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THE

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A Method of Direction Finding of Wireless Waves

And its Applications to Aerial and Marine Navigation.

By Capt. JAMES ROBINSON, R.A.F., M.Sc., Ph.D.

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4. AMBIGUITY.

In the minimum method of determining the direction of incoming waves there is always the ambiguity of 180°, and if a bearing θ is obtained it is uncertain whether the transmitting station lies in the direction $\theta°$ or $(\theta° + 180°)$.

The present system, when looked at casually, might be supposed to increase this uncertainty, so that one cannot be sure whether the bearing is $\theta°$, $(\theta + 90)°$, $(\theta + 180)°$ or $(\theta + 270)°$. However, on closer observation the two directions $(\theta + 90)°$ and $(\theta + 270)°$ are out of the question.

The reason why it may be considered to give this uncertainty of four directions is that, if the correct bearing is obtained, the signals are of equal intensity. At 90° from this direction it is obvious that the signals, on reversal, are also of equal intensity. The system of connections in use, however, makes it possible to find whether, when using the main coil alone, a signal can be heard. When on the correct bearing a signal will be heard when on the main coil alone, and this will be of the same intensity as the equal signals when both coils are used if, as is usually the case, the dampings are the same when one coil or both coils are used. When on the positions which are 90° out no signal will be heard on going over to the one coil position. It is impossible to make this error of 90° if the method for finding a bearing as described

Y

above is followed, where an approximate determination of the maximum of the main coil is first obtained.

There is another obvious method of knowing whether one is on the correct bearing or 90° out. In practice, the coils are used with the area-turns of the auxiliary coil two or three times that of the main coil. Hence, when on the correct bearing, the set is very sensitive, and, when on the position 90° out, the set is very much less sensitive, it being necessary to move the coils 5° or more without making any appreciable change in the intensity of the signals on reversal.

5. General Application of the Method.

So far the method has only been described in its relations to rotating aerials, but it is capable of application to any minimum method of direction finding. In the case of the Bellini-Tosi system, where the moving part is a small coil inside the instrument, known as a radiogoniometer, the same effect is obtained by rotating this moving coil through 360° as is obtained by rotating a single loop aerial through 360°. It is only necessary to construct a radiogoniometer with two movable coils fixed rigidly at right angles to each other, so as to have no mutual induction, one of them to be equivalent to the main coil in Fig. 1, and the other to the auxiliary coil. Fig. 4 shows the connections.

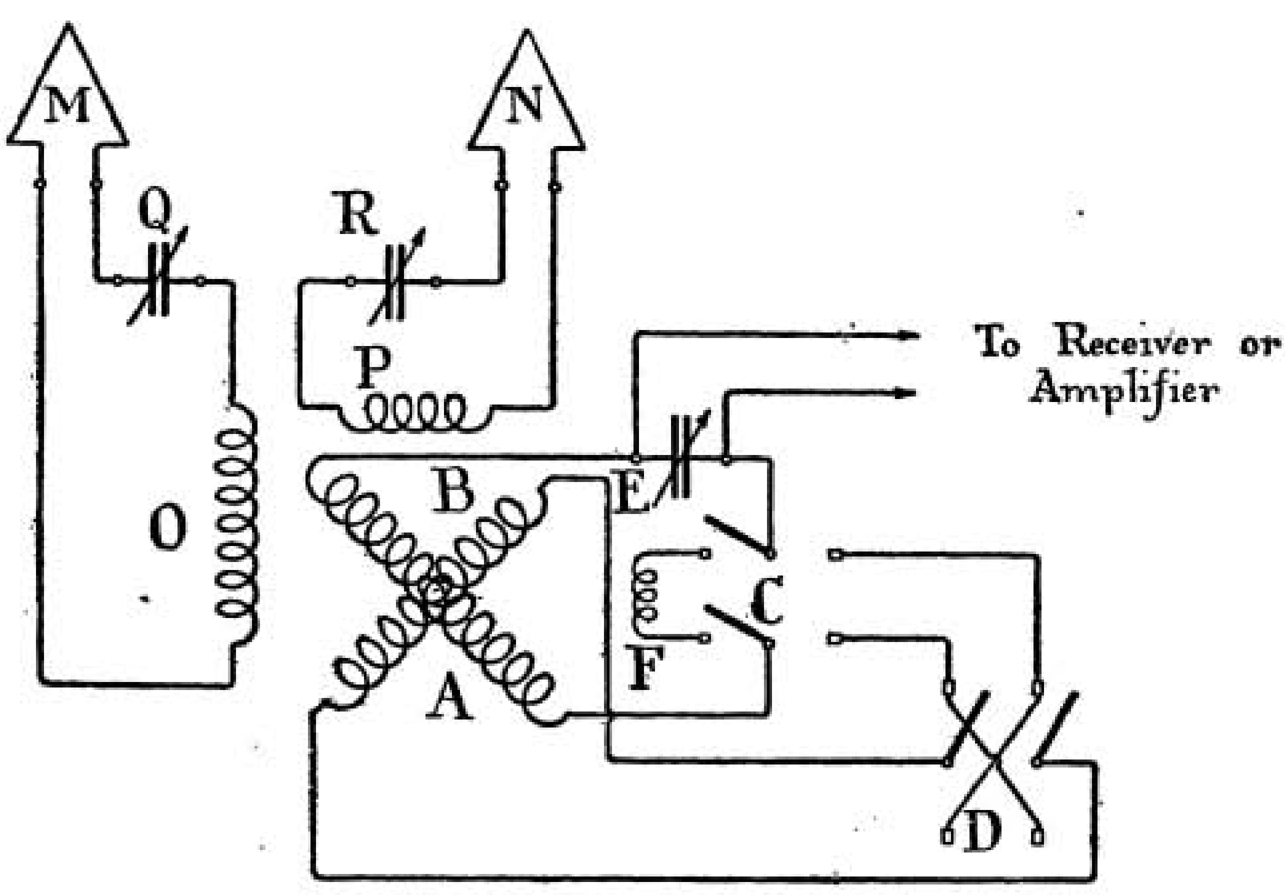

Fig. 4.

M and N are the fixed aerials at right angles to each other. O and P are the fixed coils of the radiogoniometer. Q and R the aerial tuning condensers. A and B are the two movable coils rigidly fixed together. A corresponds to the main coil, B corresponds to the auxiliary coil, C is the change-over switch, and D the reversing switch, as in Fig. 1, F being the balancing inductance. For a workable sensitiveness the area-turns of B will be made two or three times those of A.

Another method of applying this system to the Bellini-Tosi method is to use two distinct radiogoniometers with the movable coils capable of rotation together. The radiogoniometers should not have any influence on each other. The moving coil of one will form the main coil, and that of the other the auxiliary coil.

6. D.F. ON AIRCRAFT.

The method of direction finding which has just been described is suitable for application to aircraft, and in fact was designed originally for this purpose. The conditions on aircraft are such that a minimum method would be inaccurate, as the external noise of the engines makes it impossible to hear weak signals. With a minimum method, the region in which the signals are inaudible is much wider than in similar conditions on the ground, and thus on aircraft it would be much more inaccurate.

Directional wireless is of the first importance for aircraft for the purpose of navigation. The problem of navigation of the air presents many features different from those at sea. One that stands out clearly is dead reckoning. At sea it is possible to use dead reckoning methods, by knowing the course steered and the distance travelled. In the air, however, the course steered may be quite different from the course made good, and the air speed is no criterion for the ground speed, because of the unknown factor of drift. Hence the importance of the determination of position by any possible method, or failing that, the finding of directions on fixed places from time to time. The problem of aerial navigation is vast, and it is only proposed here to indicate how this method of direction finding acts as an aid to it.

(A). We shall first consider the case of an aeroplane making for a spot where there is a wireless station, which transmits from time to time. In such a case the D.F. aerials can be fixed to the aeroplane and the aeroplane turned to get its head on to the station. This method of applying the D.F. system, we shall call the *wing coil method*, as the aerials can be most conveniently fitted to the wings.

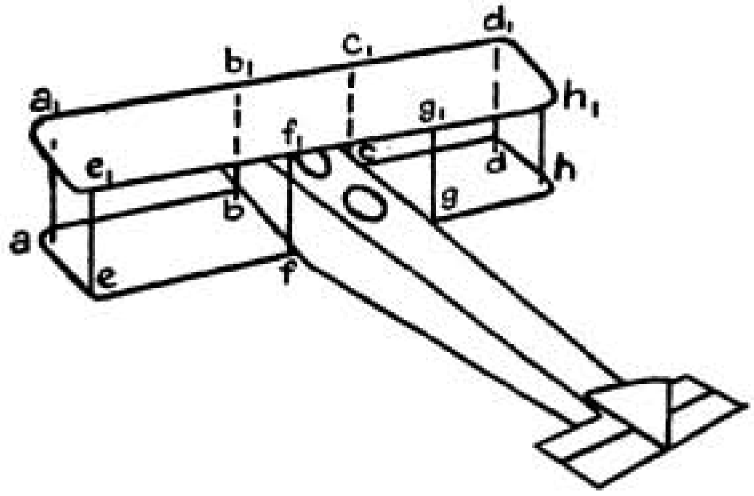

FIG. 5.

Fig. 5 shows how the coils can be conveniently fitted. We take the case where there are two pairs of struts on each side of the fuselage, aa_1, bb_1, cc_1, dd_1, being the struts near the leading edge and ee_1, ff_1, gg_1, hh_1, those near the trailing edge. The main coil is the coil whose maximum is to be determined and it must be fixed so that its plane is in the fore and aft line of the aeroplane. The auxiliary coil is then fixed with its plane athwartships. The main coil is usually fixed in two parts, one on each side of the fuselage, *i.e.*, some turns on the struts aa_1, ee_1, and some on the struts dd_1, hh_1. The auxiliary coil may be in one part only, either on the leading or trailing edges, *i.e.*, up hh_1, along the upper wing to e_1, down the strut e_1e, and along the lower wing to h. Again the auxiliary coil may be also in two parts, a device which is suitable for aeroplanes with folding wings. Leads from the coils are brought into the fuselage. By this method it is simple to keep the head of the aeroplane pointing towards the transmitting station, and thus to find the way to the destination.

It is worth noting that if there is a cross wind, this will make the aeroplane drift from its path, and if bearings on the home station are taken at intervals, it will be found that the effect of the cross wind is to make the bearing on the home station alter continuously, and the path of the aeroplane will be curved. A skilful navigator can however get some idea of this drift from consecutive bearings and apply corrections so as to make his path much less curved.

The wing coil method can be used for determination of position if two or more wireless stations or beacons transmit so that two or more bearings on known stations can be found. It is necessary to turn the aeroplane towards or away from the beacons in turn, reading the compass in every case when dead on the beacon.

This wing coil system is excellent for head bearings and also for tail bearings, but it has not been used much for determination of position in the air because of the time lost in turning from one's course though good results have been obtained. Very accurate bearings can be taken by the wing coils on the ground, by having a working party to turn the aeroplane round. There appear to be no errors with the wing coils, and in every case when a bearing is obtained, the fore and aft line of the aeroplane is along this bearing, assuming that there is no error in installing the coils. Tests have been made on the ground by taking head and tail bearings on a station and recording the direction of the fore and aft line of the aeroplane in each case by an accurate magnetic compass on the ground. Within the limits of accuracy, the bearings differ by 180°. In one particular case with the ratio $k = 4$, the head and tail bearings were within $\frac{1}{4}°$ of 180°.

(B). For the more formal problem of navigation it is advisable not to have to turn the aeroplane from its course in order to determine its position, or even to determine a single bearing. Then it is essential to make the D.F. system with the moving parts capable of rotation apart from the aeroplane. This is done by installing D.F. coils on frames that can be rotated inside the fuselage. We shall refer to this system as the *fuselage coils system.* By it, bearings can be taken no matter what course the aeroplane is on, and position determined if a sufficient number of bearings be taken. The problem of working out the bearings and thence of working out position is a well-known problem of navigation and will not be gone into in detail here, but certain features that are of interest from the wireless aspect will be dealt with.

The size of coils that can be used inside the fuselage of aeroplanes is not large, even with the largest aeroplanes known at present. With the ordinary Handley Page, the framework of the coils is about 4 feet 6 inches high × 3 feet 4 inches diameter.

On smaller machines the coils are proportionally smaller and in one case coils 2 feet high and 2 feet diameter were successfully used. In any case the coils give much weaker signals than the wing coils, as the area turns are very much less.

Determination of position is similar to the method of sights used at sea except that for long distance bearings great circles must be considered.

The direction of the incoming waves is determined with regard to the fore and aft line of the ship, and recorded red or green for port or starboard. Knowing the course steered by the aeroplane, the direction of the incoming waves is determined. In practice certain corrections have to be applied,

(*a*) The magnetic variation.

(*b*) The deviation of the compass ; and

(*c*) The quadrantal errors of the D.F. coils, *i.e.*, the angle between the direction of the waves in space and the apparent direction recorded by the coils (see below).

Great care is needed in taking these bearings, especially if the beacon is a long distance away. For a distant beacon, an error of 2° means a large error in distance. It must be remembered that it is a very difficult matter for a pilot to keep a course steady to 1° for a lengthy period. Again the navigator's compass so far used has not been perfect. Again bumpy weather makes it difficult to keep the course steady and each bump makes the compass move. Once the compass starts moving it usually takes a little time to come to rest again. A considerable amount of training is required for an observer to take a bearing by his D.F. coils and to get a reliable reading of his magnetic compass at the moment his bearing is taken.

In order to lay off a bearing on a chart it must be remembered that the path of electromagnetic waves is a great circle, and if a bearing of $\theta°$ is found on a certain beacon, this means that the aeroplane lies on the great circle passing through the beacon and crossing the meridian of the aeroplane at an angle of $\theta°$. It is found that it is possible to draw a line on a chart so that at any point on this line, the bearing on the beacon is $\theta°$. Such a line is called a *line of equal bearing*. Charts are made with these lines drawn for various beacon stations.

Quadrantal errors must be carefully determined. They vary with the direction in which the waves strike the aeroplane. They are equivalent to a deviation of the waves by the aeroplane, this deviation depending on the direction of the waves. They may be due to one of two causes, or probably to both causes :—

(*a*) Actual deviation of the waves by the metal parts of the aeroplane, more especially by the engines and tanks.

(*b*) The fact that the metal parts of the aeroplane absorb energy from the waves, part of which energy is re-radiated in a definite direction.

Evidence seems to point to the fact that the second cause accounts for most of the deviation.

The nature of the quadrantal errors is as follows :—

The errors are zero in the fore and aft, and athwartships direction, and a maximum at the 45° and 135° directions from the fore and aft line. A large number of different Handley Page aeroplanes showed the same characteristics, though the actual magnitude of the deviations varied somewhat from machine to machine. In most machines however, the maximum errors were 8° or 9°, though in one machine they were as low as 3°. In another type of aircraft, the flying boat, the maximum errors were 3°. These errors are independent of the wavelength so far as our observations have gone, using waves from 2,000 to 8,000 metres. The errors are usually of the same magnitude in opposite quadrants, though at times it is found that this is not the case.

The method of determining the quadrantal errors is to swing the aeroplane and take bearings on the same beacon station, every 10° or 20° as the aeroplane is rotated. Knowing the correct bearing, the errors for each position can be calculated.

7. DESIGN OF COILS FOR ANY WAVELENGTH.

(1) *Energy absorption by loops.*—The E.M.F. picked up from electromagnetic waves by a loop depends on many factors but it is always of a small order of magnitude compared with that which is picked up by an ordinary plain aerial. Attention must thus be paid to many points in order that the best possible results may be obtained. It is usually necessary to use amplifiers in order that signals may be heard at all. Careful attention must be paid to such things as insulation, good contact, and accurate tuning.

(2) The E.M.F. depends on the dimensions of the loop and on the number of turns. Within fairly wide limits it is safe to assume that the E.M.F. is proportional to the area-turns of the loop. There has been a suggestion of a possibility that this proportionality does not continue as the number of turns is increased indefinitely, and that the E.M.F. approaches a maximum value above which it is impossible to go, no matter how many more turns are used. The writer has had no experience of this and for the coils used in practice it is not far from the truth to assume proportionality

between E.M.F. and area-turns. As many as fifty turns have been used on occasions but as a rule fewer turns are used.

• One of the first points in design is that the dimensions of the coils shall be as large as permissible, and that as many turns as possible shall be used.

(3) The number of turns that can be used is limited by the fact that inductance increases almost as the square of the number of turns. In order to have good tuning, a certain condenser value must be used, this value being small. It is found in practice that there is a best condenser value for each wavelength and that very little if any advantage is obtained by increasing the number of

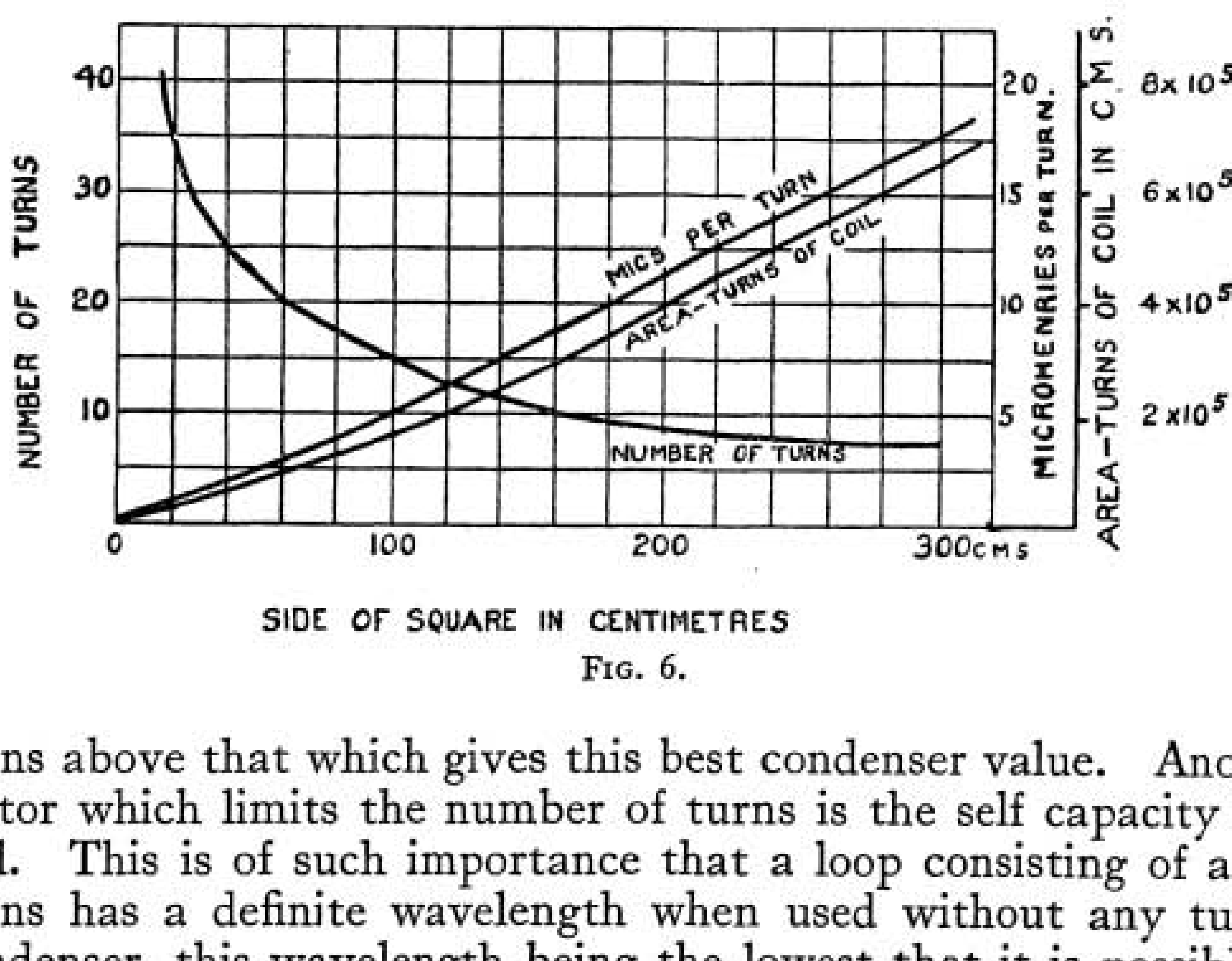

FIG. 6.

turns above that which gives this best condenser value. Another factor which limits the number of turns is the self capacity of a coil. This is of such importance that a loop consisting of a few turns has a definite wavelength when used without any tuning condenser, this wavelength being the lowest that it is possible to obtain. In order to keep the self capacity down, it is necessary to space the turns.

