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Oscillations obtained by Coupling a Secondary Circuit with a Continuous Wave Valve Oscillator.*

By Prof. J. S. TOWNSEND, M.A., F.R.S.

(1) When two oscillatory circuits of small resistance are coupled by mutual induction between the coils the frequencies of the free oscillations are given by the equation

$$(L_1C_1p^2 - 1)(L_2C_2p^2 - 1) = M^2C_1C_2p^4 \quad . \quad . \quad . \quad . \quad . \quad (1)$$

L_1 and L_2 being the self-inductions of the two circuits, C_1 and C_2 the capacities, M the mutual induction between the two coils and $p/2\pi$ the frequency.

If y be substituted for $1/p^2$ the quadratic equation (2) is obtained

$$(L_1C_1 - y)(L_2C_2 - y) = M^2C_1C_2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

the two roots being proportional to the squares of the wavelengths of the two free oscillations.

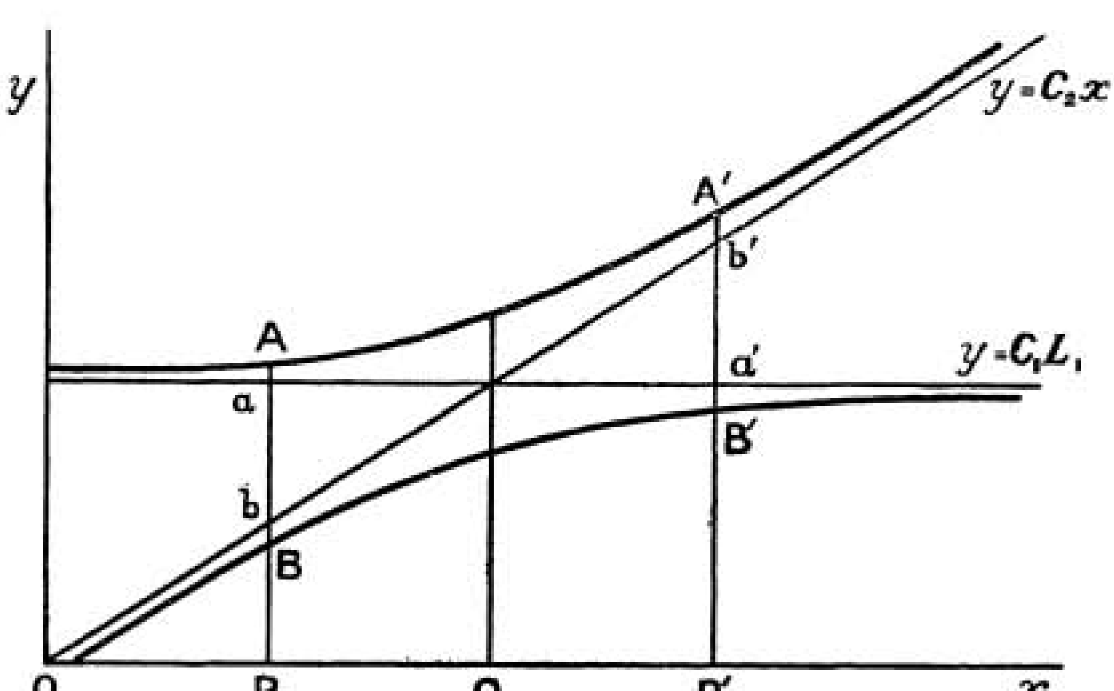

FIG. 1.

The effect of changing the oscillation constant L_2C_2 of one of the circuits

* Paper received November 15th, 1919.

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by means of an adjustable inductance $L_2 = x$ may be seen by constructing the hyperbola (Fig. 1) represented by the equation

$$(L_1C_1 - y)(C_2x - y) = M^2C_1C_2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

The two lines $L_1C_1 = y$ and $C_2x = y$ are the asymptotes, and the two branches of the curve correspond to the oscillations of long and short wavelength.

Thus for any value OP of the inductance L_2, the ordinates PA and PB are proportional to the squares of the wavelengths of the two free oscillations when the circuits are coupled, and Pa and Pb are proportional to the squares of the wavelengths of the two independent circuits ($M = 0$).

(2) Let oscillations of constant amplitude be maintained in the first circuit by connecting it to a three-electrode valve, and let the current in the second circuit be maintained by the induction between the two coils, as in a transformer (see Fig. 2). For any given value x of the self-induction L_2 of the secondary circuit, there are two possible modes of oscillation and the squares of the corresponding wavelengths are given by the points A and B on the branches of the hyperbola.

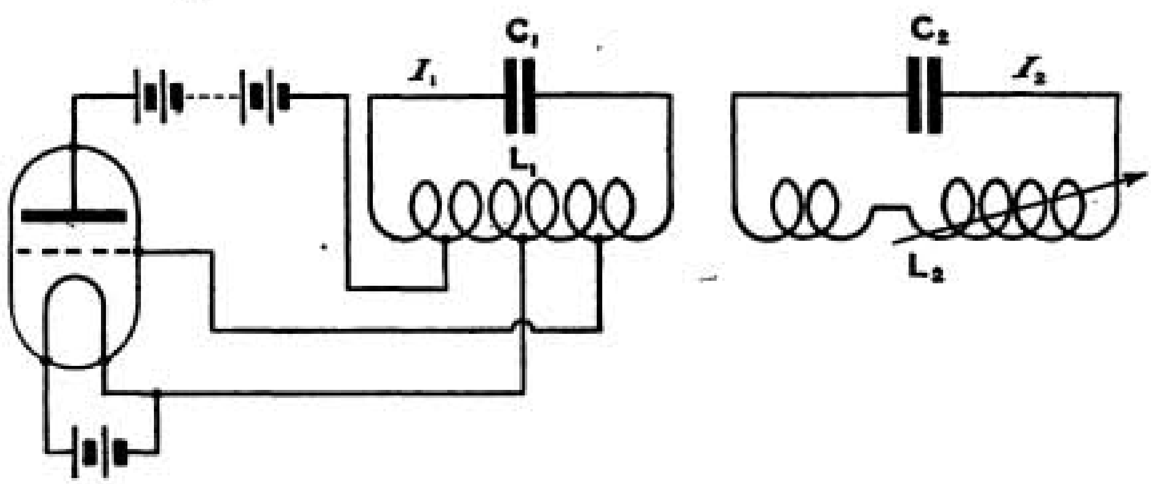

FIG. 2.

In practice two oscillations of different wavelengths very seldom occur simultaneously and the mode in which the system tends to oscillate is the one in which the wavelength is nearest to that of the primary circuit L_1C_1.

The ratio of the amplitudes of the currents in the two circuits, for each mode of oscillation, may be found geometrically as follows:

Let R_1 and R_2 be the resistances of the two circuits, i_1 and i_2 the oscillatory currents in the coils.

The equation for the current i_2 is

$$L_2\frac{di_2}{dt} + R_2i_2 = -M\frac{di_1}{dt} - v_2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

where v_2 is the potential difference between the terminals of the condenser C_2.

The current i_2 and the potential v_2 are connected by the relations

$$i_2 = C_2\frac{dv_2}{dt},$$

and

$$\frac{di_2}{dt} = C_2\frac{d^2v_2}{dt^2} = -p^2C_2v_2,$$

so that v_2 may be eliminated from equation (4) and the relation between the currents becomes

$$\left(L_2 - \frac{1}{C_2p^2}\right)\frac{di_2}{dt} + R_2i_2 = -M\frac{di_1}{dt}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

In the cases to be considered, M is supposed to be constant and comparatively large so that $\left(L_2p - \frac{1}{C_2p}\right)$ is large compared with R_2, and the relation between the amplitudes I_1 and I_2 of the two currents is found, approximately, by omitting the term R_2i_2 in equation (5).

Thus
$$I_2 = \frac{MC_2I_1}{L_2C_2 - y}$$

When the system is oscillating with the longer wavelength and $L_2 = \text{OP}$ (Fig. 1),

$$L_2C_2 = \text{Pb},$$

and
$$y = \text{PA}.$$

In this case
$$I_2 = \frac{MC_2I_1}{\text{Ab}}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

and if L_2 be increased the length Ab diminishes continuously as L_2 passes through the value OQ corresponding to resonance. Thus if I_1 were to remain constant I_2 would not reach a maximum at the point of resonance but would increase with L_2 as long as the system continued to oscillate with the longer wavelength.

When the oscillations are of the shorter wavelength

$$I_2 = \frac{MC_2I_1}{\text{Bb}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

The length Bb increases as L_2 is increased, and in this case I_2 diminishes and becomes very small when L_2 is greater than OQ.

The maxima values of I_2 which are obtained near the point of resonance, are due to the fact that the wavelength changes abruptly from the long wavelength represented by the upper branch of the hyperbola to the short wavelength represented by the lower branch as L_2 is increased from OP to OP′.

(3) In order to explain the change of wavelength it is necessary to consider the effective resistance of the oscillating system. The secondary circuit adds to the resistance, and its effect is the same as if a resistance r_1 were introduced in series with the inductance and condenser of the primary circuit which would bring the resistance of the valve circuit to the value $(R_1 + r_1)$.

It is seen from equation (5) that the effect of the condenser in the secondary circuit is the same as if the secondary were a continuous circuit of resistance R_2 and the self-induction reduced to $l_2 = L_2 - \frac{1}{C_2p^2}$. Hence as in an ordinary transformer the reaction of the secondary has the effect of increasing the resistance of the primary by the amount

$$r_1 = \frac{M^2p^2R_2}{l_2^2p^2 + R_2^2}.$$

As R_2^2 is small compared with $l_2^2p^2$ the value of r_1 becomes approximately

$$\begin{aligned} r_1 &= \frac{M^2p^2R_2}{\left(L_2p - \frac{1}{C_2p}\right)^2} \\ &= \frac{M^2p^4C_2^2R_2}{(L_2C_2p^2 - 1)^2} \\ &= \frac{C_2}{C_1} \cdot \frac{L_1C_1p^2 - 1}{L_2C_2p^2 - 1} \cdot R_2 \\ &= \frac{C_2}{C_1} \cdot \frac{L_1C_1 - y}{C_2x - y} \cdot R_2 \quad \ldots \ldots \ldots \quad (8) \end{aligned}$$

where y is one of the ordinates PA or PB of the hyperbola corresponding to the inductance $L_2 = \text{OP}$.

When the system oscillates with the longer wavelength the resistance r_1 is

$$r_1 = \frac{C_2}{C_1} \cdot \frac{\text{Aa}}{\text{Ab}} \cdot R_2 \quad \ldots \ldots \ldots \ldots \quad (9)$$

which is comparatively small when L_2 is less than OQ since Aa is then less than Ab. But when L_2 is increased above the value OQ the ratio Aa/Ab becomes very large and the oscillation of the longer wavelength would not be maintained by the valve as the effective resistance of the valve circuit becomes so large.

When the system oscillates with the shorter wavelength r_1 is

$$r_1 = \frac{C_2}{C_1} \cdot \frac{\text{Ba}}{\text{Bb}} \cdot R_2 \quad \ldots \ldots \ldots \ldots \quad (10)$$

which is comparatively small when L_2 is large. But when L_2 is reduced below the value OQ, the value of r_1 (equation (10)) becomes very large and the oscillations of short wavelength are not maintained.

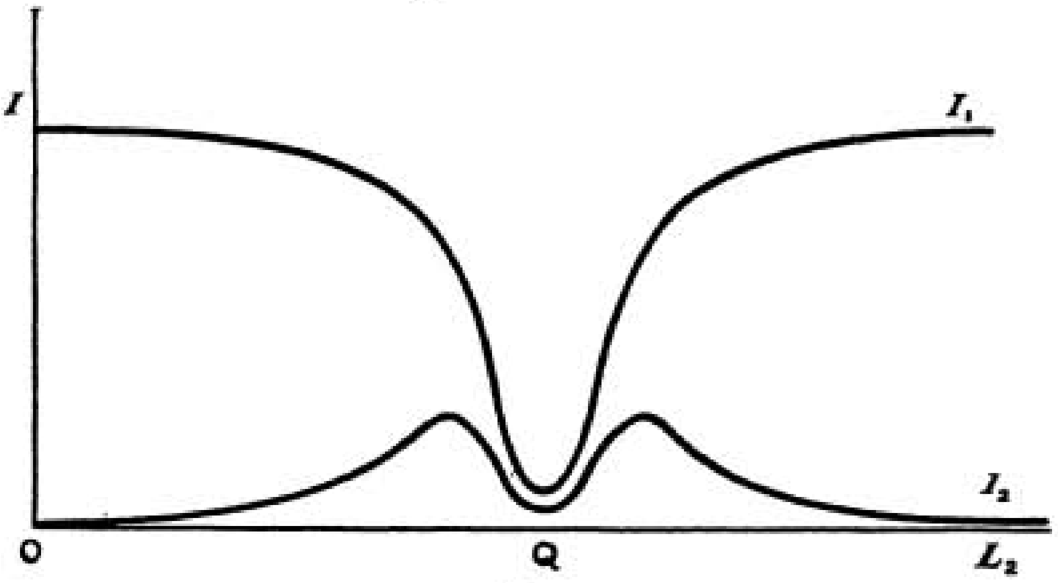

FIG. 3.

(4) The effects observed by making continuous changes in the inductance L_2 of a circuit closely coupled with a valve oscillator are easily explained by means of the hyperbola.

There are two cases which may be considered, depending on the arrangement of the valve circuit.

When the circuit L_1C_1 is connected as in Fig. 2 so that valve reaction slightly exceeds the value required to start oscillations, a large oscillating current I_1 is obtained with the circuit L_2C_2 uncoupled, but a small increase in the resistance R_1 makes a large decrease in I_1. When the second circuit is coupled with the valve circuit and the inductance L_2 is increased from a small value to the point corresponding to resonance the ratio Aa/Ab (Fig. 1) increases and the additional resistance r_1 (equation (9)) reduces the oscillating current I_1. This current may become zero before the inductance reaches the point of resonance. After passing the resonance point the oscillations start again but the wavelength is now represented by the lower branch of the hyperbola corresponding to the smaller resistance r_1 (equation (10)) which decreases continuously as L_2 increases.

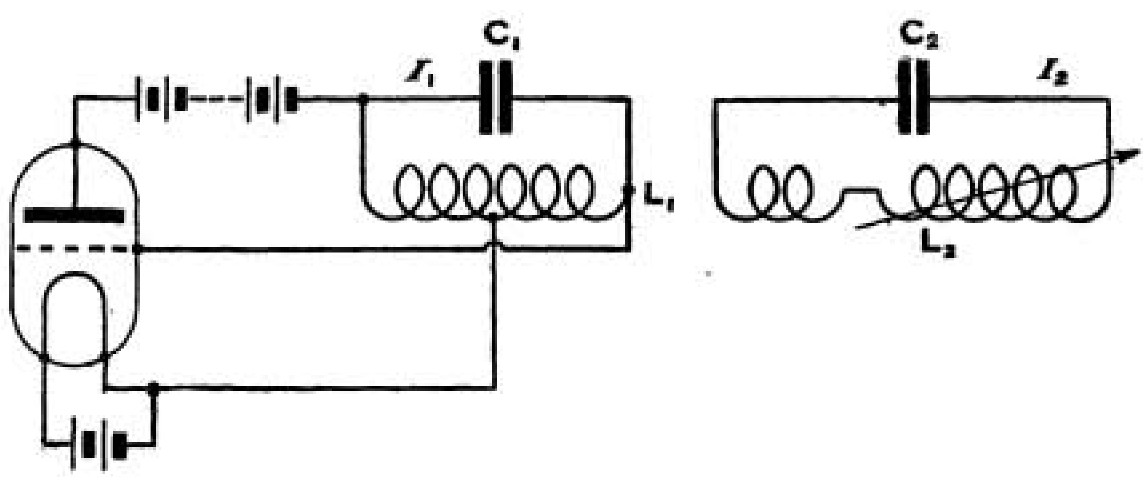

FIG. 4.

The variations in the currents thus obtained are represented in Fig. 3.

The current I_1 has a minimum value and may become zero near the point of resonance $L_2 = OQ$.

With the smaller inductances L_2 the ratio of the currents I_2/I_1 is given by equation (6) which shows that I_2 is very small when L_2 is small. As L_2 increases I_2 increases and attains a maximum value below the point of resonance.

After passing through a minimum value with I_1 and an abrupt change of wavelength I_2 attains another maximum and as shown by equation (7) becomes very small with large values of L_2.

(5) When the valve reactance is increased as in Fig. 4, the current I_1 with the circuit L_2C_2 uncoupled is reduced but it is not so much affected by variations in the resistance R_1, and the oscillations will be maintained when the effective resistance of the circuit is considerably increased.

When the second circuit is coupled to the valve circuit and the inductance L_2 increased from a small value, the oscillations which begin on the longer wavelength persist but the amplitude I_1 diminishes as L_2 passes through the point of resonance. At a point A_1 (Fig. 5) the additional resistance r_1 due to the secondary circuit becomes so large that these oscillations cease and the oscillations of shorter wavelength B_1 for which r_1 is comparatively small take place instead. At the same time an abrupt increase takes place in the current I_1 and a corresponding reduction in the current I_2.

