_{10} are inserted in the centres of the top wires of the loops to facilitate tuning at the station. L_1, L_2, L_3, is the goniometer, having the moving coil L_3 joined into an intermediate circuit coupled, both to the detecting valve and to the main receiving aerials A_1, A_1, as indicated. With these arrangements trans-Atlantic radio reception has been carried on through heavy atmospheric disturbances without any interference from such causes.

2. Reviews of Books.

The Principles of Radiotelegraphy. By Cyril M. Jansky, B.S., B.A. (New York: *McGraw Hill Book Co., Inc.* London: *Hill Publishing Co., Ltd.* Pp. ix. + 242. Price, 10*s*. net.)

This volume has been prepared in the Extension Division of the University of Wisconsin, and is intended as a students' text-book, rather than as an advanced treatise on radiotelegraphy, and, for this purpose, it is undoubtedly a useful contribution to the literature of that subject, although there is little really new matter contained in its pages.

Since radiotelegraphy is an electromagnetic phenomenon, and electric and magnetic apparatus is employed in the generation and detection of the waves, practically half the book is devoted to a discussion of electric and magnetic principles. This introduction is most desirable for a proper understanding of radio working by students fresh to the subject. In Chapters VII. and VIII. the author deals in a general way with oscillatory circuits, and in a more detailed manner with radio circuits, while the last three chapters are devoted to radiotelegraphy proper, and discuss the various arrangements of transmitters and receivers, with illustrations of different types of American apparatus.

The American custom of inventing fresh terms and expressions in describing apparatus slightly mars the value of the book for English students. For instance, such terms as *susceptance* (on p. 137) do not really explain anything, and are only extra terms to be memorised. "Capacitance," used for ordinary capacity, is perhaps more logical, as it brings the expression in line with inductance, resistance, etc., although the value of its use is open to difference of opinion.

In a few parts of the book rather incorrect ideas might be gathered. Perhaps the worst instance is in Fig. 147, described as "Typical Connections of a Receiving Station." This shows a coupled crystal receiver with the mistake, often made by W/T. operators, of feeding their crystal testing buzzer from the potentiometer cells of their receiver. Such an arrangement gives a sound in the telephones whatever the condition of the crystal. Further, the buzzer is also shown as coupled to the telephone circuit instead of to the crystal oscillatory circuit, or preferably to the aerial. This would also give false indications as to the condition of the crystal for reception. The whole trouble can, of course, be removed by coupling the test buzzer to the aerial circuit, and feeding it from an independent battery.

In the description of valve circuits the author misspells Dr. Fleming's name; and, in describing the heterodyne receiver, only shows an arc as the local source of oscillations—surely an arrangement fast becoming obsolete. It is not obvious why Fig. 179 should be described as a combined radio-telegraph and *telephone* circuit, when apparently there are no means provided for transmitting speech. The circuit shown is more correctly a species of "Tonic Train" transmitter.

Speaking of wireless telephones (which are scarcely mentioned), the use of the term "radiotelephone" (though common in America for this purpose) scarcely seems justified for describing simply a headgear telephone receiver. The term ought to be strictly confined to the complete wireless telephone apparatus, as in the analogous case of "radiotelegraph."

The description of the Goldschmidt alternator is not very clear, although the correct ideas are given. On p. 167 the author says, "In this manner the damping is *reduced*, which is called *quenching*" (the italics are mine). Quenched spark gaps usually give very high damping in their circuits, and it is not made clear that it is the decrement of the *aerial* oscillations that is reduced when such gaps are used.

Actual misprints are very few, but the transposition of the figures on pp. 4 and 5 might cause confusion to a new student. Inaccuracies on pp. 93, 169, 176, and in the numerical index in the wave-length formula on p. 180 should also be mentioned.

The treatment of the subject is quite good on the whole, and no difficult mathematics is used, while the numerical examples at the ends of the chapters and throughout the text should be very helpful. They might, however, be somewhat more useful if given in the more usually adopted practical units, particularly for the wave-length formulæ.

The general appearance of the book is good, and the printing clear. It should prove on the whole a useful radio text-book for students' use.

P. R. C.