(4) To calculate the number of turns required for any specific conditions, *i.e.*, when the wavelength and outside dimensions of the coil are given, certain formulæ are in existence which give the inductance of a single turn of a square, rectangle or circle. Square or rectangular coils are used most, so we shall restrict ourselves to these cases. The formula which has been used for a square coil is $L = 18{\cdot}424a \left(\log_{10} \frac{a}{r} + 0{\cdot}4343 \frac{r}{a} - 0{\cdot}3361\right)$ where $a =$ side of

square in cms. r = radius of wire in cms. From this formula curves, shown in Fig. 6, were made out for convenience. Three curves are shown :—

(*a*) One showing the microhenries per turn for a square of side up to 300 cms.

(*b*) One showing the number of turns required to give 1,000 microhenries for squares of side up to 300 cms.

(*c*) One showing the area-turns of such coils.

In practice it is found that when coils are made from these curves, the inductance is usually less than that required, by about 12 per cent. This may be accounted for, in part, by the fact that it is necessary to space the turns somewhat to keep down the self capacity and thus the inductance is not really proportional to the square of the number of turns.

It is observed however that there is a great advantage in keeping the size of coils as large as possible as the area-turns increase with the size of the coil.

In order to design coils for a given wavelength, certain capacities have to be allowed for, the values varying from 0·2 jar for a wavelength of 400 metres to 0·6 jar for a wavelength of 4,000 metres.

It is worth noting that it is unwise to use twin flex for the leads from the coil to the condenser or receiver, because flex has appreciable self capacity.

For rectangular coils, approximate values can be obtained by using the above curves and using the side of the square which has the same area as the rectangle, always assuming, of course, that the rectangle is not too elongated. It is safe enough to use this device for rectangles whose long side is not more than four times the short side.

(5) It will now be shown how to calculate the number of turns on the main and auxiliary coils for any specific conditions.

The wavelength being given, the capacity to be allowed is chosen to be somewhere near its best value. From this, the total inductance can be calculated. Let it be L microhenries.

Let the length of the side of the equivalent square of the main coil be a cms. and that of the auxiliary coil b cms.

Let there be n_1 turns on the main coil
and n_2 „ „ auxiliary coil.

From Fig. 6 the inductance per turn for squares of sides a and b can be found. Let them be

l_1 microhenries for the main coil, and,
l_2 ,, ,, auxiliary coil.

Suppose the ratio of the area-turns of the auxiliary to main coils is chosen to be k.

We have $n_1 a^2 =$ area-turns of main coil.
$n_2 b^2 =$,, ,, auxiliary coil

and $k n_1 a^2 = n_2 b^2$

giving $n_2 = \alpha\, n_1$

where $\alpha = k \left(\frac{a}{b}\right)^2$

The total inductance $L = n_1^2\, l_1 + n_2^2 l_2$ approximately

$$L = n_1^2\,(l_1 + \alpha^2\, l_2).$$

As L, l_1 and l_2 and α are known, n_1 can be calculated, and thus also n_2.

(6) There should be no mutual induction between the main and auxiliary coils, in order that the tuning may be unchanged on reversing the auxiliary coil.

8. Types of Coil.

From the paragraph on design of coils it is shown that the points to pay attention to are :—

(*a*) The turns must be spaced so as to keep down the self capacity.

(*b*) The area-turns should be as large as possible for the wave-length to be used.

(*c*) The auxiliary and main coils should be as nearly perpendicular as possible, so that there is little or no mutual induction between them.

Three patterns of coil have been used :—

(1) *Box pattern.*—This type has the separate turns of a coil parallel to each other and in parallel planes, the planes being separated by $\frac{1}{8}$ inch to $\frac{1}{2}$ inch.

(2) *Pancake pattern* where each coil is wound with the turns all in the same plane.

(3) *Combination of box and pancake pattern.*—The idea underlying such a combination is to get the area-turns as large as possible for the given wavelength. This is equivalent to a number of parallel pancakes, and there is so much more space for winding

than in either the box or pancake pattern alone, that it is possible to leave greater distances between the turns. This is of advantage in two ways, firstly the inductance for turns is smaller than if the turns were bunched closer together, and, secondly, the self capacity is reduced. In practice so far, only two parallel pancakes have been used.

In a subsequent paper some results will be given of the application of this method of direction finding to wireless navigation with especial regard to aircraft.

My best thanks are due to Major J. Erskine Murray, D.Sc., for the interest he has taken in the development of this method of wireless navigation, and for advice given on many occasions.

APPENDIX.

Note on the relation between the area-turns of a loop and the E.M.F. picked up from electromagnetic waves.

It has been assumed in the preceding paragraphs that the E.M.F. picked up is proportional to the area-turns of a loop. This law seems to hold when the number of turns in a loop is not too large, say up to forty turns. The following experiment proves this.

Referring to Fig. 3 we find that the curves cc_1 and dd_1 cut the axis of E.M.F. at the points S and T. Let the angle represented by SO and TO be $\theta°$.

Curve cc_1 is $Y_1 = a \cos \theta + b \sin \theta$

" dd_1 is $Y_2 = a \cos \theta - b \sin \theta$

For Y_1 or $Y_2 = 0$ we have

$$\tan \theta = \pm \frac{a}{b}.$$

This ratio $\frac{a}{b}$ is the ratio of the maximum E.M.F.'s produced in the two coils.

Now k is the ratio of the area-turns of the auxiliary and main coils. Hence if

$$\tan \theta = \frac{1}{k}$$

the above assumption is correct.

This is found to be the case within 3 per cent. for coils with turns up to forty.

The Effect of the Potential Drop along the Filament of a Valve on its Sensitiveness as a Detector.*

By E. GREEN, M.Sc.

This article is in the nature of a note on the papers by Dr. Eccles in the October—December issues of the RADIO REVIEW, and will follow his nomenclature as far as possible.

The effectiveness of a valve, as a rectifier (or detector) of small alternating currents is proportional to the value of $\frac{d^2I_a}{dE^2}$ for that point of its characteristic at which it is used. Here I_a is the plate current, and E the voltage at plate or grid, according as it is a diode or triode. *I.e.*, if ϵ is the maximum value of the small alternating voltage at plate or grid the rectified current is

$$\frac{1}{4} \cdot \frac{d^2I_a}{dE^2} \cdot \epsilon^2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

Case of Diode.

We can apply this to the formulæ given by Dr. Eccles. First consider the case of a two electrode valve (a diode), consisting of a cylindrical anode, and an axial filament of length l. Let i_a = electron current drawn from unit length of filament by voltage e_a. I_a = total current from filament. Then we have

$$i_a = Ae_a^{\frac{3}{2}}$$

where A is a constant and i_a, e_a, refer to any particular corresponding parts of filament and anode. Now assume that the filament is all at one potential, so that i_a and e_a^2 are constant throughout its length.

$$\therefore \quad I_a = A \, . \, l \, . \, e_a^{\frac{3}{2}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

and

$$\frac{d^2I_a}{de_a^2} = \frac{3}{4} \cdot \frac{A \, . \, l \, .}{e_a}$$

This has its maximum value when $e_a = 0$. In practice the alternating voltage $\epsilon \sin \omega t$ is of finite amplitude, and we cannot use $\frac{d^2I_a}{de_a^2}$ to find the rectified current when $e_a = 0$ but we can get an approximate value as follows. During half the cycle the current will be $Al(\epsilon \sin \omega t)^{\frac{3}{2}}$, and zero during the other half-cycle.

$$\therefore \text{ Rectified current} = \tfrac{1}{2} A \, . \, l \, . \, \epsilon^{\frac{3}{2}} \frac{1}{\pi} \int_0^{\pi} \sin^{\frac{3}{2}} \theta d\theta$$

and $\sin \theta \geqq \sin^{\frac{3}{2}}\theta \geqq \sin^2\theta$.

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* Paper received January 1st, 1920.

$$\therefore \frac{1}{\pi}\int_0^\pi \sin\theta d\theta > \frac{1}{\pi}\int_0^\pi \sin^{\frac{3}{2}}\theta d\theta > \frac{1}{\pi}\int_0^\pi \sin^2\theta d\theta.$$

$$\therefore \frac{1}{\pi}\int_0^\pi \sin^{\frac{3}{2}}\theta d\theta \text{ lies between } \frac{2}{\pi} \text{ and } \frac{1}{2}$$

$\therefore$ Rectified current lies between $\frac{1}{\pi}A \,.\, l \,.\, \epsilon^{\frac{3}{2}}$ and $\frac{1}{4}A \,.\, l \,.\, \epsilon^{\frac{3}{2}}$.

We will take the smaller value.

If however the voltage drop along the filament is e_f, and the anode battery is connected to the negative end of the filament, the voltage between anode and filament at any point, distance x along the filament from the negative end, will be $e_a - e_f \,.\, x/l$.

$$\therefore i_a = A\left(e_a - e_f\frac{x}{l}\right)^{\frac{3}{2}}$$

and

$$I_a = \int_0^l A\left(e_a - e_f \,.\, \frac{x}{l}\right)^{\frac{3}{2}} dx \quad \ldots \ldots \ldots \quad (3)$$

$$I_a = \frac{2}{5} \,.\, \frac{A \,.\, l}{e_f}\left\{e_a^{\frac{5}{2}} - (e_a - e_f)^{\frac{5}{2}}\right\} \quad \ldots \ldots \ldots \quad (4)$$

$$\frac{d^2 I_a}{de_a^{\,2}} = \frac{3}{2} \,.\, \frac{A \,.\, l}{e_f}\left\{e_a^{\frac{1}{2}} - (e_a - e_f)^{\frac{1}{2}}\right\} \quad \ldots \ldots \ldots \quad (5)$$

When $e_a < e_f$ only that part of the filament for which $\left(e_a - e_f\frac{x}{l}\right)$ is positive will contribute to the electron current.

$$\therefore I_a = \frac{2}{5} \,.\, \frac{A \,.\, l \,.}{e_f} e_a^{\frac{5}{2}}, \quad \frac{d^2 I_a}{de_a^{\,2}} = \frac{3}{2} \,.\, \frac{A \,.\, l \,.}{e_f} e_a^{\frac{1}{2}} \quad \ldots \ldots \quad (6)$$

Hence $\frac{d^2 I_a}{de_a^{\,2}}$ continually increases as e_a increases, as long as $e_a < e_f$.

When $e_a > e_f$, $\quad \frac{d^2 I_a}{de_a^{\,2}} = \frac{3}{2} \,.\, \frac{A \,.\, l \,.}{e_f}\left\{e_a^{\frac{1}{2}} - (e_a - e_f)^{\frac{1}{2}}\right\}$

This expression decreases as e_a increases, and therefore $\frac{d^2 I_a}{de_a^{\,2}}$ has its biggest value when $e_a = e_f$. At that point

$$\frac{d^2 I_a}{de_a^{\,2}} = \frac{3}{2} \,.\, \frac{A \,.\, l}{e_f} e_f^{\frac{1}{2}} = \frac{3}{2} \,.\, \frac{A \,.\, l}{e_f^{\frac{1}{2}}}$$

For the small alternating voltage $\epsilon \sin \omega t$ the rectified current will be

$$\frac{1}{4} \,.\, \frac{d^2 I_a}{de_a^{\,2}} \epsilon^2 = \frac{3}{8} \,.\, \frac{A \,.\, l \,.}{e_f^{\frac{1}{2}}} \epsilon^2$$

$$\therefore \frac{\text{Rectified current with no potential drop in filament}}{\text{Rectified current with potential drop in filament}} =$$

$$\frac{1}{4} A \,.\, l \,.\, \epsilon^{\frac{3}{2}} \times \frac{8}{3} \cdot \frac{e_f^{\frac{1}{2}}}{A \,.\, l \,.\, \epsilon^2} = \frac{2}{3}\sqrt{\frac{e_f}{\epsilon}} \quad . \quad (7)$$

And, as ϵ may be very small compared with ϵ_f, the value of this may be large.

Case of Triode.

Exactly analogous reasoning applies to the triode valve. If i_a = anode current per unit length of filament, e_a = anode voltage, e_g = grid voltage then neglecting potential drop along filament,

$$I_a = A \,.\, l \,.\, (e_a + ge_g)^{\frac{3}{2}} = A \,.\, l \,.\, e_l^{\frac{3}{2}} \quad . \quad . \quad . \quad . \quad . \quad (8)$$

where A is a constant, and $e_l = (e_a + ge_g)$ and is the lumped voltage.

Taking potential drop along filament into account, the lumped voltage at any point is $(e_a + g \,.\, e_g) - (1 + g)\, e_f \frac{x}{l} = e_l - e_f' \frac{x}{l}$

where $e_f' = (1 + g)\, e_f$ $\qquad \therefore i_a = A\left(e_l - e_f' \frac{x}{l}\right)^{\frac{3}{2}}$

$$\therefore I_a = \int_0^l A\left(e_l - e_f' \frac{x}{l}\right)^{\frac{3}{2}} dx \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

Comparing (8) and (9) with (2) and (3) we see that they are exactly similar in form with e_l in place of e_a and e_f' in place of e_f.

$\therefore$ we have a relation similar to (7):

$$\frac{\text{Rectified current with no potential drop in filament}}{\text{Rectified current with potential drop in filament}} =$$

$$\frac{2}{3}\sqrt{\frac{e_f'}{\epsilon_l}} = \frac{2}{3}\sqrt{\frac{(1 + g)\, e_f}{g \,.\, \epsilon}} \quad . \quad (10)$$

Here $\epsilon_l = g.\epsilon$ is a small change in e_l where ϵ is the change in grid voltage.

Therefore in a triode for use as a rectifying detector, it would be a great advantage if the potential drop along the filament could be compensated for, or minimised, as much as possible. G. A. Bauvais has patented an arrangement whereby a current is passed through the grid wire, which is in the form of a spiral; and so the drop along the filament could be compensated for. Unfortunately the capacity of the grid battery would go far to neutralise the gain in sensitiveness. In some of the audions of the Western Electric Co., with plane grids and anodes, the filament is composed of several wires in parallel, and in this way e_f is reduced, and the detector sensitiveness increased. The writer is fully aware of the many other considerations which enter into the question when using a valve in an actual receiver, but still it seemed of some interest to show the effect of the potential drop along the filament in reducing the sensitiveness of the valve as a detector.

The Coupling of Multiple-Stage Amplifiers.

By THE EDITOR.

Although thirteen years have elapsed since Dr. Lee de Forest invented the three-electrode thermionic valve, or audion, or triode, and described its use as a detector in precisely the same way as it is usually employed at the present time, it is only during the last six years that it has attracted the attention that it deserves. Few scientific discoveries have given a better return for the attention devoted to them. The possibilities of the audion and oscillion,—to use the names given to them by de Forest, than whom no one had a better right to christen them,—were just beginning to be appreciated when war broke out. In Germany it was regarded as too experimental and untried for it to be seriously considered during the early stages of the war, and little was done to develop it until it was found that, in the hands of the Allies, it had been developed into a reliable apparatus which was revolutionising the whole art of radio-communication. Not only in the United States, which as a neutral had every opportunity and inducement to develop the triode, but also in this country and in France a great number of physicists, radio engineers, and lamp makers were engaged in the development of the valve itself, its manufacture on a large scale, and the design and construction of the circuits and auxiliary apparatus for its various applications.

It will thus be seen that the triode has had the fortune—good or bad—to be developed almost entirely under war conditions and for the purposes of war. This fact has had a marked effect on the lines of development and has been the controlling factor in bringing triode apparatus to the form in which we have it at the present day. For the purposes of war apparatus must be, before all else, robust, simple in operation and as small, light, and portable as possible. The seven-valve amplifiers, consisting of say three high-frequency and three low-frequency amplifiers together with the detector, all mounted in a small box containing all the auxiliary apparatus, represented a marvellous achievement, which was not obtained without surmounting numerous difficulties.

Now that the war is over and this class of apparatus is being put to more peaceful uses, one cannot but ask whether, in many cases where portability and compactness are of secondary importance, better results could not be obtained by arranging the apparatus and dimensioning the parts differently. Very little has been published with reference to the relative merits and demerits of the various methods of coupling the successive triodes in a multiple-stage amplifier. In one method a non-inductive resistance of between 20,000 and 100,000 ohms is inserted in each anode circuit, one end being connected to the positive terminal of the anode battery, whilst the other end is connected to the anode and through a condenser to the grid of the succeeding triode. The high-frequency variations of the P.D. across the resistance are thus impressed on the grid. The condenser can be omitted if each triode has its own anode battery since the tapping can be made so that no steady P.D. is applied to the grid. At first sight one might think that such an arrangement would be independent of frequency, but such is not the case since the resistance is shunted by unavoidable capacities, the effect of which increases with the frequency. In the other and more commonly employed method a transformer is used and the grid circuit is thus electrically independent of the anode circuit except for the electro-magnetic induction; no grid leaks are necessary and the grid voltage can be adjusted to any desired value. At one frequency the inductance of the primary of the transformer in combination with its self-capacity will form a resonant circuit, with a large current in the coil but a small current in the anode circuit. If the resistance R of the primary is small, its apparent impedance at this frequency will be ω^2L^2/R, which is very large if R is very small. Under these conditions the apparent impedance will vary greatly with the frequency. To remedy this the coil must be degraded; this can be done in several ways; for instance, by winding it with high resistance wire or by shunting it with a high resistance, or again, by providing it with an iron core in which losses occur, or even by providing a tertiary winding short circuited through a suitable resistance, or wound with high resistance wire and short circuited on itself.