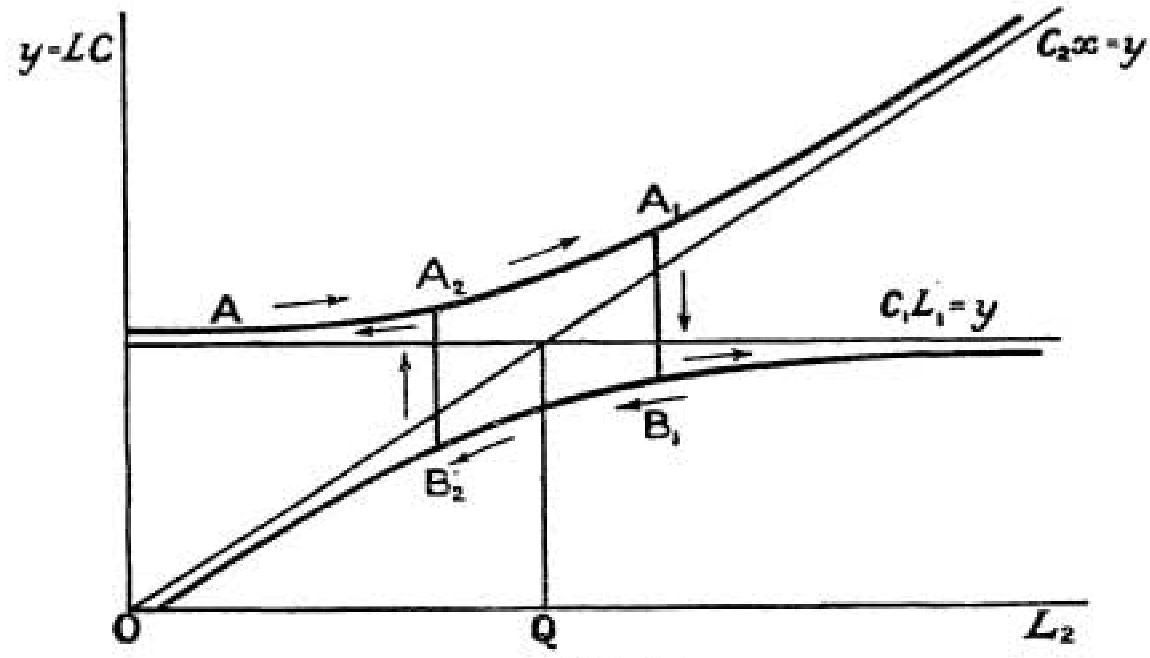

FIG. 5.

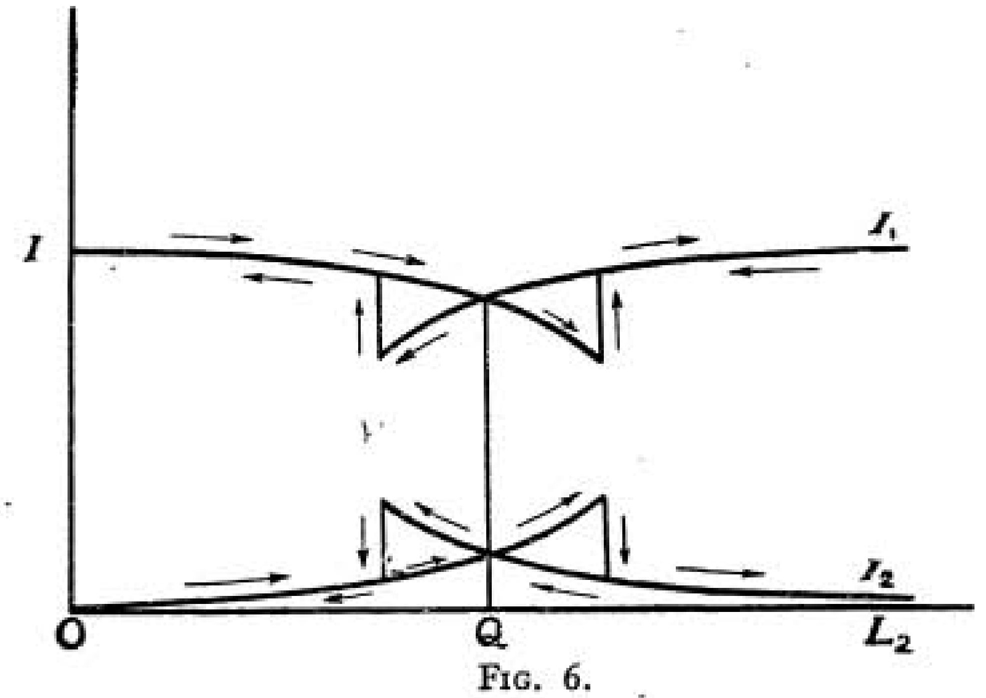

FIG. 6.

These changes in I_1 and I_2 are represented by the curves (Fig. 6), the arrows indicating the direction in which L_2 is changed. When L_2 is reduced from a large to a small value the oscillations of the shorter wavelength persist until a point B_2 (Fig. 5) below the point of resonance is obtained, the wavelength then changing from B_2 to A_2. A corresponding abrupt increase in I_1 and reduction in I_2 is obtained at the same time as shown by the curves (Fig. 6) with the arrows pointing to the left.

When the coupling is reduced a single maximum value of I_2 is obtained and the change of wavelength in passing through the point of resonance is not noticeable.

Damped Oscillations in Coupled Circuits.

By G. BRAMWELL EHRENBORG.

(*Continued from page* 336.)

Before going any further with the integration of equations (9) it is desirable to consider another matter closely related to what has been said about $\Delta\alpha, \Delta p$, etc. If we compare equations (9) with equations (1), from which they are derived, we see that they have certain features in common. In each equation there are three terms involving only one of the dependent variables and a fourth term involving only the other. That being so, there is no apparent reason why we should not be able to integrate equations (1) as they stand, if only k is small enough, instead of going to the trouble of transforming to x and y, for when k is small the correspondence between the two sets of equations seems to be very close. The difficulties appear when we proceed to the second approximation.

Consider the case where $u_1 = u_2$ and $R_1C_1 = R_2C_2$. If we put $\dfrac{R_1C_1}{u_1} = 2\eta$ and $\dfrac{1}{u_1} = s^2$, equations (1) then become

$$(D^2 + 2\eta D + s^2)\, v_1' + k\frac{u_2}{u_1} D^2 v_2' = 0$$

$$k\frac{u_1}{u_2} D^2 v_1' + (D^2 + 2\eta D + s^2)\, v_2' = 0, \text{ and consequently}$$

$$\left\{(D^2 + 2\eta D + s^2)^2 - k^2 D^4\right\} v_1' = 0$$

When k is small, the first approximation to one of the particular solutions of this equation is $v_1' = \epsilon^{-\eta t + it\sqrt{s^2-\eta^2}} = \epsilon^{\sigma t}$, say. When we proceed to the second approximation and no longer neglect k^2 the solution in question becomes $\epsilon^{(\sigma+\Delta\sigma)t}$; we calculate the value of $\Delta\sigma$ on the assumption that its square may be neglected. We obtain

$$\left\{\sigma^2 + 2\eta\sigma + s^2 + 2\,(\sigma+\eta)\,\Delta\sigma\right\}^2 - k^2(\sigma^4 + 4\sigma^3\Delta\sigma) = 0,$$

and since $\sigma^2 + 2\eta\sigma + s^2 = 0$, this reduces to

$$\frac{\Delta\sigma}{\sigma} = -\frac{1}{4}.$$

Hence the second approximation differs from the first by 25 per cent., so that if we wish to obtain any results worth having by this method, we must work out the third approximation at the very least, and probably several more. When $u_1 \neq u_2$ and $R_1C_1 \neq R_2C_2$ the algebra becomes very involved, so we infer that equations (1) as they stand are quite unsuitable for integration.

To return to equations (9); writing $\sqrt{p^2-\alpha^2} = p'$ and $\sqrt{q^2-\beta^2} = q'$ for brevity, we have seen that when k is not too small, particular solutions are obtained by equating x to one or other of the quantities $\epsilon^{-\alpha t \pm ip't}$,

$\epsilon^{-\beta t \pm iq't}$. If we had eliminated x instead of y from (9), equation (13) would have been reproduced though of course y would have appeared as the dependent variable instead of x; consequently equations (9) are satisfied if we equate y to any of the above four exponentials. If the ratio of the constants A and C is properly chosen, the following pair of values will satisfy the equations:

$$x = A\epsilon^{-at + ip't},\ y = C\epsilon^{-at + ip't}.$$

What that ratio must be we can determine by substituting these values in the second of equations (9).

We find $C = \dfrac{g(a - ip')}{(a - ip')^2 - 2\beta(a - ip') + q^2} A$

or, $$\frac{C}{A} = g\frac{2(aq^2 - \beta p^2) + a(p^2 - q^2) + ip'(p^2 - q^2)}{(p^2 - q^2)^2 + 4(aq^2 - \beta p^2)(a - \beta)}.$$

In order to simplify the determination of the integration constants as much as possible we will neglect all quantities which contain $R_1C_1 - R_2C_2$ as a factor (such as f, g, $aq^2 - \beta p^2$) if they contain another resistance as a further factor, or in other words, we will neglect all quantities which contain the factor $\left(\dfrac{R_1C_1}{R_2C_2} - 1\right)a^2$, where a has the same meaning as on Figs. 1—6. This entails little more labour than if we were to neglect all quantities without distinction which contain a^2 and gives us the advantage of getting a solution which is exact when $R_1C_1 = R_2C_2$, and not a mere approximation.

That being the case, we see that

$$\frac{C}{A} = g\frac{ip'}{p^2 - q^2}.$$

Proceeding in a similar manner, we find three other pairs of values which satisfy equations (9), namely

$$x = B\epsilon^{-at - ip't} \qquad y = -g\frac{ip'}{p^2 - q^2}B\epsilon^{-at - ip't}$$

$$x = -f\frac{iq'}{p^2 - q^2}H\epsilon^{-\beta t + iq't} \qquad y = H\epsilon^{-\beta t + iq't}$$

$$x = f\frac{iq'}{p^2 - q^2}K\epsilon^{-\beta t - iq't} \qquad y = K\epsilon^{-\beta t - iq't}$$

Equations (9) are therefore also satisfied by

$$x = A\epsilon^{-at + ip't} + B\epsilon^{-at - ip't} - \frac{ifq'}{p^2 - q^2}H\epsilon^{-\beta t + iq't} + \frac{ifq'}{p^2 - q^2}K\epsilon^{-\beta t - iq't}$$

$$y = \frac{igp'}{p^2 - q^2}A\epsilon^{-at + ip't} - \frac{igp'}{p^2 - q^2}B\epsilon^{-at - ip't} + H\epsilon^{-\beta t + iq't} + K\epsilon^{-\beta t - iq't}$$

As this solution contains four arbitrary constants, it is evidently the complete integral.

Transforming imaginary exponentials to sines and cosines,

$$\left.\begin{aligned} x &= \epsilon^{-\alpha t}\{C\cos p't + D\sin p't\} - \\ &\qquad \frac{f\epsilon^{-\beta t}}{p^2-q^2}\Big\{(\beta F + q'G)\cos q't - (q'F - \beta G)\sin q't\Big\} \\ y &= \frac{g\epsilon^{-\alpha t}}{p^2-q^2}\Big\{(\alpha C + p'D)\cos p't - (p'C - \alpha D)\sin p't\Big\} + \\ &\qquad \epsilon^{-\beta t}\{F\cos q't + G\sin q't\} \end{aligned}\right\} \quad (17)$$

To determine the integration constants we shall assume that when $t = 0$, $v_1 = V_1$, $v_2 = i_1 = i_2 = 0$. Since $i_1 = -C_1\dot{v}_1$ and $i_2 = -C_2\dot{v}_2$, we find by (7) that this is equivalent to $x = \dfrac{ku_1V_1}{p^2\sqrt{L_1}}$, $y = \dfrac{ku_1V_1}{q^2\sqrt{L_1}}$, $\dot{x} = \dot{y} = 0$.

By differentiating (17),

$$\dot{x} = -\epsilon^{-\alpha t}\{(\alpha C - p'D)\cos p't + (p'C + \alpha D)\sin p't\} + \frac{fq^2}{p^2-q^2}\Big\{F\cos q't + G\sin q't\Big\}\epsilon^{-\beta t}$$

$$\dot{y} = -\frac{gp^2\epsilon^{-\alpha t}}{p^2-q^2}\Big\{C\cos p't + D\sin p't\Big\} - \epsilon^{-\beta t}\{(\beta F - q'G)\cos q't + (q'F + \beta G)\sin q't\}$$

Hence, when $t=0$,

$$C - \frac{fq'}{p^2-q^2}G = \frac{ku_1V_1}{p^2\sqrt{L_1}}$$

$$\frac{gp'}{p^2-q^2}D + F = \frac{ku_1V_1}{q^2\sqrt{L_1}}$$

$$-\alpha C + p'D + \frac{fq^2}{p^2-q^2}F = 0$$

$$-\frac{gp^2}{p^2-q^2}C - \beta F + q'G = 0$$

These equations are easily solved to the degree of accuracy required, and the solutions are

$$C = \frac{ku_1V_1}{p^2\sqrt{L_1}} \qquad D = \frac{ku_1V_1}{p^2\sqrt{L_1}}\left(\frac{\alpha}{p'} - \frac{fp}{(p^2-q^2)}\right)$$

$$F = \frac{ku_1V_1}{q^2\sqrt{L_1}} \qquad G = \frac{ku_1V_1}{q^2\sqrt{L_1}}\left(\frac{\beta}{q'} + \frac{gq}{(p^2-q^2)}\right)$$

Having determined the values of the integration constants, we now substitute x and y in equations (8) and find after some easy algebra,

$$v_1 = \frac{V_1\left(\dfrac{1}{q^2} - u_1\right)}{\dfrac{1}{q^2} - \dfrac{1}{p^2}}\epsilon^{-\alpha t}\left[\cos p't + \left\{\frac{\alpha}{p'} - 2\left(u_1 - \frac{1}{p^2}\right)\frac{R_1C_1 - R_2C_2}{p\left(\dfrac{1}{q^2} - \dfrac{1}{p^2}\right)^2}\right\}\sin p't\right] +$$

$$+\frac{V_1\left(u_1-\frac{1}{p^2}\right)}{\frac{1}{q^2}-\frac{1}{p^2}}\epsilon^{-\beta t}\left[\cos q't+\left\{\frac{\beta}{q'}+2\left(\frac{1}{q^2}-u_1\right)\frac{R_1C_1-R_2C_2}{q\left(\frac{1}{q^2}-\frac{1}{p^2}\right)^2}\right\}\sin q't\right];$$

$$v_2=-\sqrt{\frac{L_2}{L_1}}\cdot\frac{V_1ku_1}{\frac{1}{q^2}-\frac{1}{p^2}}\epsilon^{-\alpha t}\left[\cos p't+\left\{\frac{\alpha}{p'}-(u_1-u_2)\frac{R_1C_1-R_2C_2}{p\left(\frac{1}{q^2}-\frac{1}{p^2}\right)^2}\right\}\sin p't\right]+$$

$$+\sqrt{\frac{L_2}{L_1}}\cdot\frac{V_1ku_1}{\frac{1}{q^2}-\frac{1}{p^2}}\epsilon^{-\beta t}\left[\cos q't+\left\{\frac{\beta}{q'}-(u_1-u_2)\frac{R_1C_1-R_2C_2}{q\left(\frac{1}{q^2}-\frac{1}{p^2}\right)^2}\right\}\sin q't\right];$$

and by differentiating,

$$i_1=\frac{C_1V_1\left(\frac{1}{q^2}-u_1\right)p}{\frac{1}{q^2}-\frac{1}{p^2}}\epsilon^{-\alpha t}\left[\frac{p}{p'}\sin p't+2\left(u_1-\frac{1}{p^2}\right)\frac{R_1C_1-R_2C_2}{p\left(\frac{1}{q^2}-\frac{1}{p^2}\right)^2}\cos p't\right]+$$

$$+\frac{C_1V_1\left(u_1-\frac{1}{p^2}\right)q}{\frac{1}{q^2}-\frac{1}{p^2}}\epsilon^{-\beta t}\left[\frac{q}{q'}\sin q't-2\left(\frac{1}{q^2}-u_1\right)\frac{R_1C_1-R_2C_2}{q\left(\frac{1}{q^2}-\frac{1}{p^2}\right)^2}\cos q't\right];$$

$$i_2=-\sqrt{\frac{L_2}{L_1}}\cdot\frac{C_2V_1ku_1p}{\frac{1}{q^2}-\frac{1}{p^2}}\epsilon^{-\alpha t}\left[\frac{p}{p'}\sin p't+(u_1-u_2)\frac{R_1C_1-R_2C_2}{p\left(\frac{1}{q^2}-\frac{1}{p^2}\right)^2}\cos p't\right]+$$

$$+\sqrt{\frac{L_2}{L_1}}\cdot\frac{C_2V_1ku_1q}{\frac{1}{q^2}-\frac{1}{p^2}}\epsilon^{-\beta t}\left[\frac{q}{q'}\sin q't+(u_1-u_2)\frac{R_1C_1-R_2C_2}{q\left(\frac{1}{q^2}-\frac{1}{p^2}\right)^2}\cos q't\right]$$

It is at once evident that when $t=0$ we have $v_1=V_1$ and $v_2=i_1=i_2=0$. To check the accuracy of our work we may substitute the above values in the equations from which we started. It is easy to verify that they are satisfied to the required degree of accuracy if we make use of equations (4) and (5). The work is particularly simple if $R_1C_1=R_2C_2$, when it is found that the solution is exact.

As a rule it is more important to know what is happening in the secondary circuit than in the primary, so we will give some further attention to v_2 and i_2. If we put $(u_1-u_2)\dfrac{R_1C_1-R_2C_2}{p\left(\frac{1}{q^2}-\frac{1}{p^2}\right)^2}=\tan\theta$ and $(u_1-u_2)\dfrac{R_1C_1-R_2C_2}{q\left(\frac{1}{q^2}-\frac{1}{p^2}\right)^2}=\tan\phi$, we find, always remembering the degree of accuracy at which we are aiming,

$$v_2 = \sqrt{\frac{L_2}{L_1}} \cdot \frac{V_1 k u_1}{\frac{1}{q^2} - \frac{1}{p^2}} \left[-\frac{p}{p'} \epsilon^{-\alpha t} \cos\left(p't + \theta - \tan^{-1}\frac{\alpha}{p'}\right) + \right.$$

$$\left. + \frac{q}{q'} \epsilon^{-\beta t} \cos\left(q't + \phi - \tan^{-1}\frac{\beta}{q'}\right) \right]$$

$$i_2 = \sqrt{\frac{L_2}{L_1}} \cdot \frac{C_2 V_1 k u_1}{\frac{1}{q^2} - \frac{1}{p^2}} \left[-\frac{p^2}{p'} \epsilon^{-\alpha t} \sin(p't + \theta) + \frac{q^2}{q'} \epsilon^{-\beta t} \sin(q't + \phi) \right]$$

Each of v_2 and i_2 are seen to consist of two terms, one with the frequency $\frac{p'}{2\pi}$ and the other with $\frac{q'}{2\pi}$. These two terms are often referred to as the principal or normal modes of oscillation of v_2 (or i_2, as the case may be) and the change of variables from v_1 and v_2 to x and y is called in dynamics "reduction to normal co-ordinates."

In most practical applications we may of course neglect $\frac{\alpha^2}{p^2}$ and $\frac{\beta^2}{q^2}$ in comparison with unity, so that we may put $\frac{p}{p'} = \frac{q}{q'} = 1$, $\frac{\alpha}{p'} = \frac{\alpha}{p}$ and $\frac{\beta}{q'} = \frac{\beta}{q}$. The angles $\tan^{-1}\frac{\alpha}{p}$ and $\tan^{-1}\frac{\beta}{q}$ may be readily found from Figs. 1—4, and θ and ϕ from Fig. 6.

It is of interest to know how the constant factors in the expression for i_2 vary as the ratio $\frac{u_1}{u_2}$ alters. To express them as functions of this ratio we must make some assumption as to how the inductances and capacities involved in u_1 and u_2 vary; it will be assumed here that L_1 L_2 and C_2 remain constant and that C_1 alone varies. Then we may write i_2 in the form

$$i_2 = -\sqrt{\frac{C_2}{L_1}} V_1 \left(\frac{k u_1 p \sqrt{u_2}}{\frac{1}{q^2} - \frac{1}{p^2}} \right) \epsilon^{-\alpha t} \sin(p't + \theta) +$$

$$+ \sqrt{\frac{C_2}{L_1}} V_1 \left(\frac{k u_1 q \sqrt{u_2}}{\frac{1}{q^2} - \frac{1}{p^2}} \right) \epsilon^{-\beta t} \sin(q't + \phi)$$

$\sqrt{\frac{C_2}{L_1}} V_1$, a quantity of the dimensions of a current, is independent of u_1/u_2, so we get the information we require by plotting the factors inside the brackets (which are mere numbers without dimensions) against u_1/u_2. This has been done in Fig. 7. When u_1 nearly $= u_2$ there is not much difference between the ordinates of the various curves, so that at first sight one would be tempted to conclude that at resonance the response of the secondary to the primary is not much affected by the coupling. This is only apparent, however, for when the oscillation begins the principal modes are in opposition, and when the coupling is loose they almost cancel. As the frequencies are almost equal when k is small, it is some time before the principal modes come into phase, and then $\epsilon^{-\alpha t}$ and $\epsilon^{-\beta t}$ have diminished to such an extent that the total current is small. With loose couplings, therefore, the instantaneous value of the current is never large.

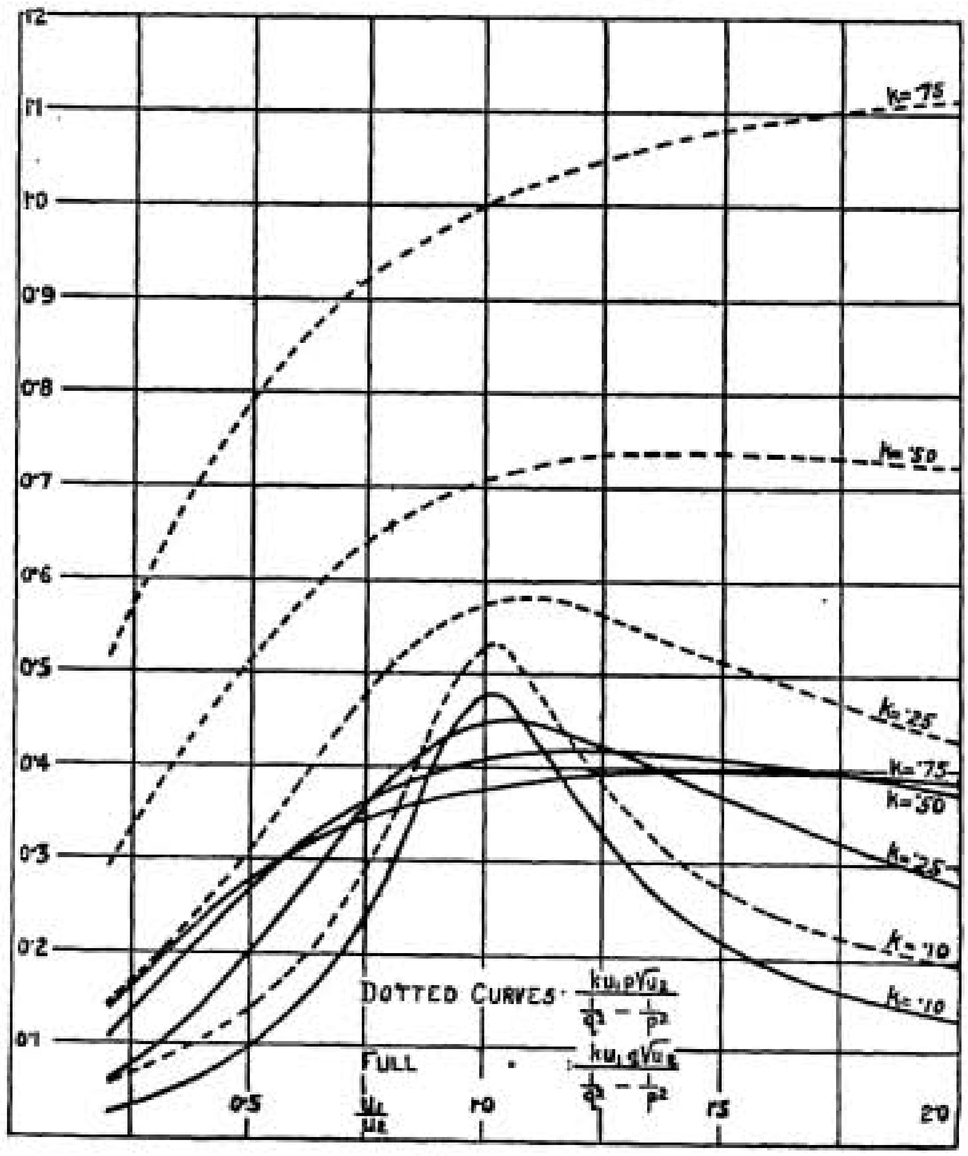

FIG. 7.

When making practical applications of the expressions we have derived, due regard must be taken to their limitations. Strictly speaking, this paper only concerns itself with the integration of a certain pair of differential equations with constant coefficients, and if the results are applied to circuits with coefficients that are functions of the time (*e.g.* circuits with spark gaps) or circuits which can only approximately be represented by concentrated resistance, inductance and capacity in series (*e.g.* antennæ and telegraph cables), nothing more than an approximate agreement with experiment is to be expected.

The method we have used can obviously be applied to circuits with electrostatic or mixed coupling ; in fact, to any pair of differential equations where the damping terms are small. If the damping terms are on an equality with the others, that is in aperiodic cases, no special benefit is obtained from its use. If the un-transformed equations contain more than one cross term each, the algebra naturally becomes rather more complicated.

The Upper Atmosphere and Radio-Telegraphy.

By THE EDITOR.

Although it has long been known that the electrical condition of the upper atmosphere has a more or less beneficial effect on long distance radio-telegraphy, results obtained during the last two or three years have shown conclusively that the effect is far more pronounced than was previously suspected. Whatever differences there have been between the results obtained by the various mathematicians who have studied the problem of the transmission of electromagnetic waves around the earth, these results have all tended to prove with a cumulative degree of certainty that the signals actually received at great distances are much stronger than can possibly be explained without calling in the aid of the upper atmosphere. Then again the variations in signal strength from hour to hour especially at sunrise and sunset indicate very conclusively that something subjected to much greater changes of electrical condition than are the earth or lower atmosphere must be concerned in the transmission. More recently the large and unexpected discrepancies which are observed in the apparent bearing of a distant fixed station have shown that the upper atmosphere plays a very important part even in the transmission over relatively short distances. When the position of a fixed station less than 200 miles away appears to change about 90° in a few minutes without any apparent cause, it is fairly obvious that the signals being received are almost, if not entirely, controlled by conditions external to the earth and to that part of the atmosphere of which we have any exact knowledge. It shows, moreover, that these conditions are subjected to rapid changes.

In the experiments with reception over long distances conducted before the war by the U.S. Navy, it was found that consistent results could be obtained only during the day, the night signals, although generally stronger, being very erratic. Similar results are obtained in direction-finding. During the day the waves come in a direct line from the transmitting station with very little trace of variation, but during the night, the direction is very variable, and the waves sometimes arrive at the receiving station by two different routes with such a phase difference that no resultant direction can be found. If the waves came with equal intensity from two directions at right-angles and had 90° phase difference they would produce a pure rotating field and the signals would be unchanged as the coil of the receiving station was rotated.

All these phenomena leave no room for doubt that the upper atmosphere plays a very important *rôle* in radio-telegraphic transmission over all but the shortest distances, but what the exact nature of this *rôle* may be is still far from clear. Near the surface of the earth the atmosphere always contains a number of free ions and the number increases rapidly as one ascends. The presence of these ions makes the atmosphere conducting, the electric current being merely the convection of these free ions in the electric field. This conductivity is undoubtedly very considerable at heights between ten and one hundred miles, the luminous effects known as the Aurora Borealis being associated with this conductivity. Of the constitution of the upper atmosphere little is known with certainty, but the rare gases, whatever they may be, are subjected during the day to the radiation from the sun which is undoubtedly very rich in ultra-violet energy of great ionising power. This results in the ionisation not only of the upper atmosphere, but also to a lesser extent of the lower atmosphere. Owing to the absorption of the ultra-violet energy the ionising power is gradually decreased as the light penetrates the atmosphere. There may be, however, well defined surfaces of separation between different gases, with sudden changes in the conductivity. It is generally assumed that during the night, the ionising cause having been removed, the lower atmosphere loses its conductivity and the sudden fluctuations of signal strength observed at sunset suggest that the recombination or removal of the ions takes place quickly. It is usually believed that the surface of separation between the conducting and non-conducting atmosphere recedes to a higher level and that above this the conductivity persists during the hours of darkness. At this point there are several alternative theories all more or less unsatisfactory. On meeting a sharply defined change of conductivity, the waves may be reflected just as light is reflected at a polished metal surface. The condition that the change must be sharply defined must be interpreted in terms of the wavelength, a thousandth of a millimetre in the case of light being equivalent to several kilometres in radio-telegraphy. Any difference in the results obtained with long and short waves may be due to this effect. It may be that clouds of ionisation can have as sharply defined boundaries as ordinary water clouds. If the change of conductivity is gradual the wave will pass without reflection, but will suffer absorption in the conducting medium. If the wave travels faster in the upper medium than in the lower it will gradually bend down towards the earth and thus give a result somewhat similar to that produced by reflection. The upper medium being conductive, however, the wave should travel more slowly through it than through the lower atmosphere. An ingenious suggestion in this connection was made by Dr. Eccles, namely, that the movement of the ions in the alternating electric field may be 180° out of phase with the displacement current and thus cause an apparent decrease of the specific inductive capacity. Since the velocity of wave propagation is inversely proportional to the square root of this constant of the medium, it would appear that the velocity should be greater than in free space. Many facts, however, lead us to regard the velocity of electromagnetic waves in free space as an absolutely impassable maximum, and one instinctively distrusts a theory which leads to a higher velocity. It may be that a more rigorous investigation would show that the scattering due to the absorption of energy by the ions and its re-radiation in all directions would be sufficient to counteract the effect of the apparent decrease of the specific inductive capacity.

The reflection theory is free from this difficulty and the work of Professor G. N. Watson has shown that a very slight conductivity would suffice to give the observed strength of signals over long distances. Assuming then that the upper atmosphere acts as a conducting reflector, what is the explanation of the difference between the day and night effects? During the night the signals are stronger but erratic in strength and direction. The increased height of the reflecting layer would tend rather to weaken than to strengthen the signals. The most reasonable suggestion is that the surface is more sharply defined by the removal of the ionisation from the lower strata when the sunlight is withdrawn. The wave is thus enabled to reach an efficient reflecting surface without passing through an absorptive medium. The irregularities in the signals at night suggest that the reflecting layer is subjected to large changes of contour. It is not easy to see, however, why the signals during the day should be so much more uniform. Is the ionisation produced by the sunlight more stable in degree and in distribution than that which persists during the night.

These are questions which we hope will be brought nearer solution by the collection and correlation of data with respect to the reception of signals at various distances from the numerous high-powered continuous wave stations.

Duplex Wireless Telephony: Some Experiments on its Application to Aircraft.

By Capt. P. P. ECKERSLEY.

(*Continued from p.* 340.)

The use of two aerials on aircraft presents some difficulty but they have been employed on American machines in the form of two single wire aerials trailed from the wing tips.

The divided earth circuit using a single aerial and two different wavelengths was extremely simple and lent itself very readily to application to aircraft. The arrangement is indicated in Fig. 3. In this diagram X represents the earth terminal of a standard type of wireless telephone transmitter, but instead of being connected directly to earth it is joined thereto through the two branch circuits L_2 C_2 and L_3 C_3. The former is tuned to the transmitter wavelength and the latter to the wavelength of the received signals. The coil L_3 is coupled to the receiver. The values of L_2 and C_2 must be adjusted so that X remains a potential node, as this reduces the tendency for current to flow through the other branch L_3 C_3. In order to prevent the power valve V_2 from generating oscillations of both the transmitter and receiver frequencies (on account of the double tuning of the aerial), it is desirable that its grid circuit L_1 should be tuned by the condenser C_1 to the frequency of the waves to be transmitted. It is better to make L_2 small and C_2 large and L_3 large and C_3 small to obtain good results. By introducing tuned stopping circuits into the two earth paths the frequency difference may be reduced to 10 per cent., whereas without stoppers it must be increased to at least 20 per cent.

(4) PARTIAL DUPLEX.

By the use of an "augmented oscillation transmitter" in which a small steady oscillation is maintained, in combination with a receiver protected wholly from the small oscillation, but with imperfect protection for larger amplitudes, a partial duplex arrangement is possible. Such a system would represent a considerable advance over the present switch operated arrangements and should be very easy to handle.

(5) SUBSIDIARY PROBLEMS.

A number of such problems are considered in the paper, one of the most important being the question of the type of receiver to be used. In all the arrangements described above low frequency amplifiers in connection with the reaction valve were used. They have certain advantages for this type of work as they are not sensitive to feeble oscillations, and therefore it is possible to work when the receiver is not perfectly protected. Such arrangements however are not particularly sensitive and high frequency amplifiers are better, although difficulties are then experienced owing to "wipe-out" effects arising from reaction from the transmitter. The best compromise between high and low frequency amplification remains to be found by experiment.