Which is the preferable method and what are the main considerations that should guide one in designing the transformer in any one of these cases in order to obtain the best results with the minimum outlay? Should toroidal coils or astatic grouping of "D" or other shaped coils be adopted to reduce stray fields? What are the relative merits of various types of coils with respect to the effects of self-capacity? If tappings are brought out from large coils so that they may be used for short and medium wave-lengths, are the results obtained inferior to those obtained with specially wound small coils? Iron-cored transformers have been proposed and used even for high-frequency amplification. In this case the laminations employed should not exceed about a twentieth of a millimetre in thickness. In any discussion of the merits and demerits of such transformers it must be borne in mind that with stations working at such wavelengths as 15 to 20 kilometres, the frequency is less than 20,000, which is approaching the audible limit. It is quite possible that for such low radio-frequencies iron-cored transformers could be employed with advantage. In all iron-cored transformers, whether for frequencies of 1,000 or 20,000, further problems arise, such as the effect of the fineness of lamination of the core, the quantity of iron which gives the best result, the relative advantages of open and closed magnetic circuits, the best ratio of turns for a given valve characteristic, and so on. These are some of the problems needing elucidation by systematic experimental investigation and it is hoped that these notes will lead to such research being undertaken, and also to the publication of results already obtained. Much work has undoubtedly been done already but in spite of the flood of thermionic literature which has been poured forth in every country, remarkably little has been published on the practical points mentioned above.

Wireless Telephony on Aeroplanes.*

By Major C. E. PRINCE, O.B.E.

This paper gave a brief summary of the subject of wireless telephony as used on aircraft. Since the use of wireless telephony on aeroplanes came into being almost entirely during the war the treatment given necessarily largely dealt with the developments of the subject by the R.A.F.

Soon after the outbreak of war an experimental set was made up and tried out in the air, and at the first tests some approximation to intelligible speech was received. This, in the summer of 1915, is believed to be the very first occasion in the world when wireless speech was received from an aeroplane. In the early stages the difficulties of reception of speech in the air were so great that only transmission from the air to the ground was attempted, and the first practical set evolved was a transmitter capable of employing either speech, continuous waves, or interrupted continuous waves (subsequently called "tonic-train"). In this set an ordinary inductive reaction coupling was used between the anode and grid circuits of the oscillating valve. The anode circuit was tuned by a variable condenser and inductively coupled to the aerial circuit. The high tension voltage was 600, and was supplied from a dry battery of small cells weighing about 36 lbs. Some of the best ground microphones proved useless in the air and the choice finally rested on an old type Hunnings Cone. The above set weighed 10 lbs. without batteries. It was used on a trailing aerial 250 feet long and employed a wavelength of approximately 300 metres, which was not very far removed from the natural wavelength of the aerial.

This apparatus was exhibited at the meeting, as well as an interesting collection of other and later sets.

Reception on the ground was first carried out with a Marconi double magnification circuit in which a single soft valve was employed for both high and low frequency magnifications and a carborundum crystal was used for rectification. Reaction was used to the utmost, and great sensitiveness was obtained. The ordinary working limit of range from air to ground was about twenty miles for telephony, thirty to thirty-five for tonic-train, and about double this distance for pure continuous waves. Signalling from ground to air was carried out by telegraphy with a ½ kw. spark set.

Later on a demand arose for communication between machines in the air, but for a long time there was still no demand for both-way working, and the machines were equipped either for transmission (for the leader to give orders), or for reception (for his formation to receive them). Dealing first with the transmitting apparatus an ordinary reaction or regenerative circuit provided the radio power, but the main electrical difficulty was the choice of the best method of applying the voice modulations. The earlier coupled system was ruled out on account of the complication of the coupling and tuning adjustments. The development of the "choke" or "constant-

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* Abstract of paper read before the Institution of Electrical Engineers (Wireless Section), on February 18th, 1920.

current " method of modulation control was traced in detail in the paper, leading up to the final simplification in which a common high tension battery was used for both the modulating and the power valve. The circuit arrangement finally adopted is indicated in Fig. I. V_1 is the oscillation valve having its anode circuit closed through the aerial inductance L_2, and its grid coil L_1 inductively coupled to the anode circuit. V_2 is the modulation valve controlled by the microphone M. The choking inductance L_0 is included in the common output circuit of the high tension battery B_2. When variations take place at speech frequency in the controlling valve anode circuit, very large surges are set up in the anode circuit of the power valve which may approximate in magnitude to the original H.T. potential and thus modulate the output from nearly double its steady value to almost zero. This choke control proved pre-eminently suitable for air working and no other method of modulation survived in competition with it. The action of the choke coil was subsequently investigated in greater detail and it was found that for a sound frequency of 750 per second an inductance of not less than five henries was required. Resistance as such was always detrimental.

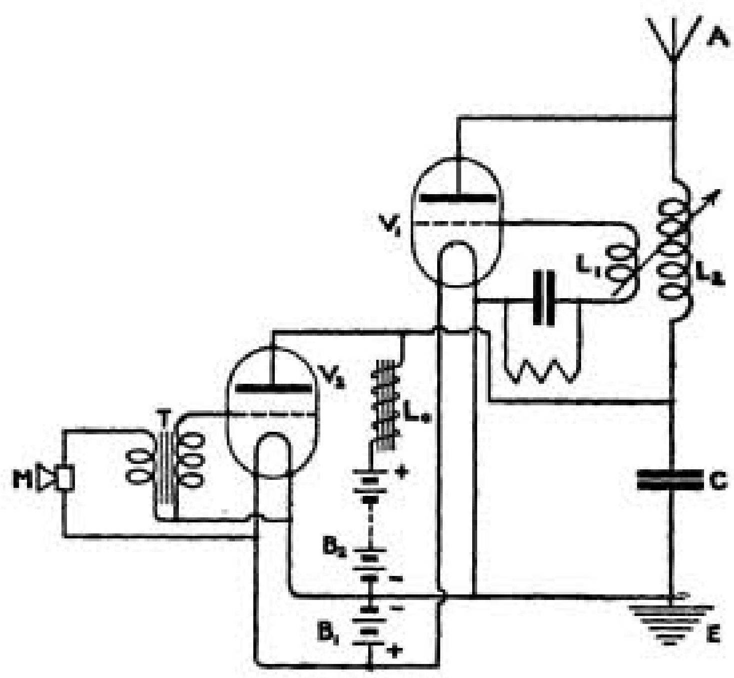

FIG. I.

In the general layout of the set on the aeroplane things were so arranged that the apparatus proper could be mounted in any convenient position at a distance, while only a very small control unit for operating it was brought within reach of the user's hand. This simplification proved very essential for aircraft work and it is probable that much of the British lead was due to consistently designing to fulfil at all costs the needs of actual service conditions rather than to a laboratory standard. Considerable difficulties were experienced in the design of a suitable microphone set and best results were in the end obtained with a microphone which was devised to be almost insensitive to sounds of the intensity of the disturbing noises but responsive to the powerful concentrated sound waves of a voice impinging upon it from a very short distance. This instrument appeared curiously dead and ineffective on the ground, but nothing else was able to work so effectively in a noisy machine.

The difficulties in the design of a receiving set for use on aircraft need no emphasis when the general uproar of the engine and wind is remembered. It was only comparatively lately that high frequency magnification became sufficiently manageable for introduction into aircraft. The arrangement which survived consisted essentially of a detector valve with reaction and two note magnifications. The detector valve was energised from the aerial through a so-called aperiodic circuit which was really a circuit approximately syntonised by its self-capacity. This arrangement was found to reduce magneto noises considerably. Reaction was controlled by varying the filament brightness, firstly because this involved only a small control unit near the user, and secondly because altering the reaction in this way caused less disturbance to the wavelength. The effect of this control was demonstrated at the meeting. The general layout of the receiving circuit is indicated in Fig. 2.

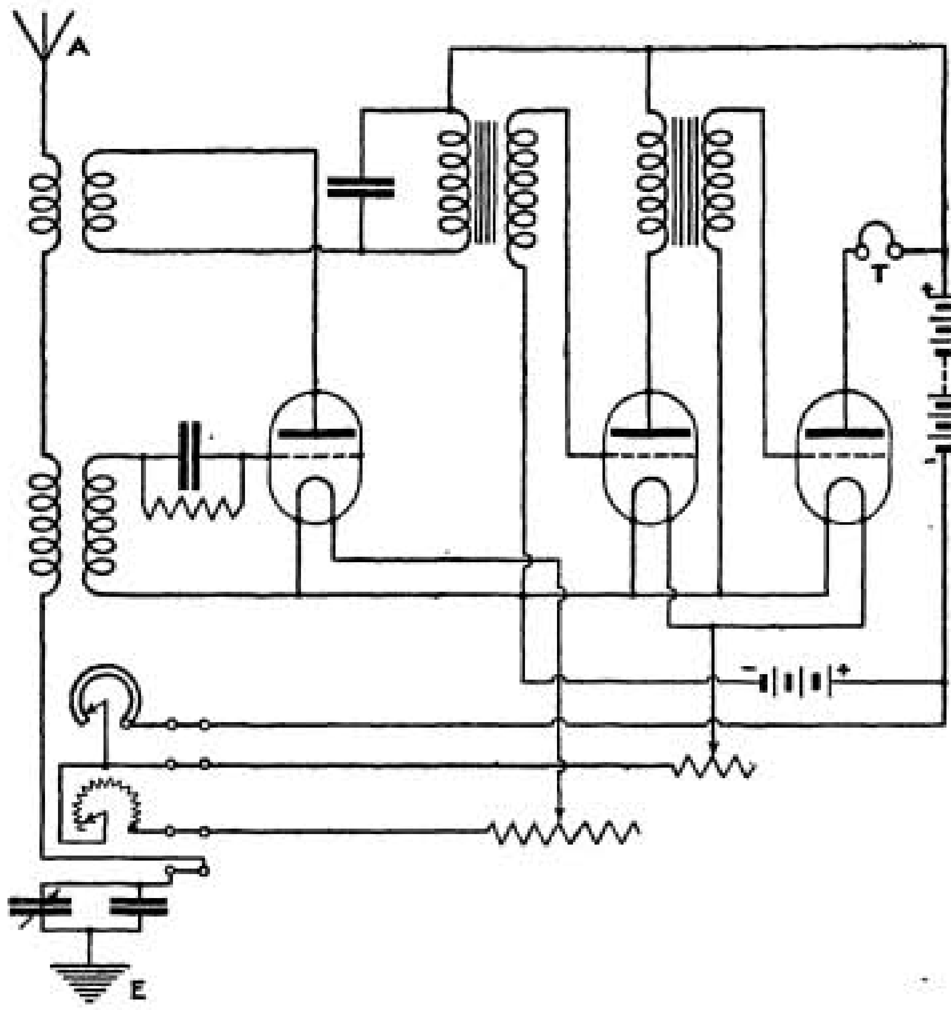

FIG. 2.

(*To be concluded.*)

Measurement of the Chief Parameters of Triode Valves.*

By Prof. W. H. ECCLES, D.Sc.

When a tube is about to be put into use we require to know one or two commonplace facts concerning it, such as the appropriate filament current and voltage which are easily found out or can be supplied by the maker. But there are other properties of the tube—such as the voltage ratio under conditions of normal use—which usually have to be specially measured and which are essential for the formation of an accurate forecast of the performance of the tube in particular applications. A large number of parameters have been suggested for expressing numerically the various properties of triodes, but not all of them are equally important nor are all of them independent. In this paper attention is devoted to parameters belonging purely to the tube. Mixed functions of the tube and its circuits can usually be deduced from the data of the circuits and of the true parameters of the tube itself.

At any given filament voltage or current the principal parameters of the triode are:—

(1) The coordinates of the mid-point of the straight part of the lumped characteristic.

* **Abstract of paper read before the Physical Society of London on January 23rd, 1920.**

(2) The voltage factor g.
(3) The differential coefficient di_a/de_a or h_a.
(4) The differential coefficient di_a/de_g or h_g.
The last-named parameter is not independent of the preceding two, since $h_g = gh_a$.

From a knowledge of these magnitudes the main aspects of the behaviour of the triode when connected to any kind of apparatus can be calculated. All of them can be deduced from the characteristic curves of the tube, but as the drawing of a number of complete curves is laborious, various methods of directly determining the most important parameters are indicated in the paper.

Direct-current methods of carrying out these measurements have certain advantages over methods using rapidly alternating currents and a telephone receiver, although they are not so quick and convenient. The use of alternating current frequently gives rise to accidental electric and magnetic coupling between portions of the same and other circuits which interfere with the accuracy of the measurements.

The coordinates of the mid-point of the straight part of the lumped characteristic may be determined by connecting a shunted galvanometer of low resistance into the anode circuit of the tube and increasing the anode voltage until the current as indicated by the galvanometer ceases to increase. Resistance may then be added to the anode circuit until the galvanometer reading is reduced to one-half of the saturation value. Calling this current of half the saturation value, i_1, the anode circuit voltage E, and the resistance added to the circuit R, the required coordinates are i_1 and $e_1 = E - Ri_1$. It should be noted that the value of e_1 obtained in this manner is a lumped voltage and that it may be made up by any anode voltage and grid voltage that satisfy the equation $e_a + ge_g = e_1$, where e_a is the anode voltage and e_g the grid voltage and g the voltage factor as defined above.

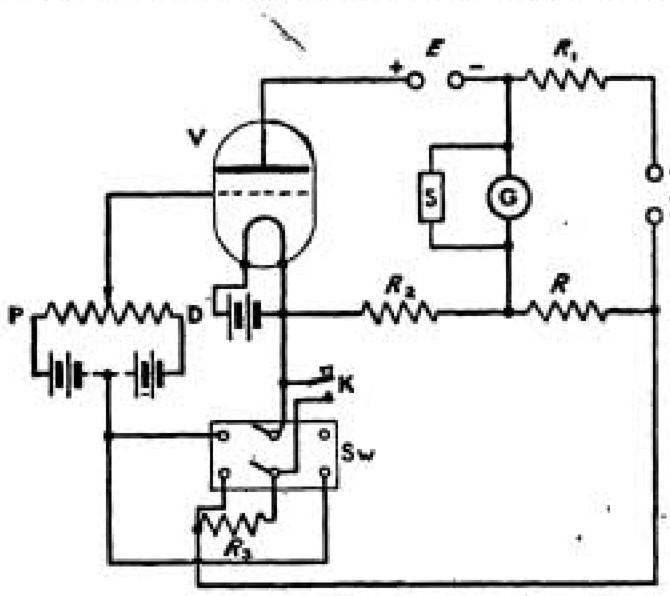

FIG. I.

Special circuit arrangements are given in the paper for determining the values of h_a, h_g and g by direct-current methods. These arrangements are of a very similar nature to those described by S. Ballantyne,* the chief difference being that direct current is used instead of the varying currents as described by Ballantyne.

The three methods of measurement described may also be carried out by the aid of a single piece of apparatus connected as indicated in Fig. I. A special feature of this arrangement is the six-point switch S_w which in the

* "The Operational Characteristics of Thermionic Amplifiers," by S. Ballantyne, *Proceedings of the Institute of Radio Engineers*, 7, pp. 129—186, April, 1919.

apparatus described was made with mercury cups in order to ensure good contacts. With the switch in the left-hand position the connections are as required for determining h_a, balance of the galvanometer being sought for in both the up and down positions of the key K, adjustment being made by varying R_1 and R while R_2 is given any desired fixed value. The value of h_a is then given by $h_a = R/R_1R_2$. When the switch is in the right-hand position h_g may be determined by balancing the galvanometer for both the up and down position of the key K, by adjustment of R_1 and R_3. R should be given some definite small value and R_2 should be made zero. The value of h_g is then given by $h_g = \frac{1}{R_1 + R_3 + (R_1R_3/R)}$. To determine g, R_3 should be made zero, the key K left up and the galvanometer balanced for the switch S_w in either the right or left-hand position by adjustment of the values of R_2 and R. The value of g is then given by the ratio of R_2 to R.

In the discussion Professor C. L. FORTESCUE said that the methods described should give great accuracy, but as they would be sensitive to very small variations of the filament current, he did not think that the author had sufficiently emphasised the importance of maintaining the filament current at a predetermined value. He also thought that for practical purposes one would frequently want to test the complete characteristic of the valve rather than determine these isolated quantities.

Professor G. W. O. HOWE said that the suggestion of a single "lumped" characteristic was attractive, but that in practical work it was very desirable to have the various characteristics for each grid voltage. He also, together with Professor O. W. RICHARDSON, criticised certain statements made in the paper as to the application of Ohm's Law to valve characteristics.

Mr. F. E. SMITH considered that the methods described by Dr. Eccles should be particularly valuable where large numbers of valves had to be tested.

On some Experiments in which two neighbouring maintained Oscillatory Circuits affect a Resonating Circuit.*

By J. H. VINCENT, M.A., D.Sc.

In the experiments described in this paper two oscillating valve circuits were set up on neighbouring benches and a wavemeter circuit arranged to be loosely coupled to each of them. When the two oscillating circuits are tuned so as to be in absolute unison, the resultant current in the resonating wavemeter circuit will be a function of the phase difference between the oscillating circuits, and on this view will be a mere matter of chance. If the induced e.m.f.'s are equal in amplitude and exactly opposite in phase, no resultant current will flow. In these experiments the resonating circuit had its condenser shunted with a carborundum crystal in contact with brass, in series with a microammeter and a telephone. No direct measurements of the wavemeter current were made but the readings of the galvanometer in series with the crystal were recorded throughout.

As no method was available for measuring the alternating currents in the

* Abstract of paper read before the Physical Society of London on January 23rd, 1920.

oscillators directly, the coil in each oscillating circuit was wound with a few turns of insulated wire which was connected in series with a microammeter and crystal detector.

The axes of the main oscillating coils were placed parallel, and the axis of the resonating circuit coil was parallel to the line joining the ends of these main coils, and a few feet away. Thus if the two maintained circuits were in phase the induced e.m.f.'s in the resonating circuit would be conspiring together. The frequencies used were of the order of 100,000, but other frequencies gave similar effects.