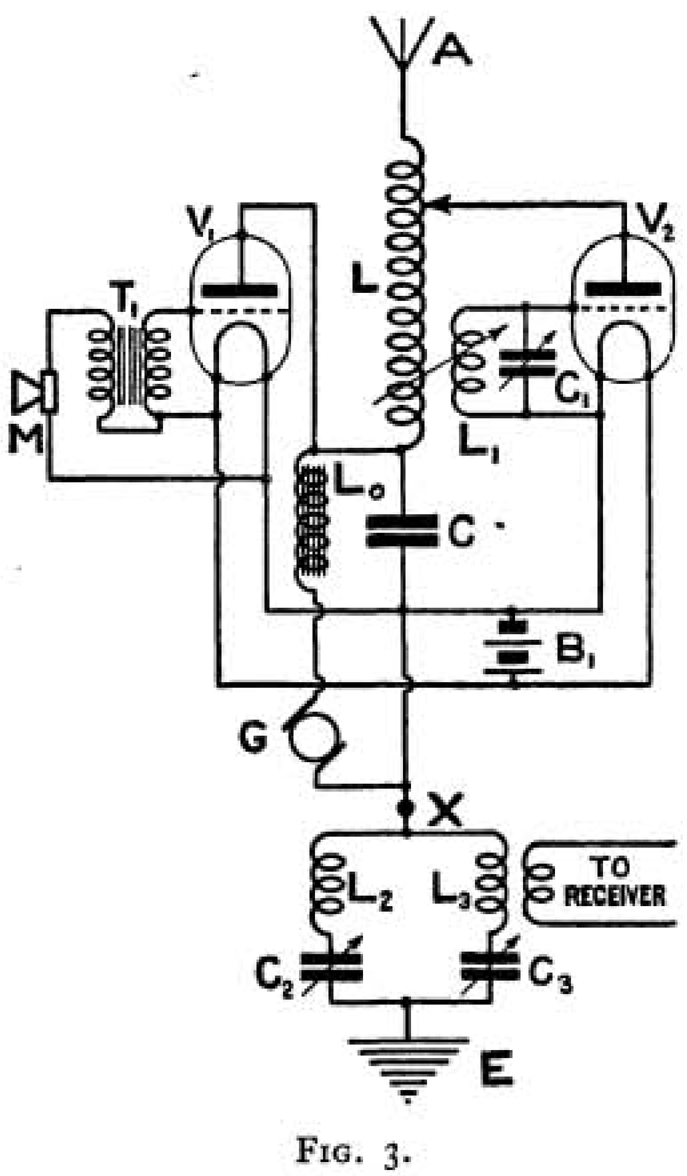

FIG. 3.

An appendix to the paper discusses the new nomenclature which has arisen in connection with this subject. This is briefly as follows :—

TRUE DUPLEX WIRELESS TELEPHONY includes all circuits which protect the receiver from the most intense oscillations generated by the transmitter, so that "chipping in" is always possible.

PARTIAL DUPLEX WIRELESS TELEPHONY includes circuits in which the receiver is protected from a small permanent oscillation generated in the transmitter, this oscillation being increased in value when speaking, proportionately with the intensity of the voice. With this arrangement "chipping in" is not always possible.

AUTOMATIC DUPLEX WIRELESS TELEPHONY includes circuits in which the transmitter only produces oscillations when speaking, which automatically paralyse the receiver meanwhile so that the system resembles only an automatic switching system.

Any type of transmitter can be used with true duplex telephony. The name AUGMENTED OSCILLATION TRANSMITTER has been given to the transmitter used with partial duplex systems ; and the name QUIESCENT AERIAL TRANSMITTER has been given to the one used with the automatic duplex system.

In the discussion attention was drawn to the advantages which had undoubtedly accrued owing to the great number of brilliant young scientists who had been led by the necessities of the war to concentrate their energies on problems connected with radio-telegraphy and telephony. It required considerable optimism to attempt to obtain good speech by means of the quiescent aerial systems described in the paper. Contrary to the impression gathered from a perusal of the technical journals of other countries since the armistice, it is made abundantly clear by this paper, and by the other papers recently read before the Institution, that research work of the highest order was carried out in this country and that in the design and application of wireless apparatus to meet the novel conditions continually arising, the scientific workers attached to the various branches of the services were second to none.

Harmonics in C.W. Transmission.*

By Capt. L. A. T. BROADWOOD, A.M.I.E.E.

This paper summarised the results of some experiments carried out in France in December, 1916, on C.W. Transmitters. They were fundamentally concerned with measuring the efficiency of the transmitter, by determining the effective resistance of the aerial using a substitution dummy aerial circuit. The aerial capacity was measured by means of a charge-and-discharge commutator and the dummy aerial capacity given the value determined in this way. The effective resistance of the aerial was then determined at various wavelengths by adjusting the resistance of the dummy circuit until the same current was obtained as in the actual aerial. The curve of resistance was found to exhibit peaks at various wavelengths which were exact multiples of the fundamental wavelength of the aerial, and the efficiency curve likewise showed similar peaks (Fig. 1).

The paper concluded with a graphical construction for obtaining the waveform of the plate current from the static characteristic of the oscillating tube. The wave was found to be flat-topped and unsymmetrical for the case considered in the paper. The harmonics in the plate current, which in the direct-coupled transmitter flow through the aerial tuning inductance, excite the natural harmonics which are found in the aerial circuit itself by reason of its distributed capacity and inductance.

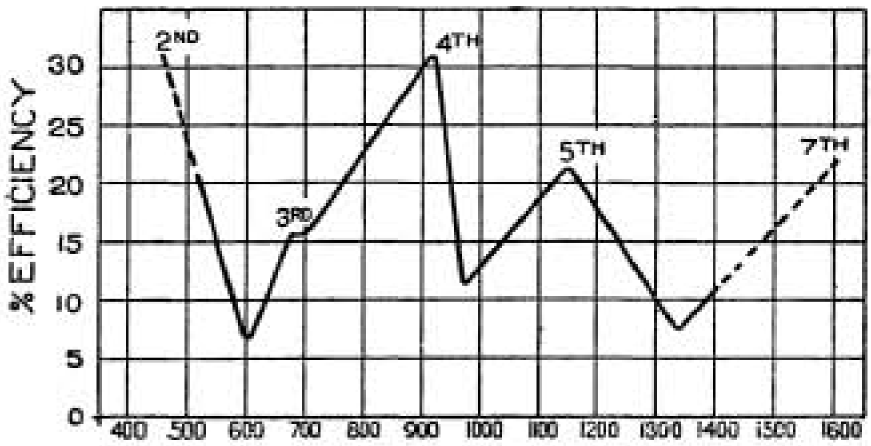

FIG. 1.

In the discussion a simple method was described for detecting the presence of an unsymmetrical wave in the transmitter, by coupling it to a tuned wavemeter circuit across which was shunted a crystal detector and galvanometer. By reversing the coupling a different deflection will be obtained on the galvanometer if the waveform is unsymmetrical.

* Paper read before the Wireless Society of London on March 26th, 1920.

H H

Review of Radio Literature.

1. Articles and Patents.

325. THEORETICAL INVESTIGATION OF THE RADIATION FROM ANTENNA SYSTEMS. M. Abraham. (*Archiv für Elektrotechnik*, 8, p. 92, 1919.)

A study of the radiation from two neighbouring antennæ oscillating in synchronism and of the effect on the radiation resistance and frequency of each due to the other with various degrees of coupling. A study of the effect both in sending and receiving antennæ of erecting in the neighbourhood an auxiliary unexcited but tuned antenna, which by its absorption and radiation produces screening and reflection effects.

See also RADIO REVIEW Abstract No. 91.

326. THE ELECTRO-DYNAMICS OF RADIATION CIRCUITS. K. W. Wagner. (*Archiv für Elektrotechnik*, 8, p. 145, 1919.)

This is mainly concerned with arrangements of inductances, capacities and resistances to produce an artificial aerial.

327. AN INVESTIGATION OF SO-CALLED QUENCHED SPARKS. V. Pieck. (*Jahrbuch der Drahtlosen Telegraphie*, 15, pp. 40—67, January, 1920. See also *Göttinger Diss. and Annalen*, 54, p. 197, 1917. *Technical Review*, 6, p. 225, March 2nd, 1920.)

An experimental investigation of the effect on the quenching phenomenon of the material of the electrodes, of the nature of the gas and of its pressure, of the shape of the electrodes, of the frequency and of the amplitude of the current. This is followed by a theoretical study of the phenomenon of quenching, following the theory of Roschansky. The spark is treated as an electric arc and oscillograph records are given of low frequency arc phenomena. It is shown that the spark discharge can be completely explained in this manner.

323. THE MANDELSTAM METHOD OF ABSOLUTE MEASUREMENT OF FREQUENCY OF ELECTRICAL OSCILLATIONS. J. Tykocinski-Tykociner. (*Philosophical Magazine*, 39, pp. 289-294, March, 1920.)

Describes the method used for calibrating wavemeters devised by Dr. Mandelstam of the Russian Siemens and Halske Works in Petrograd. A buzzer B (Fig. 1) excites an aperiodic circuit (a) thus providing a source of oscillations of a wide range of frequencies owing to the non-sinusoidal character of the current waveform. Oscillations, the frequencies of which are exact multiples of the buzzer frequency have the largest amplitudes. The circuit (b) the frequency of which is to be measured is coupled with the aperiodic circuit and also with the detector circuit (c) which is used for indicating resonance in (b). If n is the interrupter frequency and s the number of maxima observed between two settings of the condenser C_2, corresponding

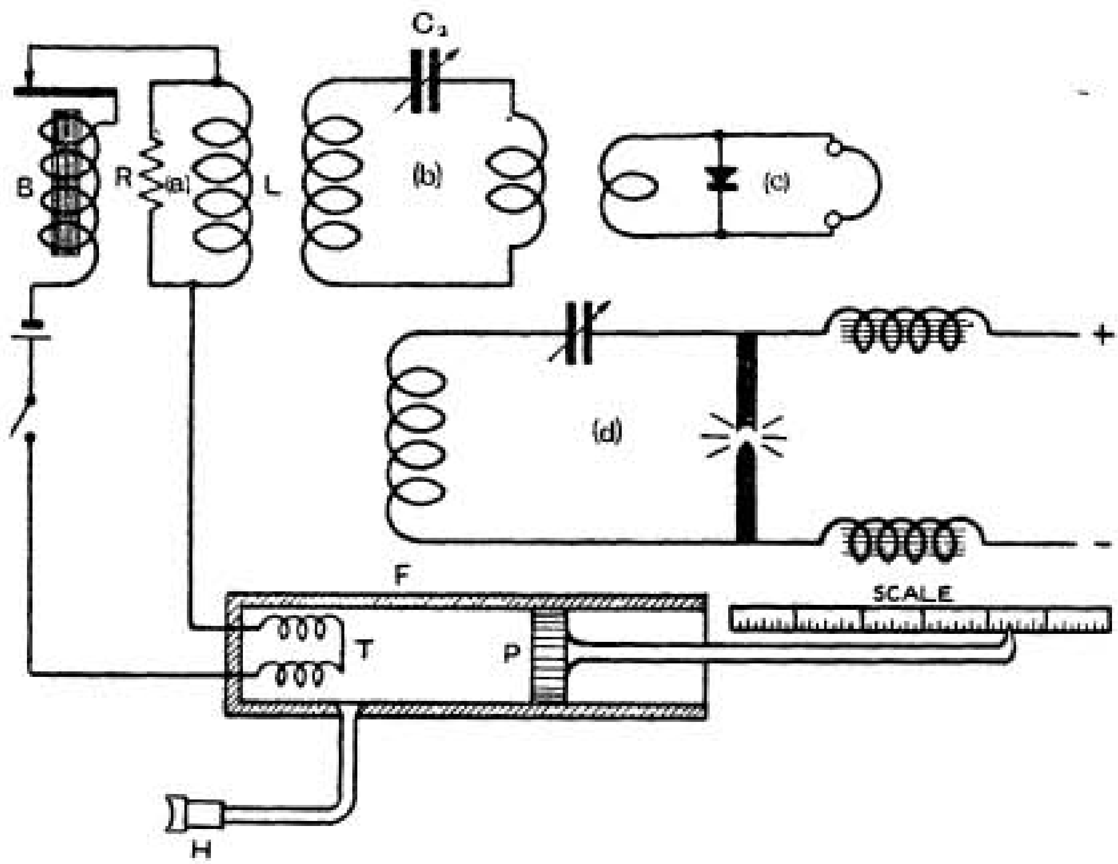

FIG. 1.

to natural frequencies ν_2 and ν_1 of circuit (b) it is shown that

$$\nu_1 = s \, . \, n \frac{1}{\left(\frac{\nu_2}{\nu_1} - 1\right)}$$

Thus the frequency for one setting of C_2 can be determined if $\frac{\nu_2}{\nu_1}$ is known.

It is found most convenient to make $\frac{\nu_2}{\nu_1}$ a whole number. This is done by adjusting a continuous wave generator (d)—arc or triode—so that ν_1 and ν_2 are the frequencies of known harmonics of the generator. The interrupter frequency is determined by measuring the wavelength of the sound wave emitted by a telephone T in the circuit. The telephone is fixed at the end of a tube F and the positions of the piston P for maximum sound intensity in the earpiece H are determined, from which the wavelength can be found. An accuracy of 0·5 per cent. is claimed.

329. THE CALCULATION OF THE SELF-INDUCTANCE OF MULTI-LAYER COILS. A. Esau. (*Jahrbuch der Drahtlosen Telegraphie*, 15, pp. 2—26, January, 1920.)

Unlike previous methods this is not based on the assumption of a uniform current distribution over the whole space occupied by the coil, but upon the self and mutual inductance of the several turns. The result is expressed in the form of $L = 4\pi rmn(S_1 + S_2)$ for a coil of m layers, each of n turns, and of mean radius r. S_1 and S_2 are complicated functions of r, m, n, the radius of the wires and the pitch of the turns. Tables and curves are given whereby S_1 and S_2 can be determined with sufficient accuracy for all practical purposes. With the help of numerical examples the new formula is compared with the previously known approximate formulæ of Maxwell, Perry, Weinstein and Stefan.

330. EXPERIMENTS WITH LOOP ANTENNÆ. C. L. Whitney. (*Radio Amateur News*, 1, p. 283, December, 1919.)

The experiments were carried out aboard ship about 600 miles from Nauen. Various shaped loops were tested, and best results were obtained on a triangular loop with apex vertical about 40 feet above the deck and with both ends earthed.

331. MEASUREMENT AND COMPARISON OF SIGNAL INTENSITIES IN WIRELESS RECEIVERS. H. de Bellescize. (*Revue Générale de l'Électricité*, 7, pp. 325-328, March 7th, 1920.)

A method of comparing the intensity of the signals from a distant continuous wave station with those of a local calibrated triode emitter is described. The local source is wholly enclosed in a Faraday cage F_1 (Fig. 2) with the exception of the coil J (of variable self-inductance) which is included in the oscillatory circuit of the triode emitter. The effect of J on the receiver

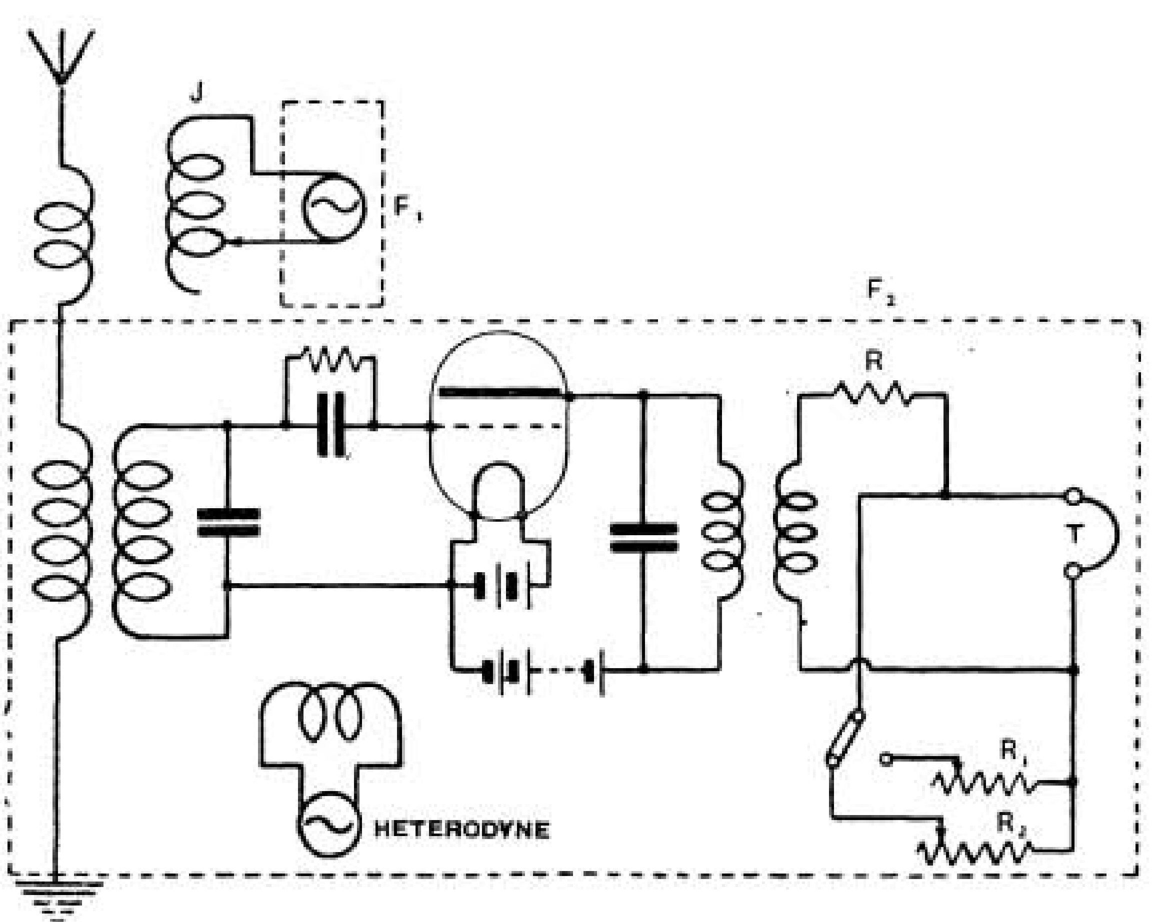

FIG. 2.

is proportional to the current I through the coil (I is found to be approximately proportional to the anode battery voltage).

A chronographic arrangement for alternating the signals of the distant station and of the local station (each being heard ten seconds at a time) is used. The final adjustment to equality is not made by altering the value of I but by means of non-inductive shunts R_1 and R_2 across the telephones T. If the values of these two shunts for the two cases of distant and local signals are respectively R_1 and R_2 and N is the number of turns of the coil J included in the oscillatory circuit of the local emitter, then the signal intensity I_x is given by $\kappa INR_2/R_1$ where κ is approximately constant. The resistance R is of the order of 2,000 ohms so that the variations of R_1 and R_2 make little variation in the total resistance of the telephone circuit. To reduce as much as possible the effect of external disturbances the receiver is enclosed in an earthed cage F_2.

A method of determining the amplifying power of any triode arrangement is described, the intensities of the signals being determined with and without the amplifying assembly included.

332. IMPROVEMENTS RELATING TO RADIOTELEGRAPHIC TRANSMITTERS. A. Taylor. (*British Patent* 135111, April 4th, 1919. Patent accepted, November 20th, 1919.)

In connection with the well-known method of controlling the output from an arc transmitter by short-circuiting with the sending key a loop of wire inductively coupled to the aerial circuit,* provision is made in the case of high power stations for the splitting up of this loop into a number of separate segments each arranged to be short-circuited by electromagnetically operated keys. For obtaining a definite group frequency for the transmitted waves interrupters may be connected in series or shunt with each pair of relay contacts.

333. TRANSMITTERS. A. Taylor. (*French Patent* 497798, April 3rd, 1919. Published December 17th, 1919.)

The specification describes a system of radiotelegraphic transmission. For further particulars, see British Patent No. 136059.†

334. RADIOTELEGRAPHIC TRANSMISSION SYSTEMS. A. Taylor. (*British Patent* 136059, March 25th, 1919. Patent accepted, December 11th, 1919.)

In a system of wireless signalling the emission of radiation from the aerial is controlled by an auxiliary circuit. In Fig. 3 the aerial is supplied by the arc A_1 fed from the D.C. generator G. The auxiliary circuit includes the condenser C, the inductance L and a winding L_1 on an iron core T. This iron

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* *Cf.* RADIO REVIEW Abstracts Nos. 114, 189.
† RADIO REVIEW Abstract No. 334.

core is also provided with a second winding L_2 through which direct current flows when the signalling key K is in the position of rest. This current is arranged to saturate the iron core and oscillations will then take place in the

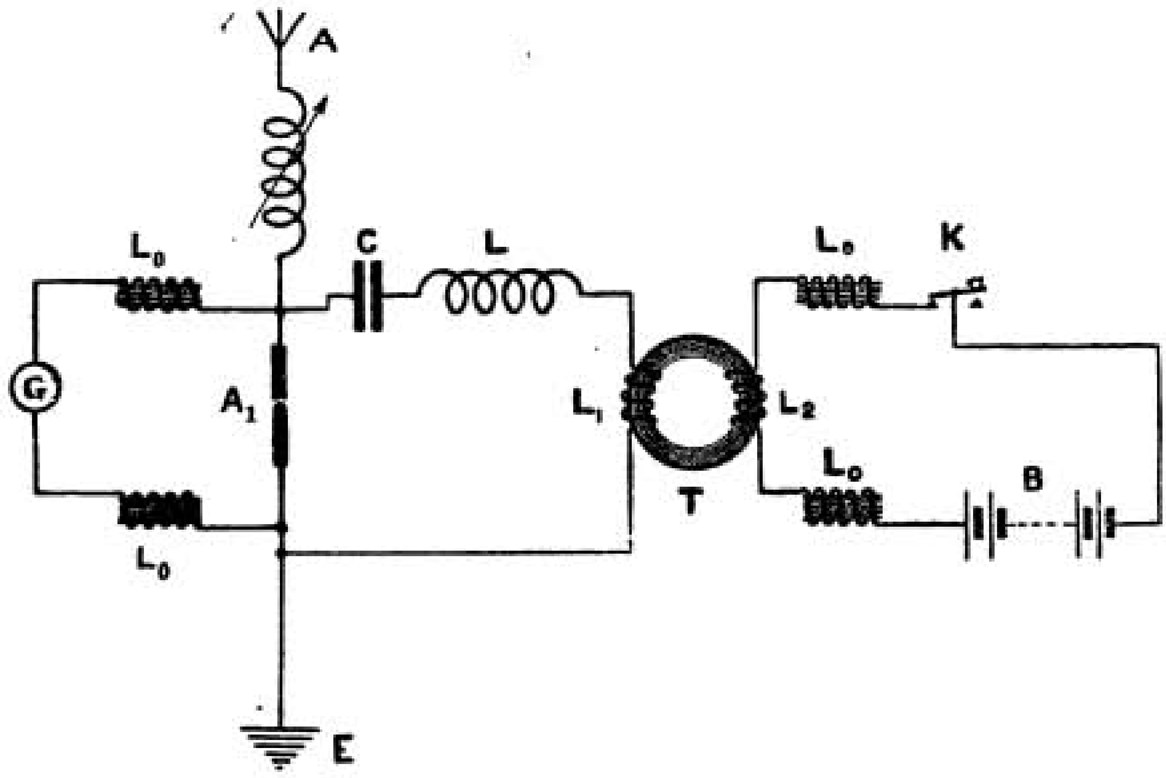

FIG. 3.

auxiliary circuit $C\,L\,L_1$ to the exclusion of the aerial circuit. When the key is pressed the direct current is interrupted and the large hysteresis loss which then occurs in the iron core chokes back the high frequency current from the auxiliary circuit. Choke coils L_0 may be inserted in the direct current circuit to prevent the flow of high frequency current in that circuit. The iron core may be water or oil cooled.

335. CONTINUOUS WAVE TRANSMITTERS. L. F. Fuller. (*French Patent* 496096, February 21st, 1919. Published October 25th, 1919.)

The invention described in this specification consists of an oscillation generator of the arc type. A cathode, for example of carbon, and an anode of less width than the cathode are both enclosed in a casing so that the arc may be produced in an atmosphere of hydrogen, and the poles of a magnet extend into the said casing to produce a magnetic flux in the gap between the anode and the cathode. The distance between the anode and the poles is greater than the distance between the cathode and the poles, and is also greater than the distance between the anode and the cathode.

336. INDUCTOR ALTERNATORS. E. F. W. Alexanderson. (*British Patent* 134830, October 28th, 1919. Convention date November 4th, 1918. Patent not yet accepted but open to inspection.)

Special constructional details for the inductor of an Alexanderson type high-frequency alternator are described in this patent. Two circumferential rows of radial slots filled with non-magnetic material are provided for.

337. IMPROVEMENTS IN FREQUENCY TRANSFORMATION. General Electric Company, U.S.A. (*British Patent* 134045, October, 1918. Patent accepted, October 29th, 1919.)

A radiotelephone transmitter is described using a high-frequency alternator as the source of oscillations. In Fig. 4, the current from the alternator G is deformed by the coil L_3 so that a higher harmonic may be used in the aerial

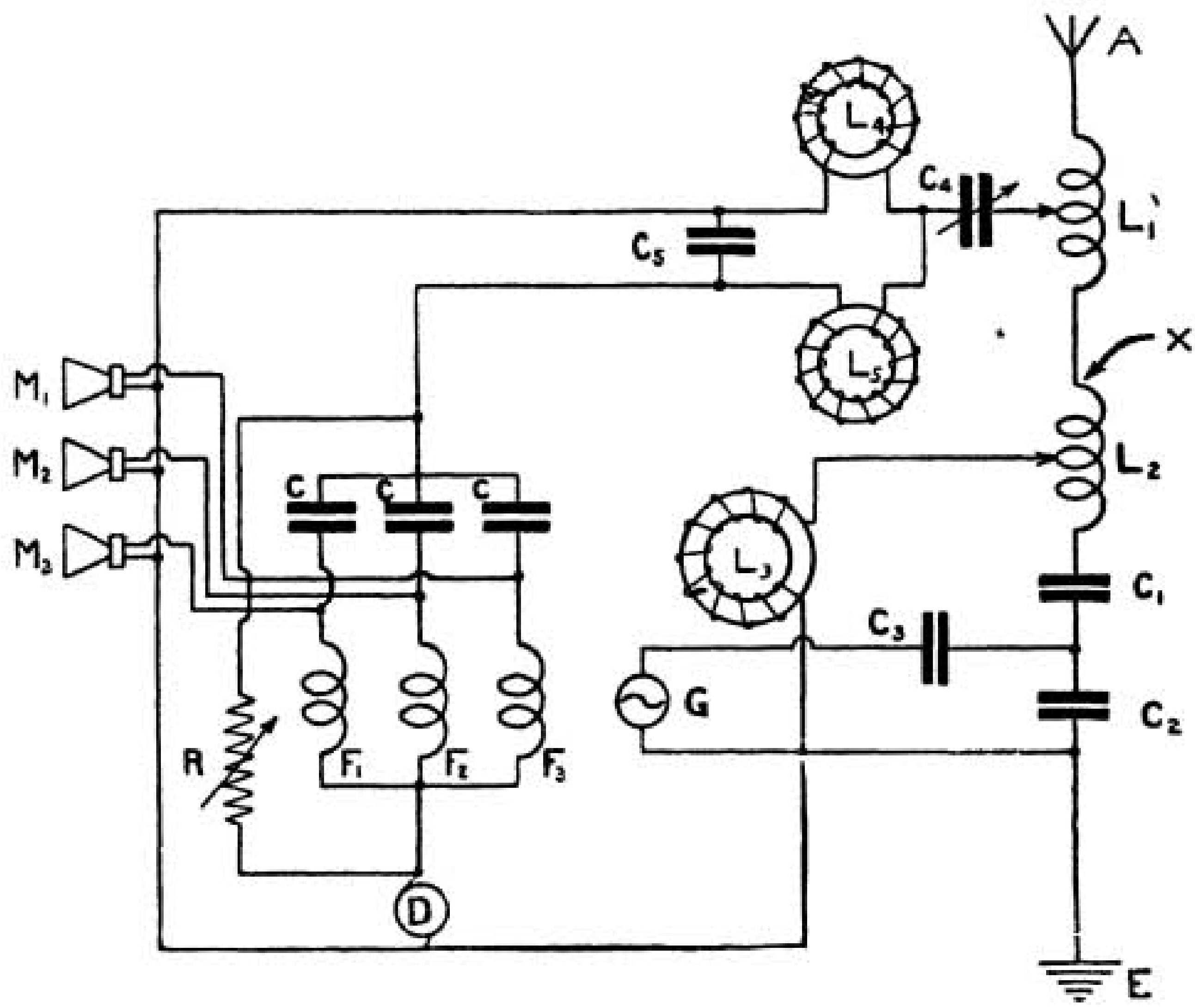

FIG. 4.

circuit. The condenser C_3 compensates for the internal inductance of the alternator G. Condenser C_2 compensates for the inductance of coil L_3, and condenser C_1 for that of L_2. In order to prevent current of fundamental frequency flowing in the aerial circuit the upper point X of the coil L_2 is arranged to be approximately at earth potential. The aerial circuit is tuned to the higher harmonic. For controlling the amplitude of the continuous wave radiation, multiple microphones M_1 M_2 M_3 (all under the influence of a single mouthpiece) are arranged as shown to modify the magnetic saturation of the iron core inductances L_4 L_5 which are supplied from the direct current generator D. These two inductances therefore act as a variable shunt to the aerial circuit. Condenser C_5 is arranged to offer a low impedance to the high-frequency currents. F_1 F_2 F_3 represent the divided field windings of the alternator G and serve mainly as steadying inductances in series with the microphones.

338. THE MODULATION OF HIGH-FREQUENCY OSCILLATIONS. Western Electric Company, U.S.A. (*British Patent* 133366, June, 1918. Patent accepted, October 16th, 1919.)

A wireless telephone transmitter is arranged so that the modulation current from the microphone M (Fig. 5) is amplified by the valve V_1 which

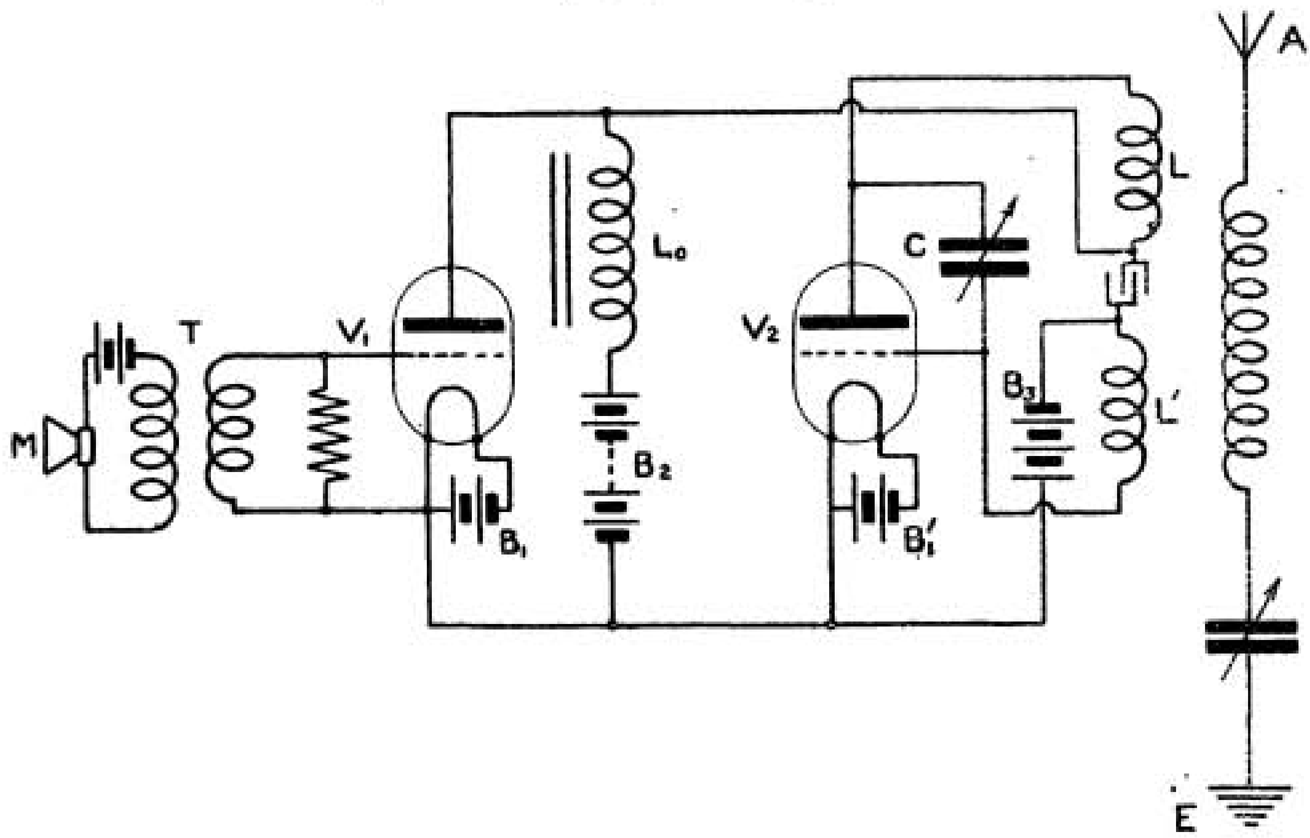

FIG. 5.

is joined across the high tension battery B_2 and the choke inductance L_0 which form part of the plate circuit of the oscillation generating valve V_2. The voltage supply to the plate circuit of the generating valve V_2 is thus varied in accordance with the speech signals from M. The circuits of V_2 for generating the oscillations may be arranged in the well-known manner indicated—L L′ C being the oscillation circuit.