The resonating circuit was carefully tuned to the circuit on "Bench 1," and the capacity of "Bench 2" circuit slowly increased through the resonance point. The curve of current indicated by the resonating circuit galvanometer is indicated in Fig. 1, which also shows the currents induced by either

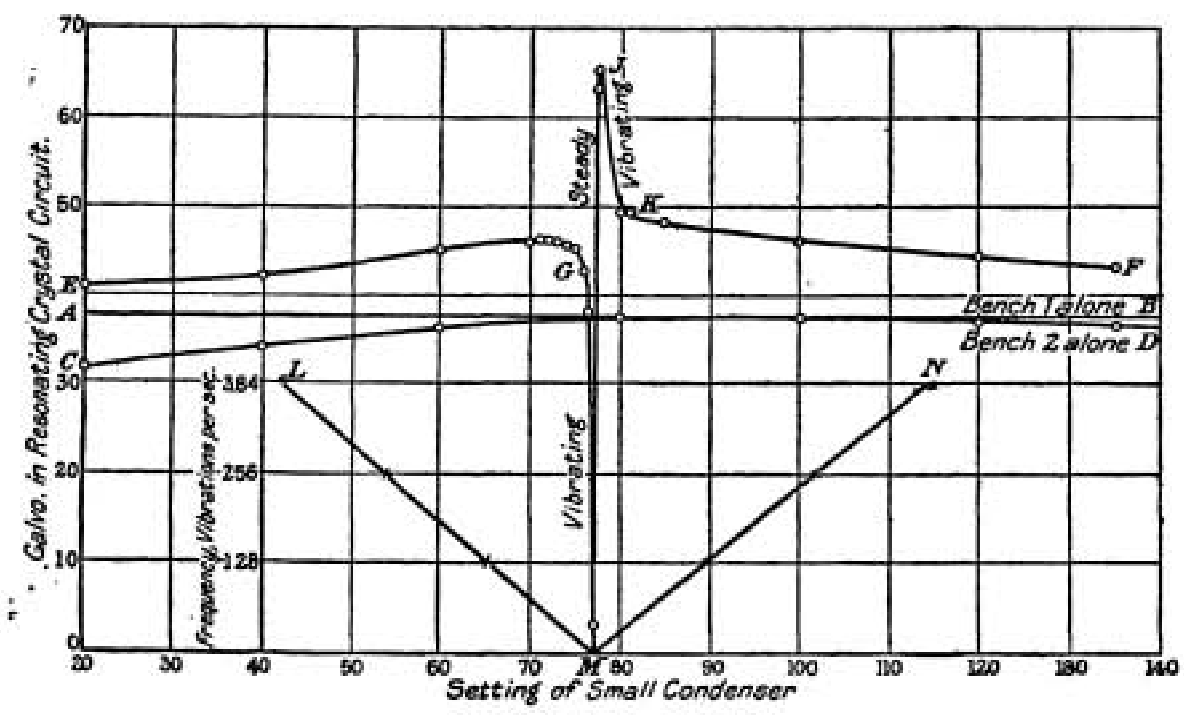

FIG. 1.

oscillating circuit when operating alone. At the same time the pitch of the note in the telephones fell uniformly with the increase of the Bench 2 capacity, as indicated by the line LM in the figure. At the point G the wavemeter galvanometer showed signs of vibrating. This vibration decreased in frequency till M was reached when the two oscillating circuits were in exactly opposite phase, and the resultant current in the wavemeter was zero. On further increasing the capacity the two circuits were gradually brought into phase, and at J this was complete. The change from M to J was brought about by an increase of capacity of a twentieth of a centimetre in a total capacity of 450 cm. During this change from M to J the galvanometer needle did not vibrate.

It was found that when the amplitude of the oscillations in either circuit was sufficiently reduced, the minimum (opposition of phase) occurred before or after the maximum according as Bench 1 or Bench 2 circuit was weakened.

When coupling was introduced between the maintained circuits, the shape of the curves was somewhat altered and the peak became much more rounded, while in particular the dead space over which the capacity could be adjusted without change in frequency was very much increased.

These experiments provide a means of observing very small changes of frequency by means of a galvanometer instead of by the usual beat method.

The paper was followed by a short discussion in which Dr. W. H. ECCLES, Professor O. W. RICHARDSON, and Mr. C. E. WEBB took part, and emphasised the extreme sensitiveness of the method. Some such arrangement will probably become a standard form of wavemeter in the future.

Dr. VINCENT in reply stated that he had not been able to add any theory to the paper, but that the results were put forward purely as an experimental research.

On the Measurement of Amplification given by Triode Amplifiers at Audible and at Radio Frequencies.*

By F. E. SMITH, F.R.S., and the late H. C. NAPIER, M.A.

The quantitative measurement of the amplifying powers of valves is a matter of considerable interest. In the first tests described a four-valve low-frequency amplifier was used, having iron-cored transformers between the successive valves. The first valve of the set was used as a standard of comparison, and the amplification of the remaining three valves was compared with it. A buzzer was first used as a source of sound, but it was subsequently replaced by a triode valve set generating oscillations of an audible frequency. To this valve set an aperiodic circuit was coupled containing the primary winding of a special air-core transformer, having two secondaries crossed at right-angles and capable of rotating together about a vertical axis passing through the plane of the outer primary winding. The mutual inductance between the primary and either secondary was measured for various angular positions by means of a Campbell inductometer. A special multi-contact switch was used to connect either secondary to the grid circuit of the first valve, and simultaneously to change over the telephones from the anode of the first valve to the anode circuit of the last. The position of the two secondaries was then adjusted until equality of sound was obtained in each case. The ratio of the mutual inductances to the two secondaries is then a measure of the voltage amplification of the three valves. For large amplifications (over twenty) the switch is arranged to vary the magnitude of the primary current from the oscillating valve simultaneously with the change-over from one valve to the amplifier. The ratio of mutual inductances must then be multiplied by the ratio of currents to give the amplification. Comparisons were made with a modified shunted telephone method, in which the sound in the telephone using the four valves was shunted down until it was of the same intensity as the sound obtained with one valve. The results obtained with the two methods were similar, but the shunt method tended to give lower values for the larger amplifications. The conditions of operation of the valves are not however the same.

For measurements on a radio-frequency amplifier the above method was found to be scarcely suitable owing to stray couplings between the cir-

* Abstract of paper read before the Physical Society of London on January 23rd, 1920.

cuits. For the high-frequency tests a single-valve oscillator was used and connected to a rotating contact maker that intermittently joined a second inductance in parallel with the main oscillation circuit inductance and thus threw the valve out of tune. This gave better results than interrupting the anode circuit. "Chopped" high-frequency circuit was thus obtained with a note frequency of about 800 per second. The essence of the method used for measuring the amplification lies in comparing the intensity of the note obtained with a single receiving valve plus rectifier, with the intensity obtained from two or more valves plus the same rectifier. The intensities of signals in each case were adjusted by varying the oscillatory current at the source and reading the two values on a thermoammeter. The variations in the strength of the oscillatory current were brought about by varying the grid potential by means of a switch. The grid potentiometer was adjusted until equal sounds were heard in the two positions of the switch, after which the two oscillatory currents could be read off at leisure.

A Method of Measuring the Amplification of a Radio-Frequency Amplifier.*

By F. W. JORDAN, B.Sc.

The particular amplifier examined by this method was the French radio-frequency amplifier, type L.1, having six valves — three for radio-frequency amplification, the fourth for rectification, and the fifth and sixth for audio-frequency amplification. As source of radio-frequency waves a single oscillating valve was used with the plate voltage supplied from the filament battery. An audio-frequency voltage derived from a "tuning-fork alternator" was also superimposed upon the plate circuit and the magnitudes of the voltages adjusted until the radio-frequency oscillations were extinguished once in each cycle of the applied audio-frequency. A variable coupling was then arranged between the valve oscillator and the amplifier, special care being taken that all connecting leads, etc., were effectively shielded in earthed tubes. The amplifier was about 18 feet away from the oscillator and in another room.

The procedure which was adopted in making a comparison of the different groups of valves was to vary the input energy to the receiving circuit of the amplifier by means of the above-mentioned variable coupling, until the intensity of the note in the telephones was equal to a comparison standard.

A comparison standard of sound of the same frequency as the note in the telephones was obtained by inserting a dial potentiometer in the plate circuit of the "fork alternator." This potentiometer was brought close up to the receiving circuit, the leads being encased in earthed lead tubing. A switch was provided for quickly changing over the telephones from the amplifier to the potentiometer for the comparison sound, and *vice versâ*.

A simple method was also described by means of which the scale of the variable coupling used between the amplifier and the oscillator could be

* **Abstract of paper read before the Physical Society of London, January 23rd, 1920.**

calibrated. For this purpose a second secondary coil having half the number of turns of the proper secondary was mounted on the opposite side of the primary. These two coils were connected in series in opposition, and by adjusting their relative positions the distance at which the mutual inductance was halved was readily determined. A binary scale for the mutual inductance was thus very easily obtained.

The object of the experiments was not to attain a high order of accuracy, but to devise some trustworthy method of comparing the performance of the separate valves of an amplifier and of different amplifiers.

Direction and Position Finding.

By Captain H. J. ROUND.

(*Concluded from p.* 237.)

Notes on Night Effects.—Large swing readings are better than minimum readings. To obtain readings of the actual minima at night is also very difficult. With signals from a spark station when there is no definite zero, peculiar changes of note are often heard. A very distinct difference of note will often be obtained in the two positions on opposite sides of the minimum. In England and France errors of swing readings on spark stations are present up to about 7° at night, and seldom more, but at Salonica the apparent position of Sofia would sometimes shift through as much as 90°. Nearly always, but not invariably, night variations are accompanied by bad minima.

Continuous waves give much greater variation than spark waves and with them directions are often seriously wrong even when the minima are extremely sharp. The apparent direction is apparently a function of the wavelength. Horsea arc station sent Press messages with a spacing and marking wave. These two waves sometimes gave directions differing by 30°, although each wave gave a perfectly sharp minimum. This point may be intimately connected with the results obtained at San Francisco by Dr. Lee de Forest some years ago on interference effects.

There is no strong evidence to show that the night variations on long waves are greater than those on short.

In England variations from east to west are certainly greater than those from north to south, but as far as is known this result does not agree with results from the East and from America.

When signals come oversea from moderate distances and practically no land intervenes the results are then the most reliable.

The minimum distance at which night effects have been noticed in England or France is about fifteen miles.

Captain Tremellen noticed that when two transmitting stations with differently shaped aerials were side by side, the apparent directions obtained at night by a Bellini-Tosi receiving station were different.

Mountainous country between the stations seems to give the worst night effects.

Daylight Errors.—The daylight errors were seldom as large as the possible errors of the instruments. Stations on the edges of high cliffs, near high trees, or near a wood gave trouble.

Refraction over a coast-line also undoubtedly exists. The presence of hills on one side of the station even some miles away, tends to give bad daylight minima in that direction.

Further Improvements.—After 1915, aperiodic aerials were used, but this brought about additional error due to an exaggerated form of "vertical." This error was overcome by earthing the mid-points of the two direction-finder coils.

With the introduction of an aperiodic direction-finder it was found that direct reception on the coils of the receiver was causing slight errors. In the case of the search coil of the radiogoniometer, this error can be avoided by placing the radiogoniometer in the correct position on the table. In the case of all other coils it may be avoided by a metal shield. A metal shield inserted between the windings of the transformer coupling the radiogoniometer to the amplifier is effective except on waves under 400 metres, when in addition it is necessary to earth the centre point of the aerials. Direction-finders for 200 metres constructed with either eleven or even twenty-two valves in cascade enabled a watch to be kept on buzzer intercommunicating sets.

Maps.—In certain side lines direction finding required investigation work, more particularly in map projection. At first Mercator charts were used, but these were very troublesome. A great improvement was obtained when charts on the gnomonic projections were used.

Atmospherics.—An interesting side line of D.F. work was its bearing on X-stopping. At night time, particularly in spring and autumn, X's exhibited very frequently (in fact most of the time in England) a sharp direction which centred a little round the position of 165° east of north. It was suggested that this direction was curiously near the magnetic meridian and perhaps it may be possible to determine if freak signals and consequently X's have more tendency to be reflected along the earth's magnetic field by the Heaviside layer.

Frame Aerials.—If the frame required is large and it is proposed to use a coupled circuit to the detector, a one-turn frame is as good as anything else, provided the resistance losses in the wire and in the condenser are kept small. If direct reception is required on a frame, then with all modern amplifiers with a non-conducting grid circuit, the frame should have the maximum number of turns and the smallest condenser which the receiver will take.

The conclusion of the paper briefly referred to some experiments carried out with several ships of H.M. Navy and in some Handley-Page aeroplanes. Appendix I. of the paper considered mathematically the action of the waves on two-spaced aerials. Appendix II. gave an elementary mathematical consideration of the valve as an amplifier, and Appendix III. a few notes on the use of a valve for limiting the strengths of loud signals. The last concluded with a reference to an arrangement due to W. T. Ditcham which consisted in dulling down the filament of a valve, and instead of working at the rectifying point, having a grid potentiometer which controlled the characteristic from end to end. It was found that with a particular filament brilliancy, at one point of the potentiometer signals from one station would vanish, and at another point a different station would vanish. An extremely fine adjustment was necessary since small changes of the order of $\frac{1}{100}$ of a volt are sufficient to cut out one station or another.

DISCUSSION.

Admiral Sir HENRY JACKSON referred to the great value that the direction-finding stations had been to the Navy and stated that the observed small movement of the German ships as indicated by the direction-finding readings enabled our fleet to intercept them at the Battle of Jutland.

Dr. J. ERSKINE-MURRAY referred to the difficulties experienced with the Bellini-Tosi system which had led to the development of the R.A.F. frame aerial receiver for aircraft. The latter arrangement usually gave an accuracy of $1\frac{3}{4}°$ in the air and about $\frac{1}{4}°$ on the ground.

Prof. G. W. O. HOWE thought that these experiments were likely to throw considerable light upon theories of transmission, and also inquired as to the relative accuracy of the readings in Fig. 1. If these are correct the movements of the ionised layers must be extremely rapid.

Colonel WACE stated that the disadvantages of wireless for linking up D.F. stations were entirely due to the use of plain language in such communications instead of code.

Mr. J. E. TAYLOR in referring to the coupling often obtained between the two Bellini-Tosi aerials stated that this difficulty was not obtained with frame aerials. He also thought that the question of the reflection of the waves from ionised layers in the atmosphere was not yet proved, and suggested that there ought also to be reflections from irregularities in the surface of the ground.

Major PRINCE in referring to the R.A.F. direction-finding system thought that this arrangement was really a minimum method and not a maximum one, and that it could be looked upon as a signal of sensibly constant strength from the main coil upon which was impressed the signal from the auxiliary coil at its minimum position.

Mr. St. V. PLETTS in referring to the question of map projections thought that gnomonic plotting was only best when there were more than two stations to be considered. It gives true directions and also gives true distances by a simple graphical method as has been shown by Dr. Eccles. Unfortunately it gives considerable distortion if a long narrow strip of country is considered. He thought it better to magnify the scale of the map in one direction. This could be done without destroying the advantages of the projection.

Capt. HUGHES referred to the difficulties experienced in France through the errors of direction finding. He thought it had been fairly well established that the apparent direction of stations to the east of the sunset line tended to swing to the southward. It was also probable that at sunrise there would be an opposite effect. There was a certain regularity in the sunset effects, but their magnitude varied from day to day. The sunset variations were less on a frame aerial than on a Bellini-Tosi arrangement, and there frequently appeared to be a sharp minimum on the frame when the minima were flat on the Bellini-Tosi. In connection with reception from Horsea Station the minima appeared to be flatter on some harmonics than on the fundamental. In the case of D.F. stations on hills, the position on the hill was very important.

Lieut.-Commander DITCHAM thought that the perfection of direction-finding arrangements had been one of the great technical successes of the war. He stated that in his experience the night effects were more pronounced with continuous waves than with signals from spark transmitters.

Capt. J. ROBINSON considered that this paper was one of the most complete that had been published on direction-finding work, but he also thought that the statements made relative to the crossed coil arrangements were scarcely fair to the R.A.F. With reference to the night effect errors he had never observed as much as 30° variation when working in these latitudes. He thought that some complications might arise with C.W. reception owing to the heterodyne radiation, and referred to Armstrong's paper read before the Institute of Radio Engineers.

When using a radiogoniometer the coupling between the search coil and the fixed aerial coils would depend upon the position of the search coil and therefore when rotating the search coil the heterodyne radiation varied, and so the "heterodyne" amplification would vary. Consequently the position of the minimum would not be quite accurate. With any direct coupled system such errors are not introduced, and this may be the reason why the R.A.F. crossed coil arrangement gives more accurate results. He thought that small frame coils were best in order to reduce the effect of night variations. With reference to the "radiophares" referred to in the paper, their use might lead to considerable simplifications in direction-finding work on aeroplanes.

Mr. GOSSLING emphasised the value of this research work which had been carried out through all stages of the war and covered a wide range of subjects.

Mr. SHAUGHNESSY referred to experiments he had carried out, and in particular to the use of a small inductive "coupling-balancer" connected in circuit with the two aerials so that any external coupling between the aerials could be balanced out. He thought that the errors arising through such coupling between the aerials would not exceed ½°.

Dr. ECCLES thought that the paper was very useful, particularly from a scientific point of view, and that it confirmed the work of French engineers on the same subject. He thought that as regards night and day work there was an additional component of wave energy arriving at the receiver at night as compared with that received during the day. This extra component arises through reflection by the ionised layers which are regular at night but not during the day. It would frequently be out of phase with the direct component of the wave and hence would give rise to the badly defined minima.

Capt. ROUND briefly referred to the possible errors arising through heterodyne reception mentioned by Capt. Robinson. The fact that these errors occurred only at night time scarcely supported the view put forward. He also pointed out that the total mutual inductance between the search coil and the two fixed aerial coils remains practically constant throughout the revolution of the coil, and that, therefore, the intensity of the heterodyne amplification would not appreciably vary when moving the search coil.

A Portable Set, and some Properties of C.W. Circuits.*

By R. C. CLINKER.

The apparatus shown at this meeting consisted of a complete unit comprising frame aerial and two-valve receiver mounted inside a single containing case with carrying handle. The box measures approximately 14 ins. × 12 ins. × 5 ins., and weighs about 20 lbs. complete with accumulators. The frame aerial is wound round the box inside, and a smaller coupling coil is hinged in front. This latter coil is joined in the anode circuit of the first valve and provides an adjustable regenerative coupling. The first valve acts as a detector (and self heterodyne when required) while the second is a low frequency amplifier. The filament accumulators (4 volts) and high tension battery of dry cells (43 volts) are also included in the case. These are mounted inside the frame coil, and although they increase the decrement losses when in that position, this increased loss is not found to be serious. Illustrations of the set will appear in the Society's official report of the meeting.† The lid of the case, when the set is in use, may be detached and thus forms a base with pivot round which the frame may be turned for determining approximate directions of incoming signals.

* Abstract of paper delivered before the Wireless Society of London on January 29th, 1920.