339. LIQUID MICROPHONES. S. G. Brown. (*British Patent* 134865, August 13th, 1918. Patent accepted, November 13th, 1919.)

In one form of the liquid microphone described in this specification, the containing vessel is divided horizontally into two portions by an insulating barrier. The centre of this insulating partition is pierced with a small hole over which a valve is arranged in such a manner that the effective opening between the two parts of the containing vessel is varied by the motion of the diaphragm to which the valve is coupled. In Fig. 6, A is the containing vessel, D the diaphragm, B the insulating partition, H the small hole through this partition and V the valve connected as shown to the diaphragm, D. E_1 and E_2 are the two electrodes of the microphone. Other modifications are described in the original—in one of these the diaphragm forms one wall of a narrow passage through which the electrolyte passes, so that its effective cross sectional area is varied by the motion of the diaphragm.

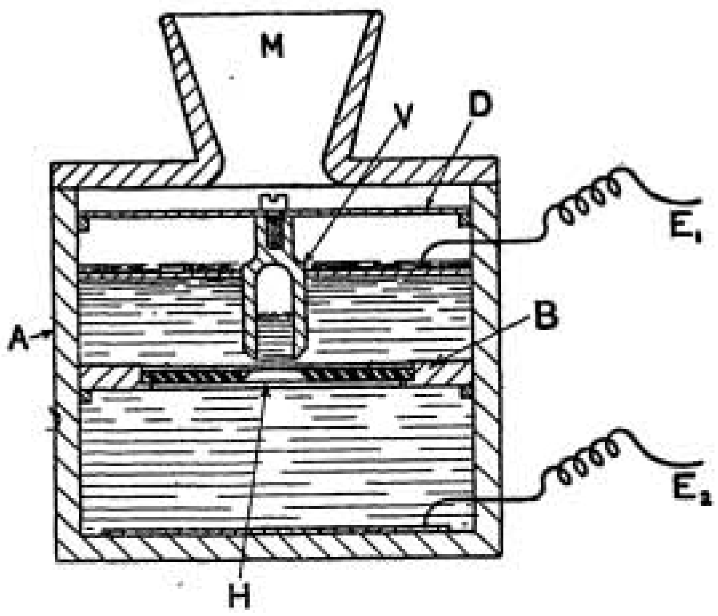

FIG. 6.

340. APPARATUS FOR CONTROLLING ELECTRICAL ENERGY IN SIGNALLING SYSTEMS. C. D. Ehret. (*British Patent* 134725, February 20th, 1919. Patent accepted, November 13th, 1919.)

One of the arrangements described is illustrated diagrammatically in Fig. 7. The microphone M is arranged to control the output of the valve

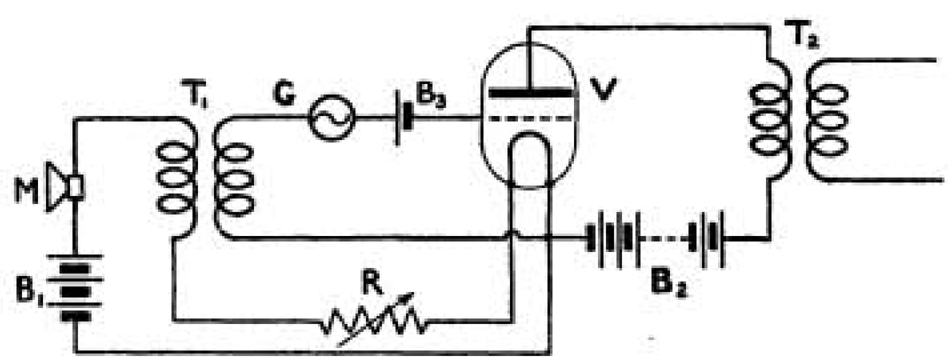

FIG. 7.

amplifier V by controlling simultaneously its grid potential (through the transformer T_1) and its filament current. In the arrangement indicated no reaction is provided between the plate and grid circuits in order to cause the valves to set up oscillations, but a source of high frequency fluctuating or alternating current is impressed upon the grid circuit at G. Various other modifications of this idea are described, including a very similar arrangement suitable for use when reaction coupling in the valve is employed.

341. TELEPHONE TRANSMITTERS. E. S. Pridham and P. L. Jensen. (*British Patent* 133365, June, 1918. Patent accepted, October 16th, 1919.)

Telephone transmitters for use on aeroplanes and in other noisy situations have their diaphragm exposed on both sides to the noise vibrations, whereas the speech vibrations act only on one side. By suitably adjusting the distance between the instrument and the speaker's mouth the effect of the undesired noises may be reduced to a minimum.

342. TELEPHONE TRANSMITTERS. A. Marr. (*British Patent* 133527, November 1918. Patent accepted, October 16th, 1919.)

The constructional features are described of a telephone transmitter in which the vibrations of the diaphragm are transmitted to the movable electrode of the microphone through a confined layer of air.

343. TELEPHONE TRANSMITTERS. E. M. C. Tigerstedt. (*British Patent* 135183, November 10th, 1919. Convention date November 8th, 1918. Patent not yet accepted but open to inspection.)

In one of the forms of microphone transmitter described, the electrodes are in the form of circular discs between which are placed layers of insulating cloth. The discs are connected alternately to the two terminals of the instrument. The edges of the disc are surrounded by a thin layer of granular microphonic material held against the electrodes by a flexible covering which is operated upon by the speech waves, so as to vary the pressure upon the granules. Other modifications are described, for example one in which the electrodes are in the form of annular rings separated from one another by the insulating cloth and with the layer of granules pressing against one set of edges of the rings.

344. TELEPHONE TRANSMITTERS AND RECEIVERS. Western Electric Company, U.S.A. (*British Patent* 134872, September 20th, 1918. Patent accepted, November 13th, 1919.)

In order to increase the natural period of vibration of the diaphragm of a telephone transmitter or receiver, or of similar acoustic apparatus, a broad flat surface is rigidly mounted at a distance of not more than 2½ mils. (0·0025 inches) behind the vibrating diaphragm. The layer of air between the diaphragm and the flat surface increases the damping of the diaphragm.

345. WIRELESS TELEPHONY. A. Meissner. (*Telegraphen- und Fernsprech-Technik*, 8, pp. 45—48, July, 1919.)

A brief review of the subject, more especially of methods used by the Telefunken Company. As generators of the high-frequency current alternators can be used for large powers and large wavelengths, arcs and valves for medium and small powers. The arc can only be used for waves above 2,000 metres. The future belongs to the thermionic valve. The precautions necessary to make a number of microphones work in parallel are described. The microphone current can be made to affect the iron of the frequency doubling transformers inserted between the alternator and the aerial (diagram given in original). Two methods of using thermionic generators are described, one suitable for small powers with the microphone in the aerial, and the other for large powers with the microphone acting on the grid. A three valve amplifier is shown for insertion between the receiving end of a telephone line and the control of the wireless transmitter. Two-way working by means of two separated aerials tuned to slightly different frequencies is discussed.

346. IMPROVEMENTS CONNECTED WITH THE VALVES OF WIRELESS TRANSMISSION SYSTEMS. C. E. Hiatt. (*British Patent* 131668, July, 1918. Patent accepted, September 4th, 1919.)

A special arrangement of spring is described for maintaining the tension on the filaments of valves. The spring is constructed of platinum-coated nickel steel and should be freed from gas in the same manner as the other parts of the valve.

347. IMPROVEMENTS RELATING TO THE MANUFACTURE OF ELECTRICAL VALVE TUBES. L. Robinovitch. (*British Patent* 131670, July, 1918. Patent accepted, September 4th, 1919.)

To improve the vacuum some or all of the metal parts are provided with a film of oxide or other compound with the metal of which the parts are constructed, or with a film of gas capable of chemical combination with such parts. The plate or grid may, for instance, be heated in oxygen, dry air, chlorine, sulphur dioxide, or it may be electrolytically coated with a film of oxygen in dilute acid or with chlorine in brine. After sealing off the tube, the anode is again brought to a dull red heat for a few seconds. Prolonged ageing to remove the residual gas is unnecessary.

348. VACUUM TUBES. C. E. Hiatt. (*British Patent*, 133181, October, 1918. Patent accepted, October 9th, 1919.)

The grid and anode of a vacuum tube for use in wireless consist of wires stretched across the tube and anchored into the walls by fusion of the glass.

349. THE CONSTRUCTION OF VACUUM TUBES. R. S. Hawkins. (*Radio Amateur News*, 1, pp. 278—279, December, 1919.)

A general description of the manufacturing methods of vacuum tubes particularly of the Moorehead Tube.

350. IMPROVEMENTS IN ELECTRICAL DISCHARGE DEVICES. Cutler-Hammer Manufacturing Company, U.S.A. (*British Patent* 133783, October 1918. Patent accepted, October 17th, 1919.)

This patent deals with a particular construction of three-electrode vacuum tube with double flat anodes. The grid electrode consists of a fine wire closely wound over two transverse springs mounted in the plane of the filament, the grid wires being held out on each side of the filament by one or more flexible transverse wire bridges. The grid wire should be fine and closely wound.

351. IMPROVEMENTS IN THREE-ELECTRODE VACUUM TUBES. J. Erskine-Murray. (*British Patent* 133413, October, 1918. Patent accepted, October 6th, 1919.)

The particular feature of the valve described is the arrangement of the position of the grid electrode, so that an increase in its potential causes a decrease in the current passing between the anode and cathode, and *vice versa.*

352. OSCILLATION CHARACTERISTICS OF THREE-ELECTRODE LAMPS USED AS GENERATORS OF SUSTAINED OSCILLATIONS. A. Blondel. (*Comptes Rendus*, 169, pp. 676—680, October, 1919.)

The ordinary method of studying the oscillations set up by 3-electrode valves based on a consideration of the straight part of the characteristics does not take into account the limitation of the amplitude of the oscillations by the curvature of the characteristics. The author shows that a more general method of treatment may be based upon the "oscillation characteristics" of the valve, and it is shown how the ordinary static curves may be transformed graphically to give the dynamic curves. These curves are preferably plotted with plate current as abscissæ and plate voltage as ordinates thus resembling the dynamic characteristics of oscillating arcs.

If U_1 = the normal plate voltage without oscillations,
V_1 = the normal grid voltage without oscillations,
I_1 = the normal plate current without oscillations,

these three values determine the co-ordinates of one point upon the complete system of curves for the valve. If then the establishment of oscillations causes a variation i in the plate current (this variation being approximately sinusoidal), there will be a corresponding variation u in the potential at the terminals of the plate circuit. By reason of the reaction provided between the plate and grid circuits this change u will give rise to a voltage variation v which will be superimposed upon the steady voltage V in the grid circuit. Hence a new point upon the "oscillation characteristic" has co-ordinates of $(I_1 + i)$, $(V_1 + v)$, and $(U + u)$. By giving various values to i throughout the cycle, the complete curve may be delineated.

Three cases are considered in the paper :—

I. Inductive coupling, for which $v = -au = -(M/L)u$ where M = the mutual inductance between plate and grid circuits and L = inductance in plate circuit, at the terminals of which the voltage variation u takes place—assuming that the resistance of L is negligible. a = a constant of proportionality = M/L in this case.

II. Resistance or "potentiometric" coupling in which the grid voltage is derived from the change in p.d. at the terminals of a resistance in the plate circuit.*

For this case $v = + bi$, where b is some constant.

III. The general case for which $v = \phi(u, i)$ including the special case which combines I. and II. for which the function ϕ is linear—viz., $v = + au + bi$.

353. THEORY OF THE OPERATION OF THE AUDION DETECTOR. F. Carbenay. (*Revue Générale de l'Électricité*, 6, pp. 579—583, November, 1919.)

A mathematical article dealing particularly with the use of a triode valve as a detector of high-frequency oscillations. The sections covered by the paper are as follows :—

(1) The semi-empirical equations of the valve.
(2) Arrangement of audion detector and equation of the grid potential.
(3) Reception of trains of sustained waves.
(4) Reception of wave trains of any type.
(5) The use of an auxiliary oscillation generator (heterodyne).
(6) Low-frequency power output in the plate circuit.
(7) The response (output) of the audion detector.

354. A SIMPLIFIED THEORY OF THE VALVE AMPLIFIER. E. Mallett. (*Post Office Electrical Engineers' Journal*, 12, pp. 134—137, October, 1919.)

The theory given is based on the assumptions that over the range used, the plate current—grid voltage, and plate current—plate voltage curves, are straight lines. The author then shows that the total change in plate current is the sum of the changes due to the voltage impressed on the grid and to the consequent changes in plate voltage. Hence the voltage amplification is $\frac{\mu Z}{R_0 + Z}$, where $\mu = \frac{\tan\theta}{\tan\phi} = \frac{\text{slope of grid voltage—plate current curve}}{\text{slope of plate voltage—plate current curve}}$, R_0 = the internal impedance of the valve, and Z = external plate-circuit impedance.

355. THE DESIGN OF MULTIPLE-STAGE AMPLIFIERS. C. L. Fortescue. (*Electrical Review*, 85, pp. 700—701, November 1919.)

See RADIO REVIEW, 1, pp. 83—88, 134—143.

356. THE MEETING OF THE BRITISH ASSOCIATION : DISCUSSION ON THERMIONIC VALVES. (*Electrician*, 83, pp. 306—307. *Electrical Review*, 85, pp. 380—382, September, 1919. *Engineering*, 128, p. 357, Abstract. *Radio Review*, 1, p. 26—38, October, 1919.)

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* See also RADIO REVIEW Abstracts Nos. 236 and 237.

357. Triode Amplifications and Detector Sensitivity. A. Press. (*Electrician*, 84, pp. 35—36, January 9th, 1920.)

This article is designed to remove the confusion between the formulæ used by L. B. Turner* and those employed in discussions at the Institute of Radio Engineers. Formulæ for the potential and current magnifications, and for the detector sensitivity, are evolved from the relation $i_a = f(v_a, v_g)$. [i_a = anode current, v_a = anode voltage, and v_g = grid voltage.] It is shown that the potential magnification is given by

$$\frac{dv_a}{dv} = \frac{-R_g}{1 + R/\Omega} = -\frac{R\frac{\partial i_a}{\partial v_g}}{1 + R\frac{\partial i_a}{\partial v_a}}$$

where R = resistance in anode circuit, R_g = resistance in grid circuit, and $\frac{1}{\Omega} = \partial i_a/\partial v_a$ = the internal plate-filament conductance determined with v_g constant. The current amplification is given by $\frac{di_a}{di_g} = \frac{g\omega}{1 + R/\Omega - R\omega gg'}$, where ω = the internal grid-filament resistance determined with v_a constant, $g = \partial i_a/\partial v_g$ = mutual conductance, and $g' = \partial i_g/\partial v_a$ = the conjugate mutual conductance, and is much smaller than g. The detector sensitivity, $G = di_a/dv_g = -\frac{R_g}{\Omega}\cdot\frac{1}{1+R/\Omega} + g = \frac{g}{1+R/\Omega}$.

358. Waveform obtained from the Aluminium Rectifier. N. H. Williams and J. M. Cork. (*Electrical World*, 74, pp. 937—938, November, 1919.)

The use of several rectifying cells in series, to enable voltages up to 2,200 to be rectified, is dealt with in this article. Some oscillograms are given of the waveforms of the voltage and current showing the smoothing effect of capacity in parallel with the D.C. load, and of inductance in series with the load. The special arrangement of double rectifier and smoothing condenser indicated in Fig. 8 is also described. This arrangement is attributed to Schultz and it enables D.C. voltages to be obtained up to about two and a half times the R.M.S. alternating voltage.†

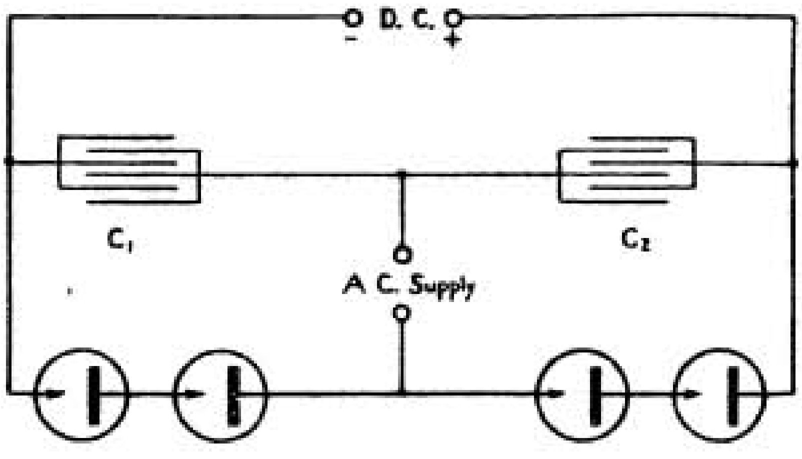

Fig. 8.

* *Electrician*, 83, pp. 4—5, 34—35, July 4th and 11th, 1919.

† An analogous arrangement using valve rectifiers was described in Radio Review Abstract No. 119.

359. WIRELESS DIRECTION FINDING. N. P. Hinton. (*British Patent* 134644, November 22nd, 1918. Patent accepted, November 13th, 1919.)

The direction of a wireless transmitting station is determined by employing three, five, or more immovable directive aerials and comparing signals received when the aerials are connected in series in various orders, or when the aerials are placed in circuit singly in turn. The arrangement particularly described has three aerial systems crossing one another at angles of 60°. These may either be joined up in series in various combinations or any one of the three may be connected in turn to the receiving apparatus. The circuit of the three aerials is completed through the movable coil of a special type of radiogoniometer having the same number and arrangement of fixed windings as there are receiving aerial systems. These fixed windings are connected to the receiver proper, and they are arranged in the same combination as are the external aerials. The change over of the connections for the various combinations is effected simultaneously for the aerial systems and for the radiogoniometer coils. In taking a reading of direction the two aerials which give the loudest signals are used and the connections are changed over from one to the other while the position of the radiogoniometer search coil is adjusted until equal intensity of signal strength is obtained in the two positions. The pointer attached to the moving coil then indicates the direction of the waves.

360. THE U.S. NAVY RADIO COMPASS. (*Everyday Engineering Magazine*, 8, pp. 109—111, November, 1919.)

This article describes in general terms the directive action of a loop aerial, and then gives the combined antenna and loop aerial arrangement used to obtain the absolute direction instead of two alternative directions as given by the simple loop. In Fig. 9 A_1 is an ordinary elevated aerial and A_2 is a frame aerial inserted in the tuned secondary circuit coupled to A_1. V is

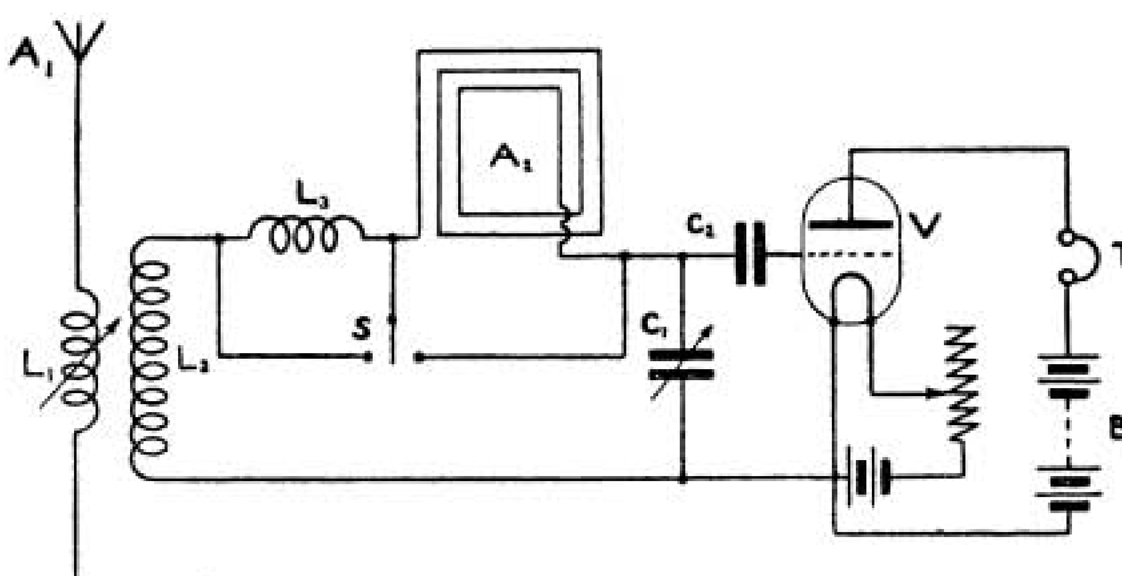

FIG. 9.

any usual form of valve detector. The inductance L_3 is made equal to that of A_2, so that the wavelength of the circuit L_2 C_1 remains unchanged when the loop is cut out of this circuit by the switch S. Signals are first picked up on A_1 and carefully tuned with A_2 cut out. The loop A_2 is then inserted in the circuit, and the absolute direction determined approximately. The ordinary aerial A_1 is then cut out and the directional line of the incoming waves determined exactly, using the sharper minimum positions on the receiving loop. Further details are to follow in a subsequent article.

361. HOW AEROPLANES ARE NAVIGATED BY WIRELESS. R. Keen, (*Wireless World*, 7, pp. 389—393, October, 1919.)

An elementary description of the use of the radiogoniometer, and of D.F. working between aircraft and ground stations.

362. ON THE GONIOMETRIC FUNCTIONS APPLICABLE TO DIRECTIVE AERIALS. A. E. Blondel. (*Radio Review*, 1, pp. 1—10; 58—66; 110—123, 1919.)

363. THE TRANSMISSION OF ELECTROMAGNETIC WAVES AROUND THE EARTH. G. W. O. Howe. (*Radio Review*, 1, pp. 78—80, November, 1919.)

364. RADIOTELEGRAPHIC INVESTIGATIONS—REPORT OF BRITISH ASSOCIATION COMMITTEE. (*Electrician*, 83, pp. 311—312, September, 1919. *Radio Review*, 1, pp. 24—26, October, 1919.)

365. THERMIONIC AMPLIFIERS. Siemens and Halske, Akt.-Ges. (*British Patent* 134832, October 30th, 1919. Convention date May 22nd, 1918. Patent not yet accepted but open to inspection.)

When several amplifying valves are used to form a cascade amplifier with the filaments connected in series, provision is made for suitably determining the grid potential of each valve by connecting the grids to different points on the common filament battery, or to different points on a potentiometer resistance shunted across that battery.

366. REMARKABLE AMPLIFICATION. (*Scientific American*, 121, p. 457, November, 1919.)

Mentions the use of 19-stage multivalve amplifiers by the British Navy for intercepting buzzer signals over long distances.

367. IMPROVEMENTS RELATING TO AMPLIFYING APPARATUS. M. Latour. (*British Patent* 132668, November, 1917. Patent accepted, September 25th, 1919.)

An addition to British Patent No. 130103. In the multivalve amplifier described, the plate circuits are supplied from a common high tension source B_2 (Fig. 10) and two of the valves are used for amplifying both the high and the low-frequency currents. The incoming signal is supplied to terminals T, T and is amplified by the valves V_1, V_2, V_3 which are connected together through high-frequency transformers T_1, T_2. V_4 serves as a detector and its low-frequency output circuit is joined in series with the grid circuit of valve V_2 through low-frequency transformer T_5 and the secondary winding of T_1 as indicated. The low-frequency current is thus further amplified by V_2 and V_3 coupled by the low-frequency intervalve transformer T_3, and finally led to terminals T′, T′. The windings of T_3 are shunted by condensers as shown in order to provide a bye-path for the high-frequency currents which are passed from V_2 to V_3 through the high-frequency transformer T_2.

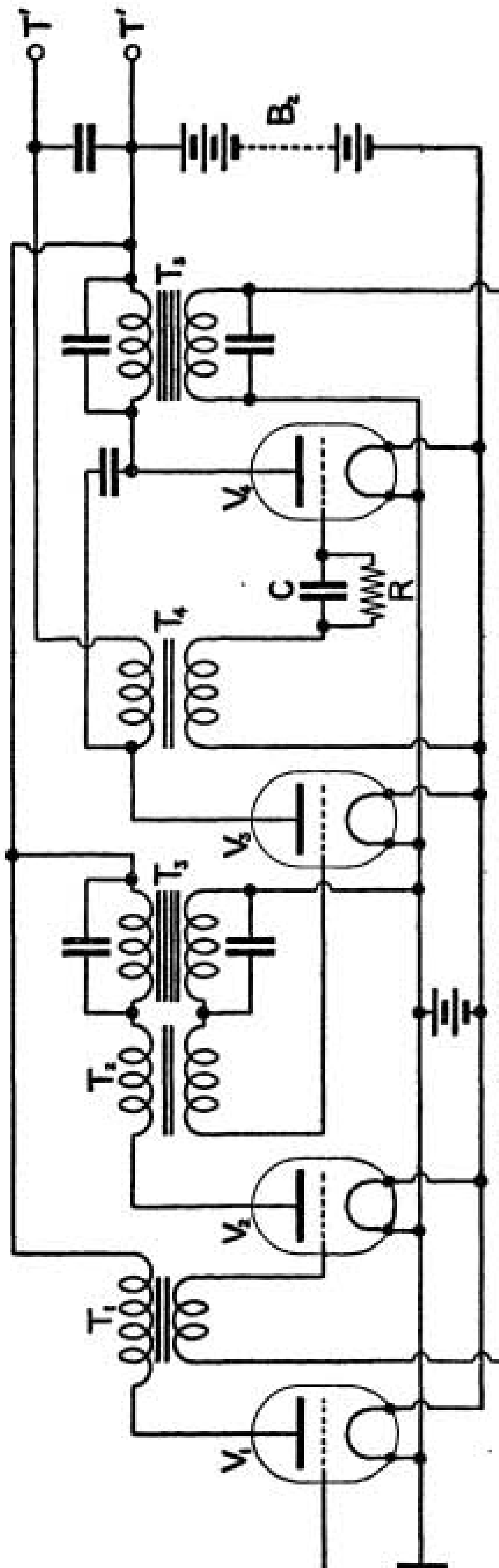

FIG. 10.

368. A THERMIONIC AMPLIFIER FOR LOW-ANODE VOLTAGES. E. Rüchardt. (*Jahrbuch der Drahtlosen Telegraphie*, 15, pp. 27—39, January, 1920. *Technical Review*, 6, p. 225, March 2nd, 1920.)

A record of some extremely interesting experiments carried out at Würzburg under the direction of W. Wien for the Army and Navy authorities, with the object of designing an amplifier which would operate with an anode voltage of 10 volts or less. In one form the filament is placed between two parallel plates about 2 mm. apart one acting as anode and the other as grid. With an anode voltage of 10 the steepness of the characteristic was only 0·6 of that of a normal 90 volt amplifier and gave only 0·4 to 0·5 of the amplification. Attempts to bring the control electrode nearer the filament introduced difficulties owing to the distances changing when the supports became heated. This led to several new types of construction being tried. Fig. 11 represents the form finally adopted; the filament is held taut between two springs of coppered steel wire which act as leads. The anode and control plate are angle plates carried on the glass stem. In Fig. 12, curve 1

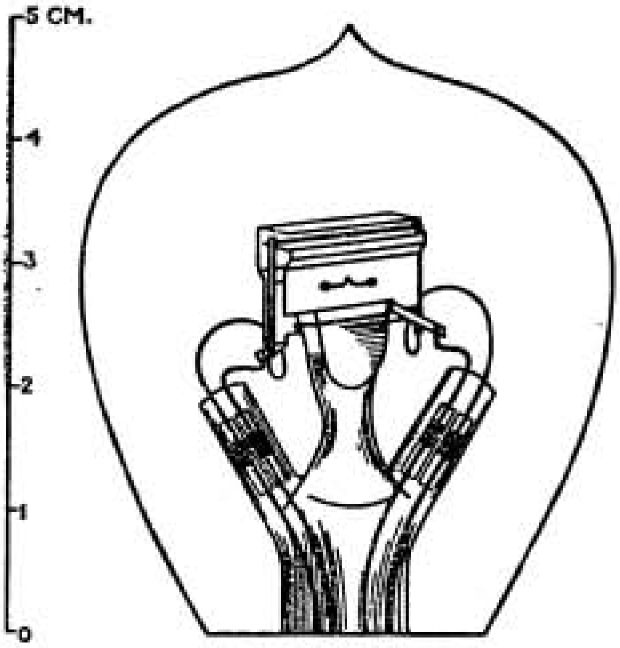

FIG. 11.

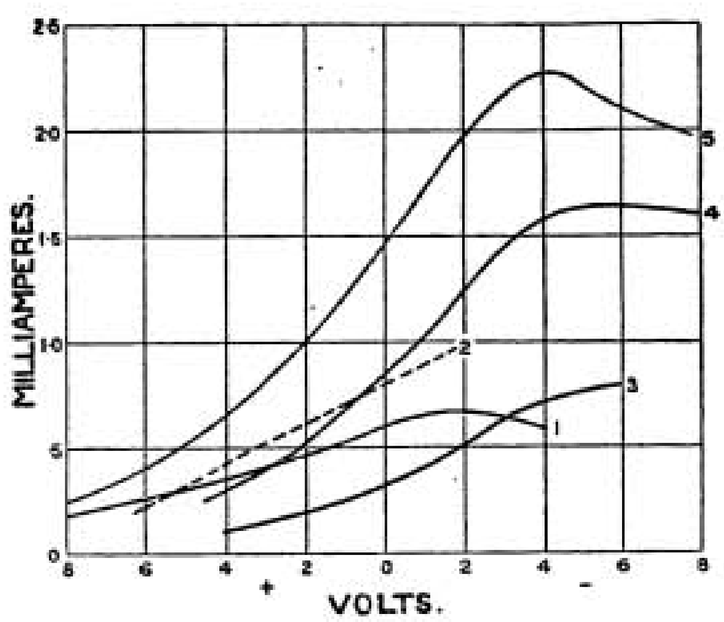

FIG. 12.

refers to the earlier type mentioned above, curve 2 (dotted) shows the normal steepness of a 90 volt amplifier and curves 3, 4 and 5 are the characteristics of the new type at voltages of 6·5, 13 and 20 volts respectively. Many of the troubles were traced to bad tungsten filaments and were overcome by using the so-called crystal wire made by Pintsch. With inferior filaments good results were only obtained by overrunning the filament.

The steepness of the characteristic is greater than in the 90 volt case, in one case three times as steep, but the internal resistance is much lower, viz., about a tenth, that is $\partial I_a/\partial E_g$ is greater, and $\partial E_a/\partial I_a$ is much less, and therefore the voltage amplification $\partial E_a/\partial E_g$ is less than in the ordinary case.

Several connections are given for two valve amplifiers, and some experiments over a range of frequencies (400 to 1,100) showing resonance effects at 600 to 800.

369. A HETERODYNING WAVEMETER. J. Scott-Taggart. (*Electrician*, 83, p. 243, September, 1919.)

A description is given of the usual type of C.W. wavemeter containing an oscillating valve, with telephones in the anode circuit. Measurements are made by adjusting the instrument until the beat frequency obtained by the interference of the wavemeter oscillations with the oscillations to be measured, becomes zero. The required wavelength is the midpoint of the silent or "dead" space.

370. HETERODYNE RECEPTION. H. Salinger. (*Physikalische Zeitschrift*, 20, pp. 488—490, November, 1919.)

This method is not suited to the determination of the component oscillations in the received wave, since, owing to the curved characteristic of the detector, various combination tones arise so that audible beats are obtained even when the two composed oscillations are pure harmonics of very different frequencies if one is a multiple of the other. Thus if the received signal has $\lambda_1 = 8750$ metres, then audible notes are obtained when the superposed oscillation has the following wavelengths, $\lambda_2 = 1675$—1750; 2060—2190; 2750—3000; 3900—4600; 7500—10400 metres. In the experiments filters were used to ensure purity of the oscillations.

371. IMPROVEMENTS RELATING TO WIRELESS SIGNALLING SYSTEMS. General Electric Company U.S.A. (*British Patent* 134585, October 4th, 1918. Patent accepted, November 4th, 1919.)

In order to minimise the effect of static disturbances on the receiving instruments, amplitude pulsations of inaudible frequency are produced either by the generation in the transmitting aerial of oscillations of two frequencies, or by supplying the second frequency from a local source at the receiving station. The currents of inaudible frequency are accumulated in a resonant circuit at the receiving station, and are detected by heterodyning from a low frequency generator or otherwise. In the transmitting arrangement described, the output of a high frequency alternator is controlled by two magnetic modulators of the Alexanderson type through which alternating currents are sent of frequencies of the order of 5,000~. The windings of these modulators are so arranged that during one half cycle the reactance of one of them is a minimum and that of the other is a maximum. The aerial is doubly tuned to two frequencies namely, the main oscillation frequency ± the local oscillation frequency (which in this case is taken as 5,000).