† *The Wireless World*, March issue.

Demonstrations of the formation of beats between two such sets placed about twelve feet apart were made, and also of the reaction of a tuned secondary coil coupled to one of the sets. The "double click" method of indicating when this external coil was in resonance with the oscillator was also shown, and the lecturer pointed out that the two frequencies at which these "clicks" occur are the two frequencies that normally occur when two tuned circuits are coupled together.

The effect of insulating the grid of a valve and the discharging effect due to the presence of radium were also demonstrated.

Prof. G. W. O. HOWE, in discussing the paper, indicated a simple method by which the presence of the two coupling frequencies could be demonstrated by considering the magnetic field linking the two coupled coils.

Mr. J. SCOTT-TAGGART briefly described the measurement and comparison of capacities using the well-known heterodyne method.

Admiral Sir HENRY JACKSON stated that he had experienced difficulties in reception on a frame coil inside a building containing a number of iron pipes, and pointed out that the experiments with the coil coupled to the oscillator formed a simple demonstration of such effects being caused by the proximity of the metal to the frame coil.

Mr. P. R. COURSEY described an alternative to the double click method using a thermo-galvanometer in the oscillating circuit and noting the drop in current when the coupled coil was brought into tune; and Mr. BROADWOOD referred to a similar method using a galvanometer in the plate circuit of the valve instead of a telephone.

Mr. R. C. CLINKER replied briefly to the points mentioned, and also demonstrated how the two oscillating circuits pulled into phase when they were coupled sufficiently closely, in a similar manner to two alternators connected in parallel.

A Wireless Calling Up System for use on Ships.

On Thursday, January 15th, 1920, a demonstration of some new instruments designed for the above purpose was given by Marconi's Wireless Telegraph Co., Ltd., at their works at Chelmsford.

The transmitter is designed to radiate a series of dots at a frequency of 180 per minute on the standard 600-metre ship's wave and the receiver is designed to respond to a series of dots of this frequency only.

The transmitter consists of a small oscillating flywheel which is controlled by a spiral spring and adjusted to swing at the desired rate. At each swing a contact is closed which operates a relay signalling key in the transmitting circuits. The wheel is set in oscillation by pressing a small key which passes a momentary current through the magnets which maintain its vibration. At the receiver a three-valve amplifier is used in conjunction with an oscillating relay of a similar type to the oscillating system used at the transmitter. The receiving relay is tuned to respond to 180 impulses per minute. The small balance-wheel of the receiving relay is set in motion by the amplified received currents which are passed through two electromagnets, and on the receipt of a sustained series of dots at the proper frequency the amplitude of the oscillations is built up until a contact is closed and the call bell operated.

The device appears to be remarkably immune from disturbance by jamming from ordinary wireless signals and to be quite reliable in operation.

Its normal working range in the present form is about eighty miles.

Review of Radio Literature.

1. Abstracts of Articles and Patents.

212. THE USE OF AMPLIFIERS FOR THE MEASUREMENT OF SMALL DIFFERENCES OF POTENTIAL. R. Depriester. (*Revue Générale de l'Électricité*, 6, pp. 619—620, November, 1919.)

Blondel has pointed out that the arrangements of amplifiers described by him* are not the only possible ones. This article describes another—indicated in Fig. 1.

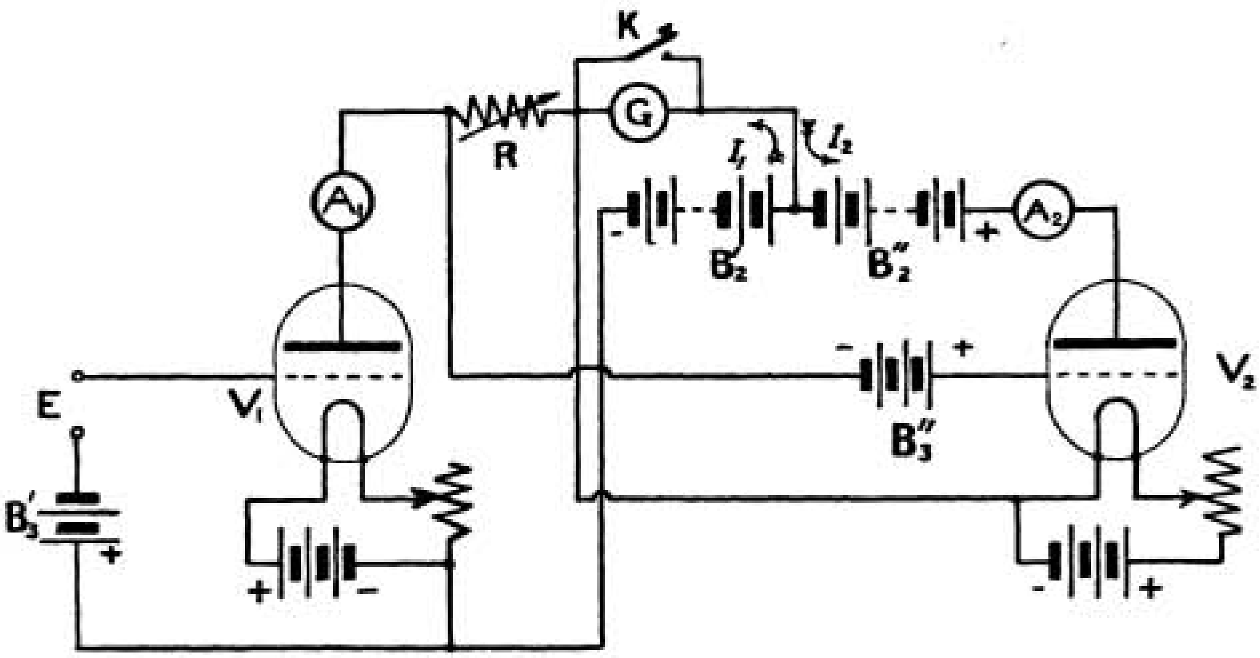

FIG. 1.

The two valves V_1 and V_2 are joined in cascade as shown, the grid of V_2 being supplied from the p.d. across the resistance R in the plate circuit of V_1.

The small p.d. to be measured is applied at E. The plate currents of the two valves flow through G in opposition, and by proper adjustment this galvanometer can be brought to zero for the normal position. The valve filament currents and a part of R are adjustable for this purpose. The short-circuiting key K is for use when making preliminary adjustments of the equality of the plate currents using the milliammeters A_1 and A_2 as indicators. Greater sensitiveness may be obtained by the use of a preliminary amplifier.

213. HIGH-FREQUENCY AMMETERS. H. A. Ewen. (*British Patent* 132567, July, 1918. Patent accepted, September 19th, 1919.)

An inductive coupling between the hot wire ammeter and the aerial circuit

* RADIO REVIEW Abstract No. 237.

is described for the purpose of measuring large high frequency currents. The calibration of the instrument may be varied by altering the coupling between the instrument circuit and the aerial circuit or by varying the resistance or inductance of either of the windings.

214. THE L.C. TABLE AND HOW TO USE IT. (*Everyday Engineering Magazine*, 8, p. 106, November, 1919.)

A table is given from which the product L.C. (inductance in cms. × capacity in mfds.) can be read off corresponding to any given wavelength.

215. THE OPERATION OF THE A.C. QUENCHED SPARK TRANSMITTER. K. Schmidt. (*Elektrotechnische Zeitschrift*, 40, pp. 562—564, November, 1919.)

A discussion of the conditions for obtaining a good musical note, viz: good quenching, exact resonance, and proper coupling. The wave form of the alternator may vary with the excitation, but at resonance the fundamental will greatly predominate. The purity of the tone is independent of the wave form, although it influences its character. Reproductions are given of cathode ray oscillograms showing the voltage and current curves with both one and two sparks per cycle. To obtain a very low number of sparks per second, that is, one spark for several cycles, it is advantageous to connect a choke coil in parallel with the alternator, thus making the total inductance of the circuit less dependent on variations in the alternator.

The protection of the alternator from high frequency surges by means of earthing condensers is discussed. Reference is made to Figs. 8 and 9, which, however, are missing.

216. TRANSATLANTIC RADIO COMMUNICATION. E. F. W. Alexanderson. (*Proceedings of the American Institute of Electrical Engineers*, 38, pp. 1077—1093, October, 1919; *Telegraph and Telephone Age*, 37, pp. 506—509, October, 1919, Abstract.)

Abstract of paper presented at a joint meeting of the American I.E.E. and the Institute of Radio Engineers. The author discusses the capabilities of large radio stations for handling the world's long-distance telegraph traffic. It is shown that, under present arrangements, the number of such world stations is limited to twelve, even when the wavelength range is extended down to 10,000 metres and up to 20,000 metres.

The tendency of present-day developments points to the following means for expansion of radio traffic:—

(1) Increase in speed of transmission.
(2) Improved selectivity based on the direction of the wave.
(3) Improved selectivity, making possible closer spacing of wavelengths.

As to (1) and (3) it is pointed out that speeds up to 100 words per minute are now practicable, and that these speeds are not incompatible with increased selectivity to work with a 1 per cent. difference in wave length between stations. As to (2) the achievements of the author's "Barrage" receiver are discussed,* as well as the arrangement of multiple antennæ at the New Brunswick, N.J., station. This consists of six independent radiating antennæ, each with separate tuning inductances. By this means the total resistance of the complete aerial has been reduced from 3·8 ohms to 0·5 ohm at 13,600 metres, and the radiation efficiency raised from about 2·6 per cent. to 14 per cent. At 8,000 metres, the total resistance of the multiple aerial is 0·6 ohm and its radiation efficiency 30 per cent. The radiation from each component of the multiple aerial may be in phase, or by regulating the phase displacement, definite directive radiation can be

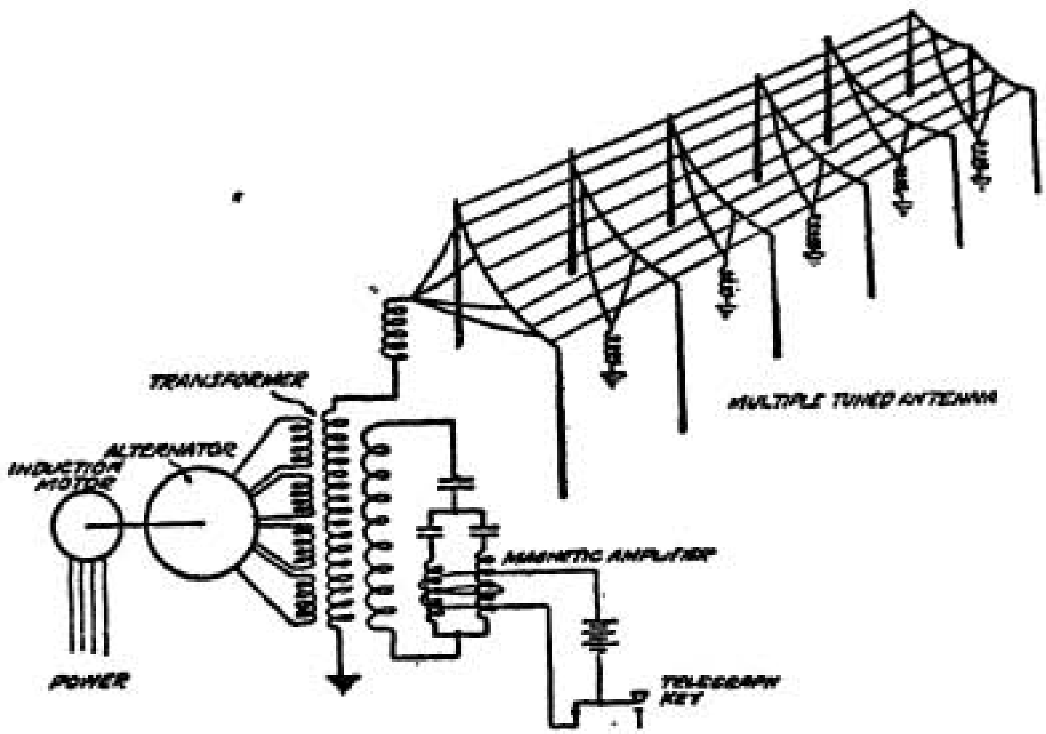

FIG. 2.

secured by utilising the interference effects between the separate radiated waves. [See, also, RADIO REVIEW Abstract No. 198.]

The arrangement of the multiple antenna is indicated in Fig. 2. It may be considered as an aggregate of several antennæ of the ordinary vertical type, each having its own tuning coil. The aerial at New Brunswick is therefore equivalent to six independent radiators placed 1,000 feet apart. The current in each ground lead is about 100 amperes, and the total power is then about 100 kw. The upper horizontal portion of the complete antenna acts as a transmission line between the separate aerial units. The tuning coil to which the alternator is connected raises the potential to 60,000 volts, and each of the oscillating circuits formed by the ground connections draws energy from this transmission line at that voltage.

* See RADIO REVIEW Abstract No. 75.

217. IMPROVEMENTS IN ARC OSCILLATION GENERATORS. C. Lorenz. (*British Patent* 132799, June, 1918, not yet accepted but open to inspection.)

Irregularities in the production of electric oscillations by means of an arc are prevented by the use of a large inductance in the high frequency circuit. The aerial circuit may be closely coupled with this large inductance in the primary oscillation circuit or may be directly coupled to it. One such arrangement is indicated in Fig. 3. In this diagram inductances L_1 L_2 are coupled to present a large impedence to the currents flowing round the circuit S C_1 L_2 L_1 but to offer a low impedence to the aerial earth currents flowing through the two coils in parallel.

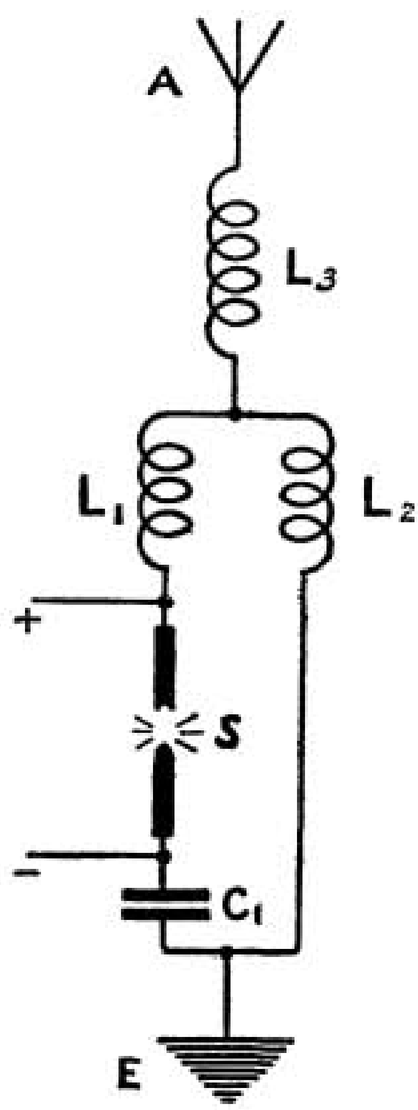

FIG. 3.

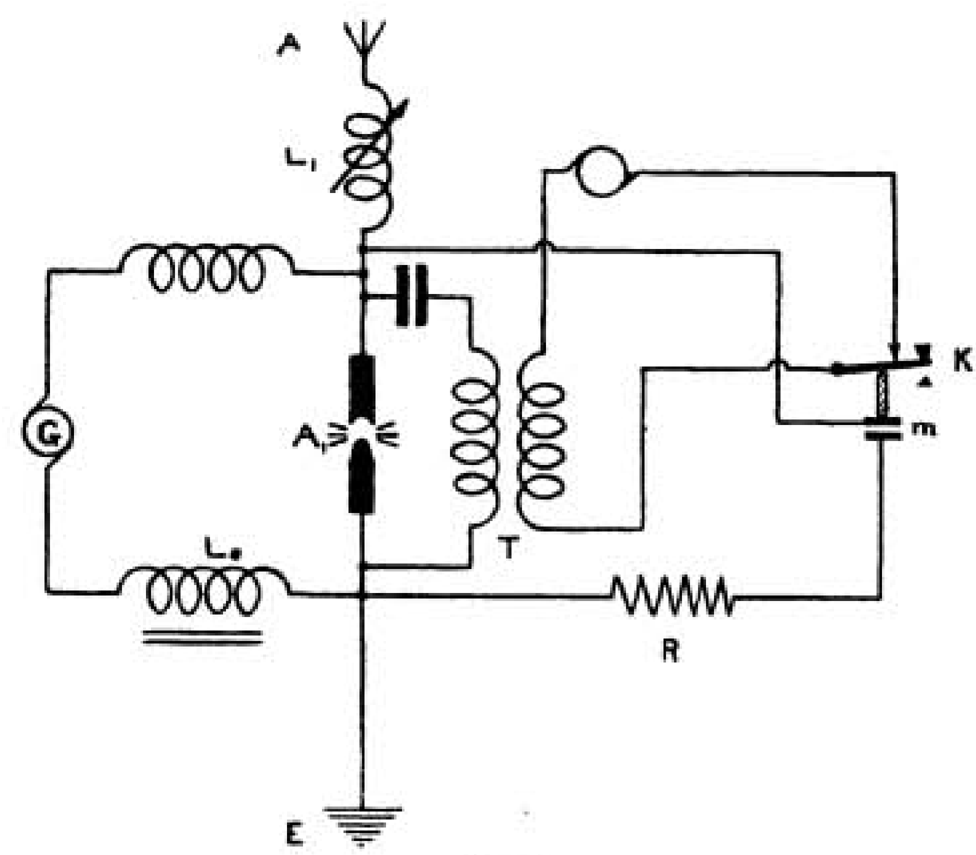

FIG. 4.

218. IMPROVEMENTS IN RADIOTELEGRAPHIC TRANSMISSION SYSTEMS. A. Taylor. (*British Patent* 133901, April, 1919. Patent accepted, October 23rd, 1919.)

For the transmission of Morse signals with an arc oscillation generator, signals are sent by interrupting the arc while maintaining the load on the supply circuit substantially constant. One arrangement is indicated in Fig. 4. The arc A_1 is shunted by the resistance R through the main contacts m of the key K so that when the key is operated the arc is extinguished. On releasing the key the momentary interruption of current through the choke coil L_0 induces a large voltage at the terminals of the arc and this brings

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about its re-ignition. In an alternative arrangement the key K when released may also close the circuit of a small auxiliary transformer, T, to induce a high voltage across the arc terminals to effect the re-ignition. The main contacts m of the key K are provided with a powerful magnetic blow-out. In a further modification described in the patent the action of the key serves to bring an auxiliary electrode into contact with one of the arc electrodes, thus shunting the arc through a resistance and causing its extinction. On releasing the key an arc is first formed between the main and auxiliary electrodes and this serves to re-ignite the main arc.*

219. A METHOD OF USING TWO TRIODE VALVES IN PARALLEL FOR GENERATING OSCILLATIONS. W. H. Eccles and F. W. Jordan. (*Electrician*, 83, p. 299, September, 1919. *Electrical Review*, 85, p. 441. *Radio Review*, 1, p. 80, November, 1919.)

220. THE THREE-ELECTRODE THERMIONIC VALVE AS AN ALTERNATING CURRENT GENERATOR. Professor C. L. Fortescue. (*Electrician*, 83, pp. 294—295, 388—390, 414—416, September, 1919. *Electrical Review*, 85, pp. 456—457, Abstract. *Engineering*, 128, p. 357, Abstract. *Radio Review*, 1, p. 83.)

221. THREE-ELECTRODE VACUUM TUBES. L. de Forest. (*Electrician*, 83, p. 477, October, 1919.)

Correspondence relative to the invention of certain circuits for the use of two three-electrode valves in parallel for generating oscillations † and also relative to new terminology for three-electrode valves.

222. IMPROVEMENTS IN VALVES FOR GENERATING ELECTRICAL OSCILLATIONS, ETC. L. M. Ericsson & Company, Russia. (*British Patent* 131680, July, 1918. Patent accepted, September 1st, 1919.)

A vacuum tube is described for use in the ordinary manner of the three-electrode valves, but with a plate cathode instead of the usual filament. This plate cathode is heated by electronic bombardment at the back from an auxiliary filament cathode. If desired a screen with a suitable aperture may be placed between the auxiliary filament cathode and the main cathode, and if necessary a suitable potential may be applied to the screen. The temperature of the main cathode may be made higher than in the case of the filament electrodes generally used.

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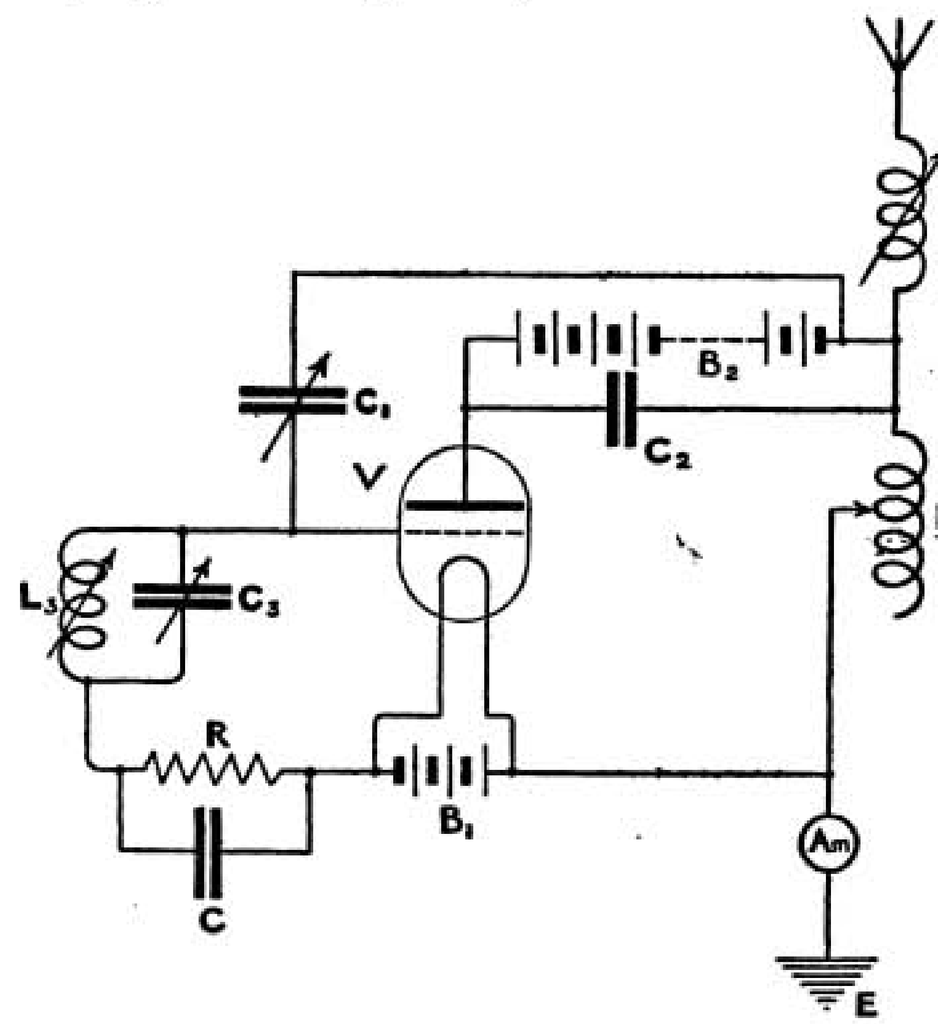
* See also RADIO REVIEW Abstract No. 114.

† See especially RADIO REVIEW, 1, pp. 80—83, November, 1919.

223. A VACUUM-TUBE TRANSMITTER OF CONTINUOUS WAVES. J. Scott-Taggart. (*Electrical Review*, 85, pp. 710—711, December, 1919.)

The circuit described is illustrated in Fig. 5. The set may be used for wireless telephony by connecting a shunted microphone in the earth lead, or for telegraphy by joining a key in series with B_2. Aerial currents of the order of 1 ampere and ranges of about 200 miles are mentioned but without reference to the aerial system, receiving apparatus, etc. Condenser C_1 provides the main retroactive coupling, but there is also some magnetic coupling between L_2 and L_3.



C_3 = 0·0004 mfd.
R = 10,000 ohms.
C = 0·001 mfd.
B_2 = 400—800 volts.
C_2 = 0·001 mfd.

FIG. 5.

224. HIGH-FREQUENCY SIGNALLING. Western Electric Company, U.S.A. (*British Patent* 132562, June, 1918. Patent accepted, September 25th, 1919.)

In the transmitting arrangement described, a high-frequency carrier wave is used modulated by a wave of intermediate but inaudible frequency, the latter being further modulated in accordance with the signal to be sent. Multiplex working may be obtained by using several non-interfering intermediate frequencies, and if desired several carrier frequencies. One arrangement is indicated in Fig. 6. G_1 is the source of high-frequency power of frequency say 1,000,000, G_2, G_3, etc., are the intermediate frequency generators, for example 20,000 or 30,000∼. These are connected through modulating valves V_1, V_2, etc., to the common grid circuit of valve V_3 as indicated. The

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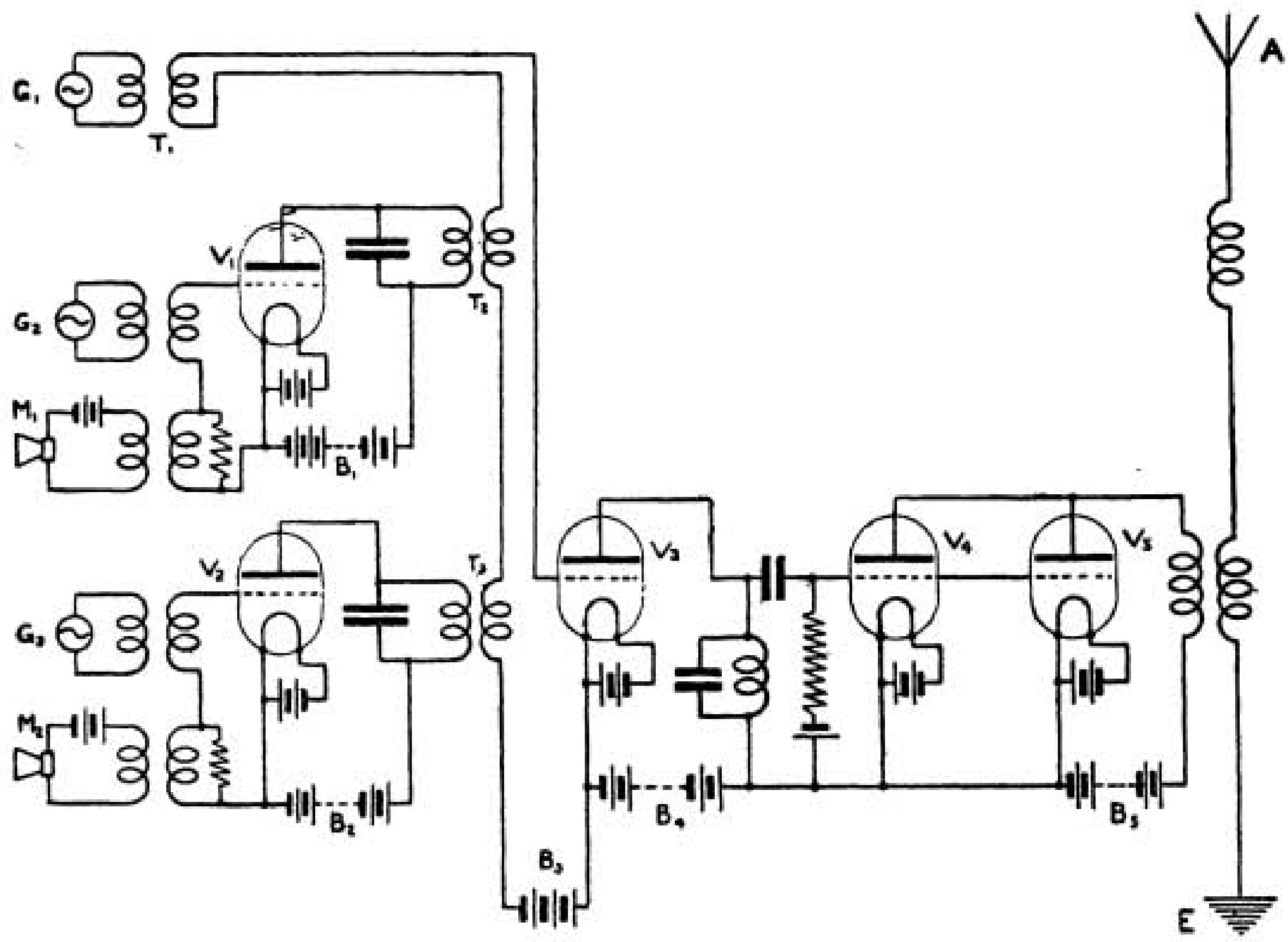

FIG. 6.

output of these valves is modulated by the microphones M_1 M_2 or other signalling apparatus. V_4 V_5 are amplifiers connected between V_3 and the aerial circuit A E. An analogous arrangement may be used at the receiver for sorting out the currents of different frequencies.

225. WIRELESS TELEGRAPHY AND TELEPHONY BY THREE-ELECTRODE VALVES. C. Gutton. (*Revue Générale de l'Électricité*, 6, pp. 365—376, September, 1919.)

Arcs and high-frequency alternators are now used in practice mainly for high-power stations, but the application of 3-electrode valves for wireless purposes has rendered practicable C.W. transmission for all wavelengths and all powers. In the present article the author deals with this application in a very thorough manner, and commencing with the use of a valve to sustain oscillations describes in turn its application to both transmission and heterodyne reception. The selectivity of heterodyne reception is discussed, and the use of the valve as a simple detector and as an auto-heterodyne is described, as well as the advantages of regenerative amplification. The article is concluded with three sections devoted to the principles of wireless telephony, radiotelephonic stations, and recent progress and the future of wireless telephony. Circuit diagrams are given showing the modulating microphone coupled to the aerial circuit, and also coupled through an amplifier to the grid circuit of the transmitting valves, the latter arrangement being suitable for coupling a land telephone line on to a radio-telephonic transmitter. An arrangement in which the microphone is coupled to the plate circuit inductance of a single oscillating valve, the energy of which is subsequently amplified before transference to the aerial, is also described as being suitable for a high-power station.

226. HIGH-FREQUENCY ELECTRIC SIGNALLING. Western Electric Company (U.S.A.). (*British Patent* 131426, August, 1918. Patent accepted, August 18th, 1919.)

This relates to high-frequency signalling systems in which the signals are transmitted as modulations of a high-frequency carrier wave, and are combined at the receiving station with locally generated waves of the same frequency. A special feature is the production of both the carrier waves and the local waves from control oscillations of an intermediate frequency. One arrangement is indicated in Figs. 7 and 8. Fig. 7 indicates the transmitting circuits, and Fig. 8 the receiving circuits. The control oscillations are generated by the valve V_1 and amplified by the valve V_2 in the usual manner. The output circuit of V_2 is coupled through transformer T_1 to the grid circuit of a "harmonic generator" V_3. This comprises a valve overloaded so as to produce a deformation of the control waves which is equivalent to adding a number of harmonics to these waves. The deformed wave is then amplified by a valve V_4 in the plate circuit of which is a tuned circuit C L for picking out one of these harmonics. This harmonic is utilised as the

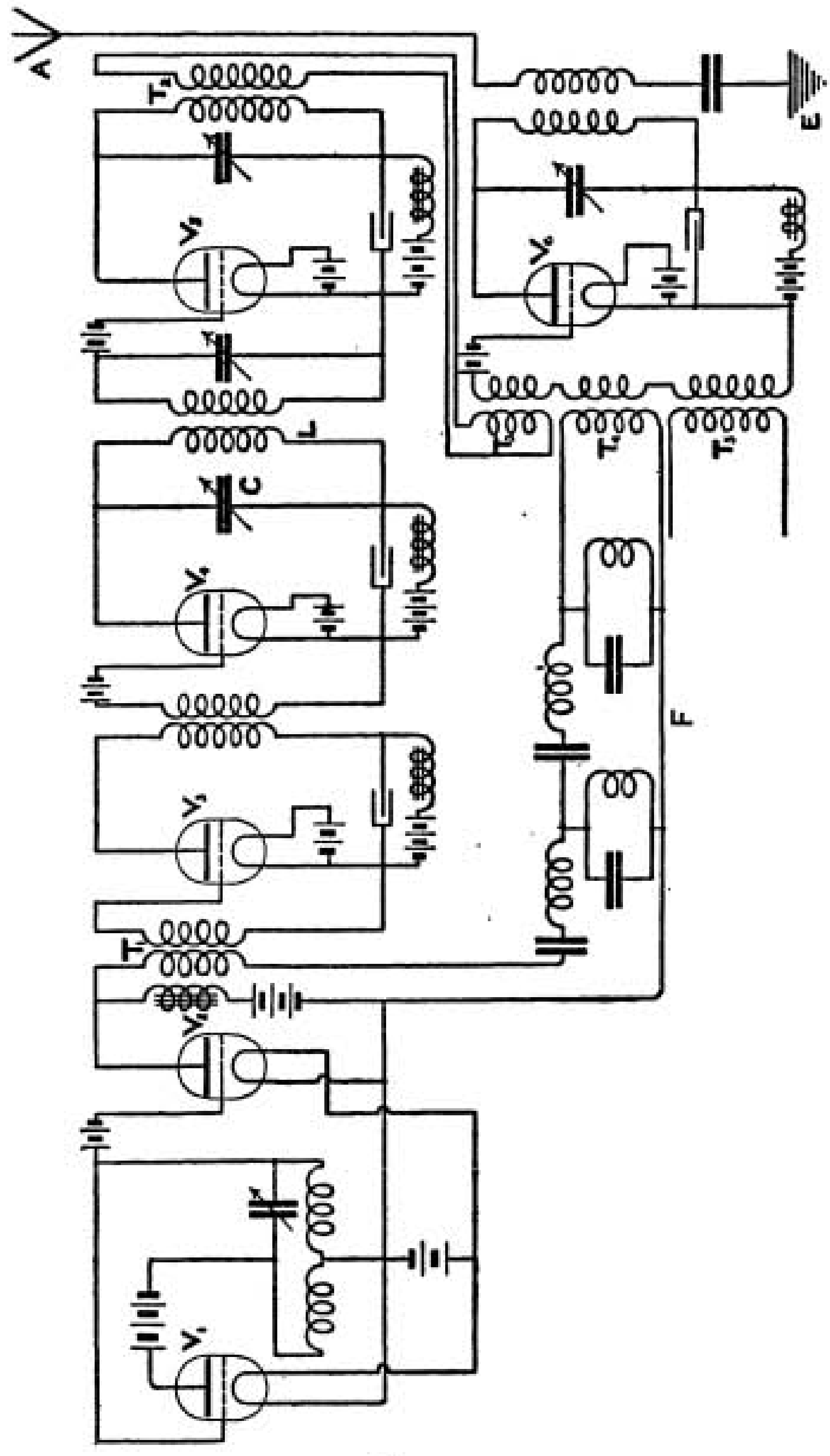

FIG. 7.

carrier frequency and is amplified by the valve V_5 to which the plate circuit of V_4 is coupled. The output circuit of V_5 is coupled through T_2 T_3 to the grid circuit of the controlling valve V_6. The grid circuit of this valve is also coupled through transformer T_4 and filter circuit F to the primary circuit of transformer T_1, which is in the plate circuit of valve V_2. The oscillations of the control frequency are therefore supplied to the grid circuit of the controlling valve V_6 as well as the oscillations of the carrier frequency. The grid circuit of V_6 is also coupled through transformer T_5 to a modulating circuit for the control of the emitted waves by the telephonic or other signalling currents. At the receiving station (Fig. 8) the received oscillations are amplified by the valve V_7 and transferred to the detecting valve V_8. The output circuit of this valve is coupled through transformer T_6 to the frequency filtering circuits F_1 and thence to the receiving circuit proper through T_7. The output circuit of the detecting valve V_8 is also coupled through transformer T_8 to a second frequency filtering circuit F_2 on to a valve V_9 which is overloaded in a similar manner to valve V_3 of the transmitter and serves

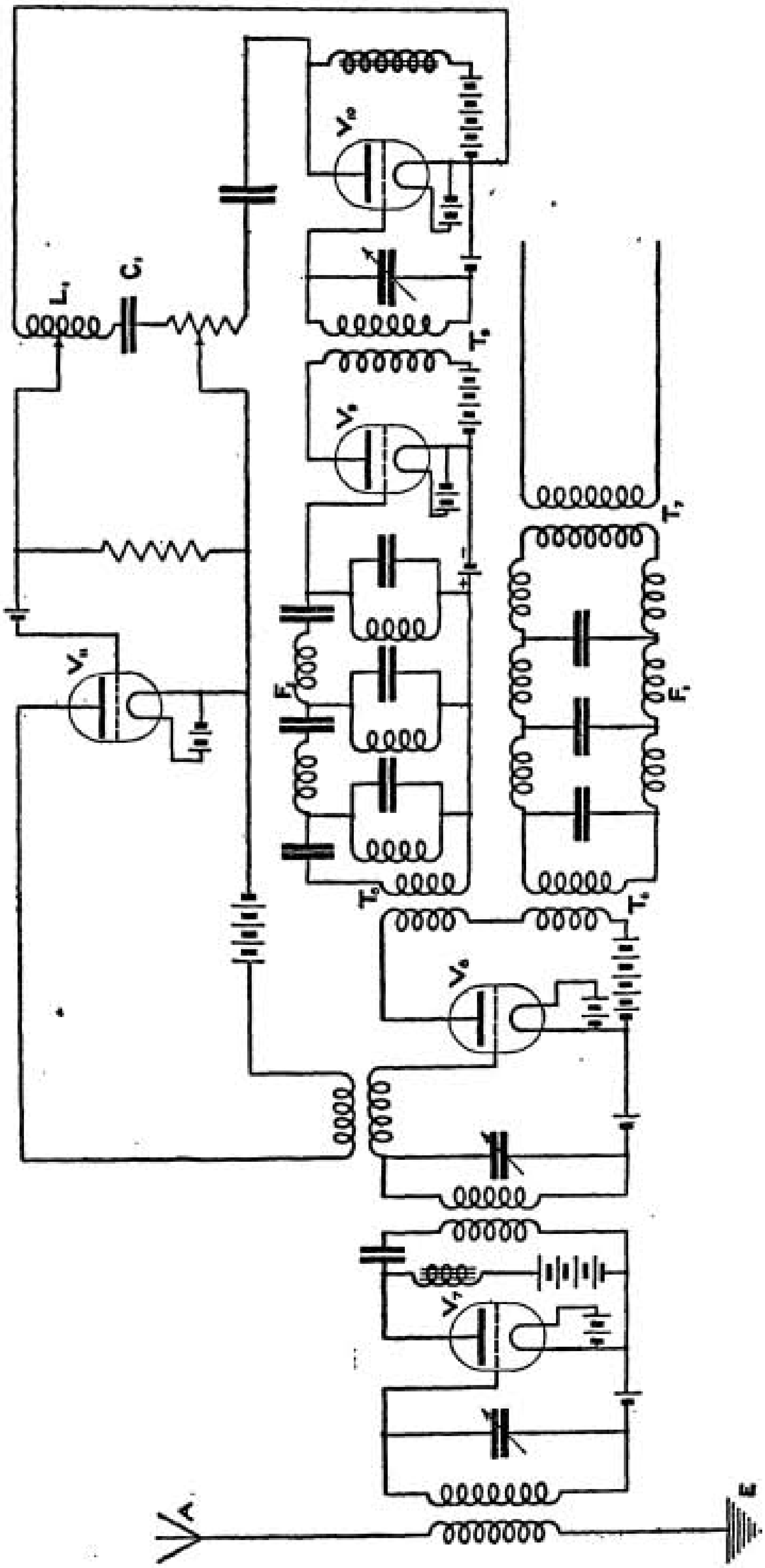

FIG. 8.

the same purpose, namely, to distort the wave form of the control frequency oscillations passing through F_2, the circuit F_2 being adjusted to prevent the passage of currents of any frequency other than the control frequency. The output circuit of V_9 is coupled through transformer T_9 to the amplifying valve V_{10} in the plate circuit of which is the tuned circuit C_1 L_1 arranged to permit the passage of a harmonic of the same degree only as that used at the transmitting station. This tuned circuit is joined to the grid of the amplifying valve V_{11} from which they are transferred back to the grid circuit of the detecting valve V_8. The modulated oscillations received from the aerial are thus combined with unmodulated oscillations of identical frequency obtained from the harmonics set up by the valve V_9. The receiver therefore appears to work on a heterodyne principle with identical frequencies, so that the modulations only, that is to say the speech or other signalling currents, pass to the receiving instrument through the transformers T_6, T_7 and the filter circuit F_1. Modified arrangements are also described by means of which a similar method may be used for multiplex radiotelephony using different carrier frequencies all obtained from the same initial control frequency.

227. MODULATORS FOR RADIOTELEPHONY. C. Schmitt. (*L'Électricien*, 49, p. 204, November, 1919.)

A general descriptive article outlining the various forms of variable resistance microphones, microphonic control by 3-electrode valves, and the Alexanderson magnetic microphone.

228. TELEPHONE REPEATERS. B. Gherardi and F. B. Jewett. (*Proceedings American Inst. Electrical Engineers*, 38, pp. 1255—1313, November, 1919.)

The historical development of telephone repeaters is given, together with descriptions of valve amplifiers and various forms of magnetically controlled arc repeaters, etc. The essential properties of repeater networks are given, with illustrations of installations.

229. IMPROVEMENTS RELATING TO THE USE OF AUDION AMPLIFYING APPARATUS IN TELEPHONY. M. Latour. (*British Patent* 131639, June, 1917. Patent accepted, September 4th, 1919.)

An addition to British patent 127318. It relates to the use of valve amplifiers for two-way telephone repeaters.

230. IMPROVEMENTS RELATING TO TELEPHONE REPEATERS. M. Latour. (*British Patent* 131704, August, 1917. Patent accepted, September 4th, 1919.)

Special arrangements of 3-electrode valves for two-way telephone repeaters.

231. The Problems of Vacuum Tube Circuits.—The Audion as a Detector. L. M. Clement. (*Everyday Engineering Magazine*, 8, pp. 112—113, November, 1919.)

An elementary account of the use of a triode valve for rectification at the lower bend of the characteristic curve.

232. The Design of Multiple-Stage Amplifiers. C. L. Fortescue. (*Electrical Review*, 85, pp. 700—701, November, 1919.)

See Radio Review, 1, pp. 178—181.

233. The Use of Impedence, Capacity and Resistance Couplings in High-Frequency Amplifiers. J. Scott-Taggart. (*Electrician*, 83, p. 221, August, 1919.)

Circuit diagrams are given of multivalve amplifiers with resistance-capacity coupling.

234. Notes on Valve Amplification. W. S. Barrell. (*Wireless World*, 7, pp. 407—409, October, 1919.)

235. High Vacuum Amplifiers. W. Schottky. (*Archives für Elektrotechnik*, 8, p. 1, July, 1919. *Elektrotechnische Zeitschrift*, 40, p. 604, November, 1919, Abstract.)

An account of investigations carried out in 1915 but unpublished for military reasons. The definition of the amplification is discussed and formulæ established for multiple cascade amplifiers. The design of the valve is then considered in order to obtain characteristics and operating conditions which lead to the best amplification. The result is obtained that the optimum amplification obtainable is proportional to the square root of the anode potential and inversely proportional to the fourth root of the grid potential. It is also stated that for cylindrical amplifiers the amplification is proportional to the root of the axial length and inversely proportional to the root of the diameter of the grid.

236. On New Arrangements of Potentiometric Amplifiers. A. Blondel and M. Touly. (*Comptes Rendus*, 169, pp. 557—562, September, 1919.)

The use of amplifying valves for the measurement of small differences of potential is further dealt with in this paper which describes simplifications of arrangements previously described.*

The arrangement dealt with comprises two amplifying stages—the second containing several tubes in parallel. A regenerative coupling is provided (by resistances) from the second stage back to the grid circuit of the first valve. The indicating galvanometer or other instrument may be connected either in series with the plate circuit of the second stage, or in shunt to a part of that circuit. Formulæ are given in explanation of the mode of operation.

* Radio Review Abstract No. 186.

237. ON BLONDEL'S AND TOULY'S NEW ARRANGEMENTS OF POTENTIOMETRIC AMPLIFIERS. A. Blondel. (*Revue Générale de l'Électricité*, 6, pp. 427—441, October, 1919.)

This article describes in greater detail the apparatus referred to in RADIO REVIEW Abstract No. 236, and also its development. The principle of one arrangement is indicated in Fig. 9. The internal resistance of valve V_1 provides the fourth arm of the Wheatstone Bridge of which R_1, R_2, R_3, are the other arms. The "battery-arm" of the bridge includes the anode battery B_2, while the "galvanometer-arm" includes the grid circuit of the second valve V_2. This second valve is also joined in a Wheatstone Bridge circuit R_1', R_2', R_3', with the indicating instrument G. The initial p.d. to be amplified is applied to T_1T_2. By interchanging the "battery" and "galvanometer" arms of each of these bridges, both valve filaments can be supplied

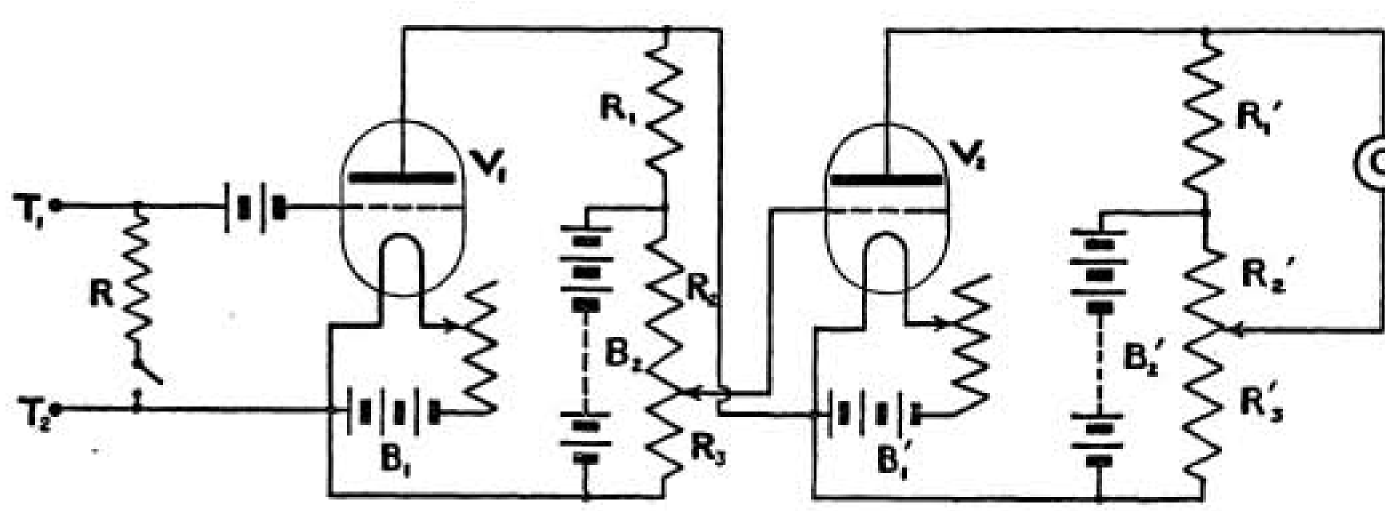

FIG. 9.

from the same battery, while a further simplification is obtained by suppressing two of the "bridge-arm" resistances which shunt the anode battery B_2 and connecting the grid of the second valve to an adjustable point on this battery, thus aiming at an amplifier with "potentiometric" coupling between the stages.

In an improved arrangement a regenerative coupling is provided between the plate circuit of the second valve and the input circuit to the grid of the first valve. This is obtained by a potentiometer resistance joined either in series with the plate circuit or shunting the plate-filament of the second valve. The latter arrangement is indicated at P in Fig. 10, which also shows a third valve, V_3 added to obtain additional amplification. This third valve may be replaced by a simple rectifying valve if desired to enable an ordinary D.C. galvanometer to be used for measuring A.C. potentials. In other arrangements described in the paper, several valves are joined in parallel in the second stage in order to augment the plate current for operating the indicating instrument. The arrangement of V_1 and V_2 in Fig. 10 follows the "potentiometric" modification of Fig. 9 described above. A common anode battery B_2 is used, with smaller additional batteries B_2', B_2'' and B_2''' for each valve. The left-hand portion of P adjacent to the filament connection is included in the input grid circuit and provides the regenerative

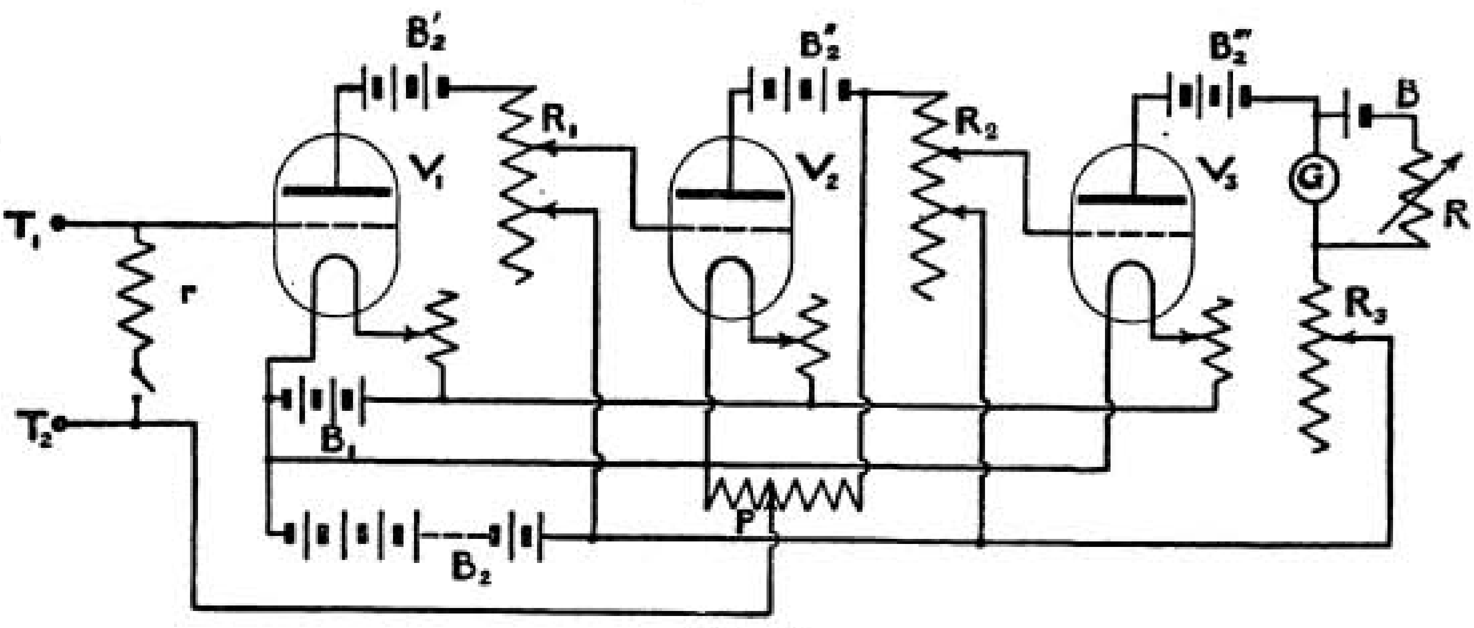

FIG. 10.

coupling. B and R are added to balance out the plate current of V_3 through the galvanometer G.

The paper also includes a mathematical explanation of the operation of each arrangement described. (See also Abstract No. 212.)

238. RECTIFIERS. B. J. Brochard. (*French Patent* 495317, filed June 18th, 1917. Published October 4th, 1919.)

For rectifiers, galena which will pass a 16-mesh screen but will not pass a screen of 18 mesh, and having a clean surface, is mixed with strong glue; and conducting surfaces, either rigid or flexible, are covered with the mixture. One cubic cm. of galena prepared according to the process described covers 12 cm. of surface.

239. RECEIVERS. B. J. Brochard. (*French Patent* 495318, filed June 18th, 1917. Published October 4th, 1919.)

The invention relates to the employment of very flexible metal brushes for use as crystal detector contacts for the reception of Hertzian waves. The said brushes are made from 15 cm. of gold or silver brocading thread, either in its usual form, or with only the metallic portion. The regulation obtained with these brushes is practically instantaneous.

240. DETECTOR. H. D. Betz. (*French Patent* 495432, filed August 24th, 1918. Published October 8th, 1919.)

This invention relates to a protector for coherers.

241. A NEW AMPLIFYING RELAY. F. Martin. (*L'Électricien*, 49, pp. 132—134, September, 1919.)

Description of an electromagnetic microphone relay for amplifying radio signals.

242. A TRIGGER RELAY UTILISING THREE-ELECTRODE THERMIONIC VACUUM TUBES. W. H. Eccles and F. W. Jordan. (*Electrician*, 83, p. 298, September, 1919. *Electrical Review*, 85, p. 441. *Radio Review*, 1, pp. 143—146.)

243. RELAYS. D. W. Brown. (*French Patent* 495385, filed August 4th, 1917. Published October 7th, 1919.)

The invention relates to a method and apparatus for relaying or increasing the effect of high-frequency electric oscillations on detectors (see British Patents 117686 and 120356).

244. RECORDING OF EIFFEL TOWER TIME SIGNALS FOR DETERMINATION OF CLOCK ERROR. L. B. Turner. (*Electrician*, 83, pp. 554—557, November, 1919.)

The use of the author's valve relay for the recording of time signals is described in this paper. A simultaneous record is made on a double-magnet chronograph of the clock ticks and of the wireless signals. Sample strips are reproduced in the paper illustrating the accuracy obtainable in most cases. The atmospherics can be distinguished from the signals by the records on these strips. A determination of the lag in the wireless relay apparatus indicated that its value was generally about $\frac{1}{200}$ of a second and was certainly less than $\frac{1}{100}$ of a second. In most cases, therefore, the lag is quite negligible.

245. RECEIVING CIRCUITS. H. J. J. M. de R. de Bellescize. (*French Patent* 495316, filed June 26th, 1917. Published October 4th, 1919.)

The invention consists in rendering open or closed wireless receiving circuits symmetrical to permit the obtaining of better syntony and of reducing the effect of atmospheric disturbances. The symmetry is obtained by disposing in each of the two connections to the condenser in the receiving circuit, an arrangement of capacities, resistances and self-inductances so as to reproduce the electrical characteristics of the apparatus connected to the other terminal, in the manner described in British Patent 132434. (This French specification contains Figs. 1 and 2 only of the British Patent but covers the same subject-matter.)

The same result may also be obtained by coupling the receiving circuit inductively to a second circuit by means of two identical coils placed electrically symmetrical to the capacity in the primary circuit.

246. ANTENNÆ. Compagnie Française pour Exploitation des Procédés Thomson-Houston. (*French Patent* 495641, filed October 1st, 1917. Published October 14th, 1919.)

For particulars of this invention, see the British Patent 130064.*

* See RADIO REVIEW Abstract No. 198.

247. LOOP ANTENNÆ AND DIRECTION FINDERS FOR AMATEUR USE. D. S. Brown. (*Radio Amateur News*, 1, pp. 60—62, August, 1919.)

Design and constructional details for Frame Aerials are given, based on the transmission formulæ and on experimental results. The strength of signals received on the loop is proportional to NAL/λ^2R where N = No. of turns, A = area, L = inductance; λ = wavelength, and R = H.F. resistance. Various tables for different size loops, etc., are given, among which are the following :—

Best Wire Spacing for Multi-turn Loops.

Size of Loop (Feet).	Spacing (Inches).
4	$\frac{1}{4}$
6	$\frac{7}{16}$
8	$\frac{9}{16}$
10	$\frac{3}{4}$
12	$\frac{15}{16}$

Best Size of Square Loops for various Wavelengths.

Wavelength (Metres).	Size in Feet.	Turns.	Wavelength (Metres).	Size in feet.	Turns.
50—150	4	1	1,200	8	12
	3	1		6	14
				4	20
200	8	1			
	6	2	1,600	8	16
				6	20
300	8	2		4	30
	6	4			
600	8	4	2,500	8	30
	6	7		6	40
	4	10		4	60
800	8	7	3,500	8	45
	6	10		6	65
	4	15			

248. ANTENNÆ. Compagnie Française pour Exploitation des Procédés Thomson-Houston. (*French Patent* 495770, filed February 14th, 1919. Published October 17th, 1919.)

The invention consists in the arrangement of multiple earth connections for radiating antennæ, the object being to divide the earth current in a perfectly uniform manner throughout all the connections and to reduce the earth resistances to a minimum.

249. WIRELESS TELEGRAPHY IN GERMANY. (*Elektrotechnische Zeitschrift*, 40, p. 527, October, 1919)

The military high-power station at Königswusterhausen has been taken over by the postal authorities for the public service mainly with the continent of Europe. The transmission between Nauen and the United States is so perfected that telegrams can be handed in at any post office; the same applies to telegrams for Spain. An experimental service with Sweden and Switzerland has been taken in hand.

250. NAUEN *v.* EILVESE. A. Meissner; A. Sörensen. (*Elektrotechnische Zeitschrift*, 40, pp. 113—115; 233—234; 429—431. 1919.)

Articles describing the activities of the Nauen and Eilvese stations during the war and discussion arising therefrom.

251. APPARATUS FOR OPERATING DISTANT DEVICES BY MEANS OF ELECTROMAGNETIC WAVES. L. M. Ericsson & Co., Russia. (*British Patent* 131166, August, 1918. Patent accepted, August 21st, 1919.)

An illuminated tube containing helium and other gases is used as the detector.

252. WIRELESS CONTROLLED TORPEDO. A. E. Ericson and G. A. Whipple. (*French Patent* 495475, filed September 11th, 1917. Published October 9th, 1919.)

253. SYSTEM OF TELEDYNAMIC CONTROL. J. H. Hammond. (*U.S. Patent* 1419678, renewed February, 1919. Published October 21st, 1919.)

Receiving arrangements for distant radio control.

254. A SYSTEM OF RADIO-DIRECTIVE CONTROL. J. H. Hammond. (*U.S. Patent* 1319068, renewed February, 1918. Patent published, October 21st, 1919.)

A system of radio control is described with a transmitting station provided with means for emitting several different types of waves (different wavelengths, etc.). The emission of these waves is under the control of separate local control stations.

255. LIGHT TELEPHONY. A. O. Rankine. (*La Nature*, 47, pp. 307—309, November, 1919.)

An illustrated article dealing with apparatus previously described by the author.*

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* RADIO REVIEW Abstract No. 178.

256. EARTH TELEGRAPHY. P. Maurer. (*L'Électricien*, 49, pp. 181—184, October, 1919.)

An article explaining the general principles, with some particulars of apparatus used during the war, and of the ranges obtainable. A special buzzer transmitter and a three-valve amplifying receiver are described and illustrated.

257. WIRELESS IN THE R.A.F. DURING THE WAR. T. Vincent Smith. (*Electrical Review*, 85, pp. 457—458. *Radio Review*, 1, p. 38, October, 1919.)

258. AIRCRAFT WIRELESS SETS: THE 52A SPARK TRANSMITTER. J. J. Honan. (*Wireless World*, 7, pp. 470—472, November, 1919.)

An illustrated description of the transmitter fitted to the trans-Atlantic Vickers-Vimy machine.

259. AIRPLANE ANTENNA REELS. L. Ryan. (*Electrical Experimenter*, 7, p. 324, August, 1919.)

Describes a type of reel designed to stand all mechanical and electrical stress under difficult service conditions. The reel is self-locking and shows at a glance the length of aerial let down.

260. IMPROVEMENTS RELATING TO ELECTROMAGNETIC WAVE RECEPTION SYSTEMS. J. Robinson. (*British Patent* 132291, November, 1918. Patent accepted, September 18th, 1919.)

To prevent interference in the wireless receiver from the magneto or other ignition system on aircraft it is proposed to connect a variable condenser between the grid and filament of the valve detector or amplifier. One or more oscillatory circuits tuned to the wavelength or wavelengths of the waves emitted by the ignition system or other disturbing source may be arranged in the connections between the loop receiving circuit and the valve amplifier.*

261. THE ELIMINATION OF MAGNETO DISTURBANCE IN THE RECEPTION OF WIRELESS SIGNALS ON AIRCRAFT. J. Robinson. (*Radio Review*, 1, pp. 105—110, December, 1919.)

262. CAN RADIO IGNITE BALLOONS? N. Tesla. (*Electrical Experimenter*, 7, p. 516, October, 1919.)

263. WIRELESS NAVIGATION FOR AIRCRAFT. J. Robinson. (*Electrician*, 83, p. 420, October, 1919, Abstract. *Radio Review*, 1, pp. 39—42.)

264. PROGRESS OF ELECTRICAL INVENTION. J. A. Fleming. (*Nature*, 104, p. 239, November, 1919.)

A brief review of the progress of radiotelegraphy is included.

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* See also RADIO REVIEW Abstract No. 261.

265. CIRCUITS FOR UNDAMPED OSCILLATIONS. Pestarini. (*L'Elettrotecnia*, 6, pp. 481—487, August, 1919. *Science Abstracts*, 22B, No. 775.)

This article discusses the generalisation of the use of a series wound dynamo connected to a condenser for generating undamped electrical oscillations. It is shown that the same result could be obtained without the condenser by inter-linking the dynamo circuit with suitable auxiliary circuits or with a second machine. The use of a special kind of ironless alternator is also mentioned as being suitable for setting up large trains of undamped oscillations.

266. ELECTRICAL OSCILLATORS. N. Tesla. (*Electrical Experimenter*, 7, p. 229, July, 1919.)

A description of the author's work on W/T transformers, with a number of previously unpublished photos of Tesla transformers.

267. WIRELESS TELEGRAPHY PROBLEMS FOR OPERATORS. W. H. Eccles. (*Wireless World*, 7, pp. 331—332; 400—403, October, 1919.)

Shows how operators may assist in research work, often with the simplest of apparatus, by making observations in various parts of the world.

268. DUPLEX TELEPHONY BY "WIRED WIRELESS." K. W. Wagner. (*Elektrotechnische Zeitschrift*, 40, pp. 383—388, August, 1919. *Technical Review*, 5, p. 80, October, 1919.)

A description is given of experiments in the direction of duplex or multiplex telephony by several superimposed high-frequency currents along a telephone line made by the German Telegraphen Versuchsamt since 1912, and in 1918. It is proved that radio-frequency currents are damped out in the line to a considerably greater extent than audio-frequency currents, partly owing to skin effect and partly to radiation losses. In the case of similar experiments along paper-insulated cables there is an increased damping arising through the large dielectric losses. With coil-loaded cables the loading coils must be bridged by condensers. The system used for the Berlin-Hanover line is described with diagrams. It includes a device for eliminating harmonics from the emitted waves and for preventing the received signals from reacting on to the sending apparatus.

2. Book Reviews.

PRÉCIS D'ÉLECTRICITÉ THÉORIQUE. By Léon Bloch, D. ès Sc. (Paris: *Gauthier-Villars et Cie*. Pp. vi. + 476. Price 30 fr.)

A simple mathematical treatise, in which, starting from the most elementary facts, the reader is taken step by step through electrostatics, magnetism and electromagnetic theory. The latter is based on the Lorentz modification of Maxwell's theory, and follows along lines very similar to those of Föppl and Abraham's "Electricity and Magnetism." Vector methods are used throughout and the whole treatment is remarkably lucid. The first ten of the fifteen chapters deal with electrostatics, magnetism, induction, etc.; the last five deal with electric oscillations, coupled circuits, propagation of waves, radiation from antennæ, electromagnetic optics, electrodynamics of moving bodies, the equations of Hertz, Lorentz and Minkowski, and the optics of moving bodies including the theories of Lorentz and Einstein.

The book can be read with ease by any one familiar with the elements of the calculus and vector algebra, and can be confidently recommended to those wishing to lay a sound foundation of electromagnetic theory.

G. W. O. H.

LA TÉLÉGRAPHIE SANS FIL, LA TÉLÉPHONIE SANS FIL—APPLICATIONS DIVERSES. By G. E. Petit and L. Bouthillon. (Paris: *Librairie Delagrave*. Pp. vii. + 304. Price 15 fr.)

In the preface Professor D'Arsonval has written to this book he refers to "the supreme achievement" of wireless telegraphy in communicating over a distance of 20,000 km. between a station and one at its antipodes. As he says, this great record has now been established, and nothing could make clearer the enormous progress that wireless telegraphy has made in the brief twenty years during which it has been a practical means of communication. It was in 1896 that Marconi first brought over to England his new "system" which many scientists looked at with some scepticism. It would indeed have been a bold man who, at that date, would have prophesied that within two decades wireless telegraphy would be used to send a message from here to New Zealand. Long distance wireless is now looked on, more or less, as a matter of course, and this book treats the subject in a scientific manner, which takes account of this phenomena very early in its pages. Like nearly all French books this treatise is very logical; the method of treatment is synthetic; the fundamental laws are stated, and the resulting phenomena are worked out. In this respect it is a book which has few equals. It starts with a simple study of the production of electromagnetic waves, the emission of waves by one conductor, and their reception by another placed on a conducting earth. The electric waves which are produced by an oscillating current in a straight wire are described and the Hertzian equation from which the magnitude of the electric waves were first calculated are dealt with simply and clearly. Next comes a short discussion of electrical oscillations and the production of a damped train of waves, the damping of a train by radiation, or, as the authors term it, "radiance," and the effect of an earthed antenna. The problem of reception is discussed and the efficiency of radio communication is defined. A very useful feature of this chapter is a summary at the end, of the main conclusions arrived at. The second chapter deals with the propagation of waves round the surface of the earth. Reference is made to the mathematical theories that have been developed to determine the magnitude of the phenomena which might be expected to be observed on the assumption of a perfectly conducting earth surrounded by a perfectly insulating medium. The theories of the space wave due to Sommerfeld and of the Heaviside layer developed later by Eccles, to explain the enormous discrepancy between theory and observed effect, when signals are sent over hundreds of miles round the earth, are discussed, but the paper by G. N. Watson referred to recently by the editor of the RADIO REVIEW, in which a mathematical calculation has been made of the effect of an upper conducting layer on the propagation of waves round the earth is not mentioned, it was published just too late for this edition; it provides a crucial proof, which ought to put beyond doubt the correctness of the Heaviside layer theory of electromagnetic propagation. The experimental results obtained by measuring the variation of signal strength from day to day and month by month are mentioned, and the necessary modifications in the empirical formula given by Austin and others are referred to. Working in logical order, from the waves, the next stage in the study of propagation is the form of the antenna, and this subject is discussed in detail in Chapter III. The various forms are mentioned, the different methods of excitation of the antenna are described, and the effect produced by capacity and inductive connections to the earth, and finally the various forms of earth connection. Following still the logical sequence, the next chapter deals with the " transmission " of electric waves. We should use the word " production," for the chapter deals with the methods that are used for producing electrical oscillations, *i.e.*, by sparks and arcs and alternators and thermionic valves.

In dealing first with the spark method, reference to the damping due to circuit resistance and to spark resistance is made and curves of variation of spark resistance with varying lengths of spark are included. One factor has always seemed to the author of primary importance in connection with spark resistance, *i.e.*, the value of the maximum current passing at the instant of discharge. The capacity across the spark is of course the quantity that controls the current, but it would be most interesting if figures could be given of the actual resistance of the spark for different currents. The various forms of rotating spark gaps used by the Marconi Co. are described, and the quenched spark arrangement of Wien. The Poulsen arc, the various forms of high-frequency alternator, and, finally, the three-electrode valve or pliotron for generating continuous waves are mentioned. The methods of coupling the oscillating circuit to the antenna are dealt with in the last part of the chapter. Next follows an account of the methods used for the reception of the electric waves. The usual types, *i.e.*, the coherer, the magnetic detector, and the various forms of crystal detectors are clearly described, and a good account given of the Fleming valve and its derivatives, included in which is a description of the method of heterodyning which has proved such an efficient means of overcoming jamming in the continuous wave sets which were developed toward the end of the war. Amplifiers are just referred to, and the various methods of recording signal strength are mentioned, the use of the Einthoven galvanometer is not described, though this has proved by far the most successful instrument (except possibly the beautiful galvanometer designed by M. Abraham) for this purpose. The methods of tuning in order to prevent jamming are next dealt with, including an account of the Marconi multiple tuner, and the methods of connecting the detector to the circuit, according to its *modus operandi* are described. Chapter VI. deals with the methods of detecting the direction from which a wireless signal is coming, and the Bellini-Tosi compass is described in detail. The second part of the book deals with radio communication, that is, with the problems that have to be considered when a wireless station has to be designed. It starts with a short *résumé* of the history of radiotelegraphy, and continues with the description of many stations of different types, including the standard 5-kw. station for land or sea work, the Eiffel Tower station, and the stations at Arlington, Sayville and Tuckerton, as well as those at Nauen and Eilvese. The last three chapters deal with radiotelephony, the transmission of photographs by wireless telegraphy, and the transmission of power. The treatment of radiotelephony is disappointing, as it gives no account of the great progress that has been made in this direction during the last year or two. The remaining chapters, too, are mere paragraphs, introduced with the view of pointing out the possibility of future developments, rather than with the object of giving descriptions of methods that are actually in use. The last part of the book contains a number of notes which will be valuable to practical radiotelegraphists. The first describes in detail the signals that are sent out daily by the Eiffel Tower. The next two describe the principles of the method adopted by M. Bouthillon in his high-frequency alternators and by Joly and Goldschmidt in the Goldschmidt alternator. The last seventy pages contain the regulations adopted by the International Telegraphic Convention, held in London, in July, 1912. As a text book for students who want to know the fundamental principles of wireless telegraphy this book is excellent, it covers the ground clearly and well. It is rather disappointing from the more practical side, and it is not up-to-date as regards all the latest developments in continuous wave practice, which have come about from an intensive study of the three-electrode valve. For the student of wireless, however, who wants to understand exactly what is happening when a wireless signal is sent out by a transmitting station and received by another station, the book is thoroughly satisfactory.

E. W. MARCHANT.

Correspondence.

TRIODE NOMENCLATURE AND SYMBOLS.

TO THE EDITOR OF THE "RADIO REVIEW."

SIR,—In his letter dated December 9th, 1919, in your issue of January, 1920, Dr. Eccles searches for a suitable symbol for the "voltage factor" of a triode, in place of Langmuir's *k*, the not uncommon *m*, and his own provisional g, each of which has something against it. This quantity is the ratio between two other quantities frequently used separately in the theory of all triode circuits; for them no generally accepted names or symbols have yet been established, and a settlement is at least equally needed.

Writing, i_g, i_a, v_g, v_a for grid and anode currents and potentials, we have to deal with the four ratios, all of the dimensions of conductance,

$$\frac{\partial i_a}{\partial v_g}, \frac{\partial i_a}{\partial v_a}, \frac{\partial i_g}{\partial v_g}, \frac{\partial i_g}{\partial v_a}.$$

The first two are the most used, and my own provisional practice has been to represent them by the symbols g and a, using g/a for Dr. Eccles' "voltage factor" g. In his recent article in this Review,* Dr. Eccles has adopted

$$h_g, h_a, g_g, g_a$$

for the four conductances respectively. The unfortunate coincidence, doubtless accidental, between the main letter and its subscript in the third symbol only, detracts from that easy consistency so desirable as a minor mental relief; and a preferable series would appear to be

$$a_g, a_a, g_g, g_a.$$

But the name is yet more important than the symbol. Algebra is mainly a thing of writing, not of speech; and a writer may begin by defining an entirely arbitrary amnemonic set of symbols such as Professor Fortescue's

$$k_1, k_2, k_3, k_4,$$

in his recent paper on multi-stage amplifiers.† The reader can always glance back. Conversation is much impeded, however, whenever A talks triodes to B or C or D, by the necessity to preface his remarks with such statements as: "When I say g, I mean the rate of change of anode current with grid potential."

It has been suggested, I think by Mr. E. V. Appleton, that the terms

anode conductance $\left(= \frac{\partial i_a}{\partial v_a}\right)$

mutual conductance $\left(= \frac{\partial i_a}{\partial v_g}\right)$

grid conductance $\left(= \frac{\partial i_g}{\partial v_g}\right)$

should be used; and this suggestion seems to provide a good basis. Mutual conductance, however, is obviously an inaccurate description: if $\frac{\partial i_a}{\partial v_g}$ is the mutual conductance, what is $\frac{\partial i_g}{\partial v_a}$? I suggest, therefore, as fairly brief and quite unmistakable, the terms set out in the table below; and I should be

* November, 1919, p. 77.

† See RADIO REVIEW, January, 1920. p. 179.

disposed to accept ν for the ratio a_g/a_a as being the most writable and speakable of the symbols offered to us by Dr. Eccles.

Quantity.	Full Name.	Colloquial Abbreviation.	Symbol.
$\frac{\partial i_a}{\partial v_g}$	Anode-grid slope conductance	Anode-grid conductance	a_g } $a_g/a_a \equiv \nu$
$\frac{\partial i_a}{\partial v_a}$	Anode-anode slope conductance	Anode conductance	a_a
$\frac{\partial i_g}{\partial v_g}$	Grid-grid slope conductance	Grid conductance	g_g
$\frac{\partial i_g}{\partial v_a}$	Grid-anode slope conductance	Grid-anode conductance	g_a

L. B. TURNER.

King's College, Cambridge,
January 10th, 1920.

TO THE EDITOR OF THE "RADIO REVIEW."

SIR,—I was very much interested to read Dr. Eccles' views on the Physics of Amplification. The arguments for an amplifying factor of zero dimensions should surely be overwhelming. It is true that one finds in a recently published book on valves, the following statement, ". . . thus small changes of grid voltage produce *comparatively* large changes of anode current" (the italics are mine) and later in the same book, the slope of the grid voltage-anode current characteristic is suggested as the current factor of amplification. In this connection it is well to note that in a typical valve under amplifying conditions a change of grid voltage of unity produces a change in the anode current of 5×10^{-4} amperes so that the phrase "comparatively large changes of anode current" appears meaningless unless the effective resistance of the anode circuit is specified. One is inclined to hesitate before assuming that this confusion has been brought about from the fact that characteristics are very often plotted on such a scale as to make the slope of the steep portion greater than 45 degrees.

E. V. APPLETON.

Cambridge,
January 19th, 1920.

ERRATUM.

Page 239. *The first line of Dr. McLachlan's Paper should read,* "In using two-electrode thermionic valves . . ."