The Fig. 13 indicates an arrangement of receiving apparatus with a

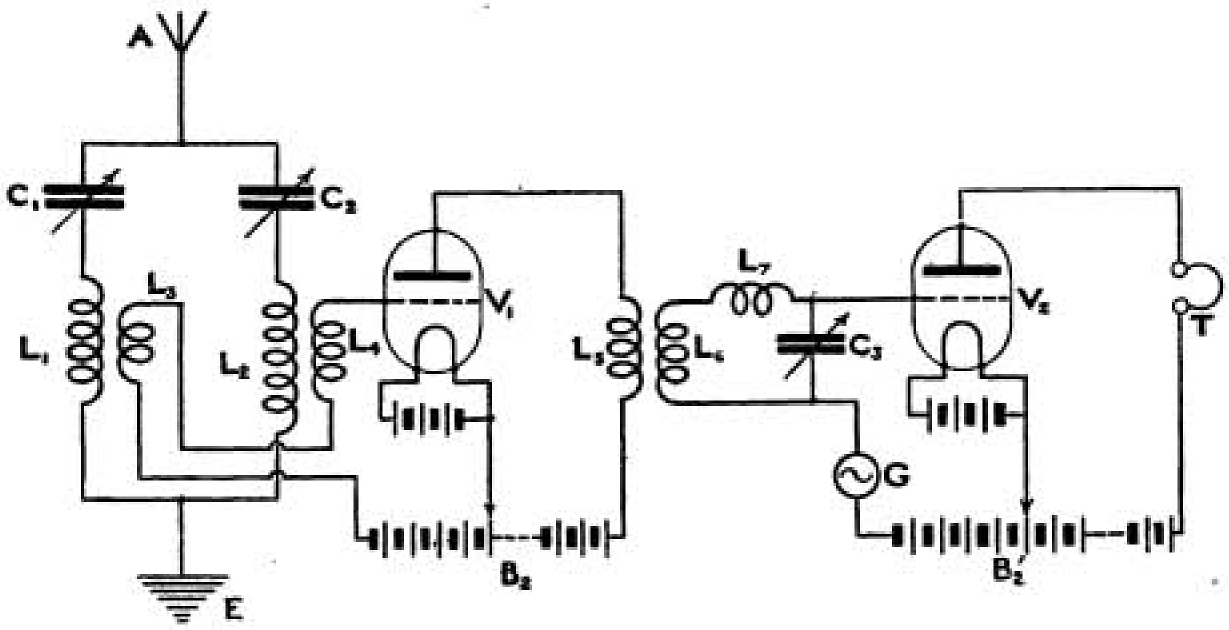

FIG. 13.

doubly tuned aerial suitable for picking up the wave emitted from a transmitter of the above type. The two branches of the aerial circuit C_1L_1 and

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C_2L_2 are tuned respectively to the two frequencies. The valve amplifier V_1 magnifies the pulsations of inaudible frequency and the circuit $L_6L_7C_3$ is tuned to this frequency. The oscillations are heterodyned by the local generator G of slightly different frequency to the difference between the two frequencies emitted by the transmitter and are then detected by the valve V_2 and the telephones T. Alternatively a highly damped or aperiodic aerial circuit may be used in place of the branched doubly-tuned aerial indicated in the figure. Fig. 14 indicates an arrangement of receiving apparatus adapted

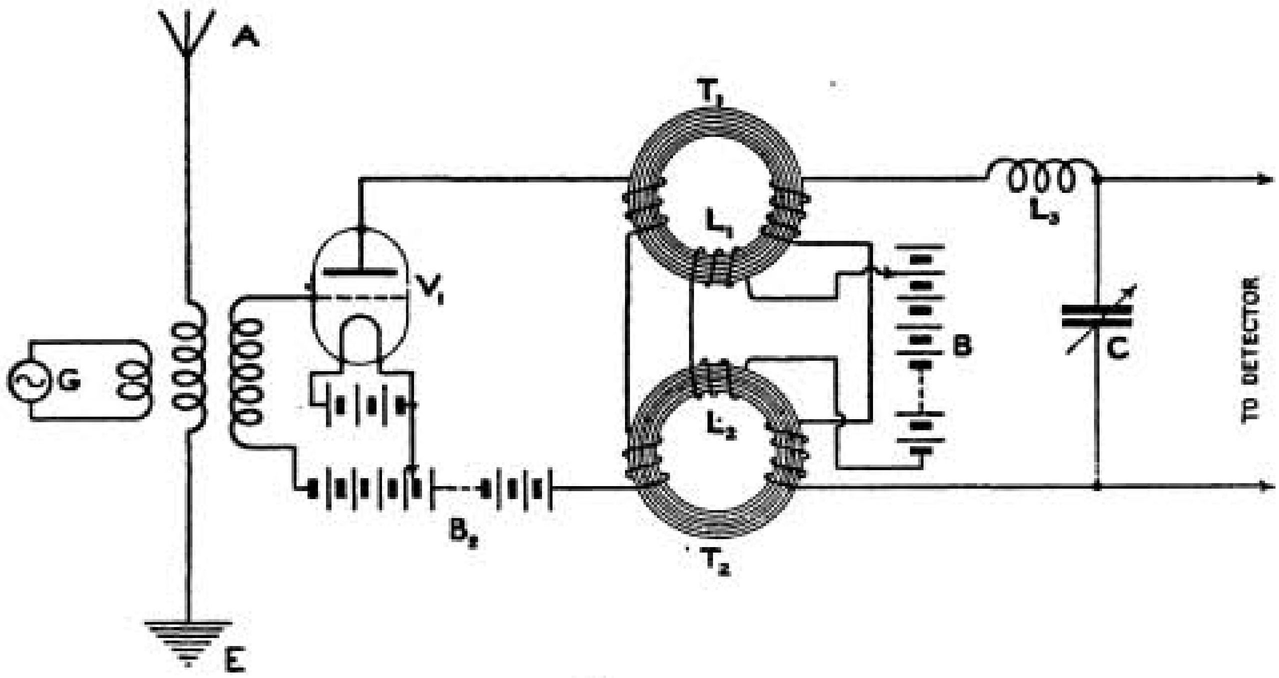


FIG. 14.

to receive waves of a single radio frequency only, the amplitude pulsations of inaudible frequency being produced by beats with a local high-frequency generator G. The circuit L_3C is partly screened from the effects of static disturbances by the inter-position of the two iron-cored transformers T_1T_2 which are provided with regulating windings L_1L_2 excited from a battery B. These transformers serve to limit the voltage that can be transmitted to the circuit L_3C as excessive shocks due to atmospherics produce saturation in the iron cores. Other slight modifications are also described in the original.

372. TRANSMITTERS. Compagnie Française pour l'Exploitation des Procédés Thomson-Houston. (*French Patent* 497446, March 22nd, 1919. Published December 5th, 1919.)

The invention relates to systems for generating oscillations. For further particulars, see British Patent No. 134585.*

373. WIRELESS SIGNALLING. Siemens and Halske, Akt.-Ges. (*British Patent* 135177, November 7th, 1919. Convention date June 18th, 1918. Patent not yet accepted but open to inspection.)

The arrangement described is shown diagrammatically in Fig. 15. The

* RADIO REVIEW Abstract No. 371.

incoming oscillations from the aerial circuit AL_1E are heterodyned to a supersonic beat frequency by the local source of oscillations H which is

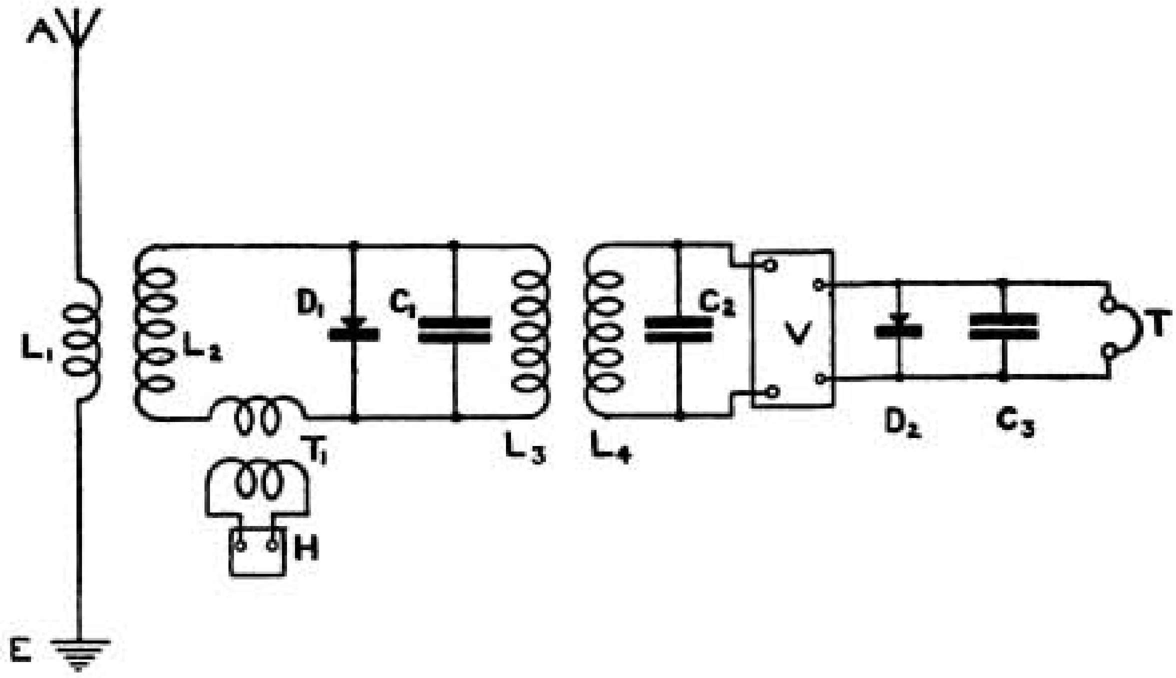


FIG. 15.

coupled to the secondary circuit L_2D_1 by the small transformer T_1. The supersonic beat currents are rectified by the detector D_1 and pass through the tuned circuits C_1L_3 and C_2L_4 to the amplifier V. Amplified supersonic beat currents are rectified by the detector D_2 and are thence passed to the receiving telephones T.

374. WIRELESS RECEIVING APPARATUS. E. F. W. Alexanderson. (*British Patent* 133965, October, 1918. Abridgment published December 17th, 1919.)

This receiver is particularly arranged for detecting signals from one station and at the same time cutting out signals from a second (interfering) station. The essential features are the use of aperiodic horizontal aerials each connected to a phase rotator consisting of two branches in parallel, through one of which the current lags and through the other it leads with respect to the impressed E.M.F. The

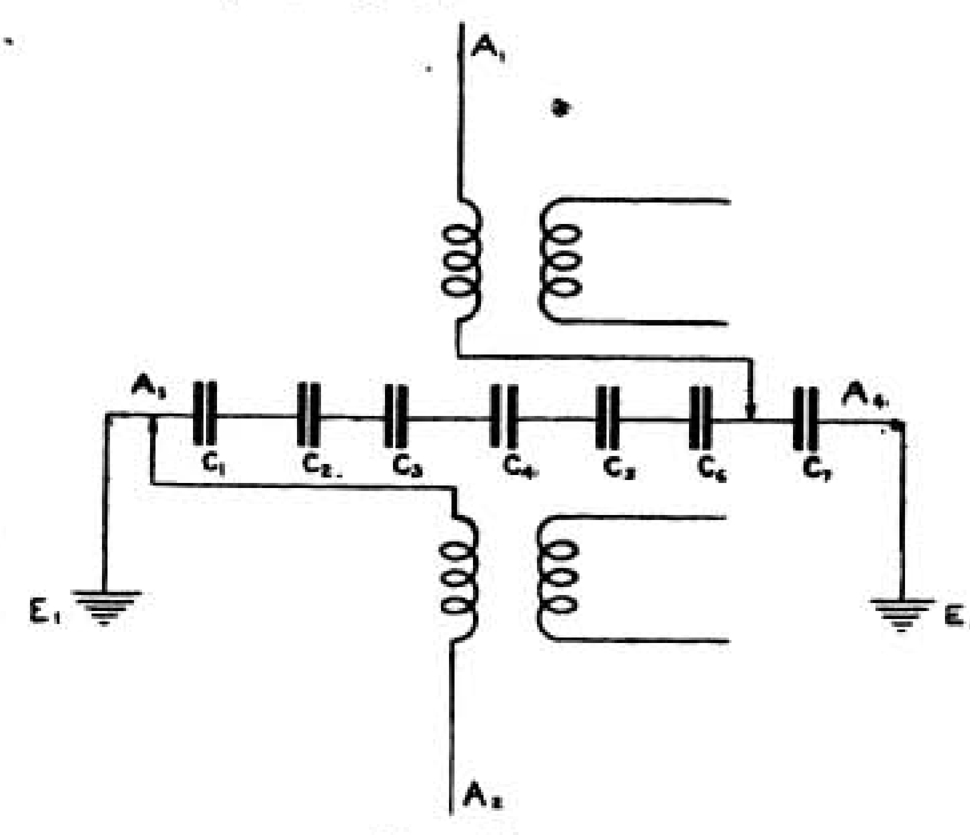


FIG. 16.

circuit diagram is that of the "Barrage Receiver" dealt with in RADIO REVIEW Abstract No. 75 (Fig. 4).

An arrangement is also described for varying the effective direction of a pair of horizontal aerials A_1, A_2 (Fig. 16) by connecting them to different points on a distributed capacity circuit joining the earthed aerials A_3, A_4, mounted geographically at right angles to the main aerials A_1 A_2. Such a circuit is indicated at $E_1A_3C_1C_2$ . . . $C_6C_7A_4E_2$. The arrangement is stated to be useful for neutralising atmospherics coming from any particular direction.

375. RECEIVERS FOR WIRELESS TELEGRAPHY. C. S. Franklin. (*British Patent* 134246, June 28th, 1918. Patent accepted, October 28th, 1919.)

A wireless receiver specially adapted for short waves is arranged as indicated in Fig. 17 so that the variations in potential produced by the received wave cause the potential of the filaments relative to its windings to vary more than the potential of the other electrodes. The diagram shows the connec-

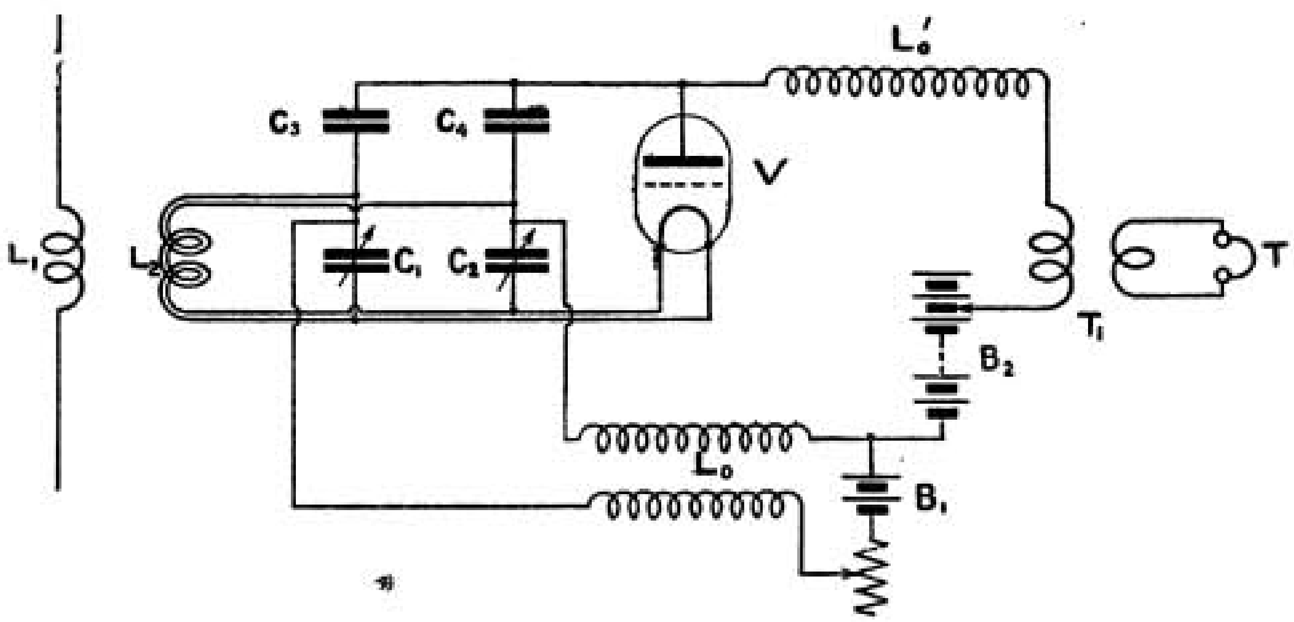


FIG. 17.

tions of a two-electrode valve receiver in which the two leads from the filament battery B_1 to the valve filament are wound together to form the secondary of the coupling jigger. The connections from the ends of these double windings to the battery B_1 are made through the choke coils L_0. The secondary tuning condenser is in two parts C_1C_2 across the two windings. By this means the capacity at the filament end of the secondary winding is reduced to a minimum.

376. AERIAL CONSTRUCTION. J. Bethenod. (*French Patent* 497313, April 20th, 1918. Published December 3rd, 1919.)

This specification describes a new system of aerials for the emission of electric waves of long wavelength produced either by a high-frequency alternator or by an arc, and it consists in the combination of two aerials at right angles and submitted to impulses which are out of phase with each other.

377. IMPROVEMENTS RELATING TO WIRELESS SIGNALLING SYSTEMS. J. H. Rogers and H. H. Lyon. (*British Patent* 133083, November, 1916. Patent accepted, October 9th, 1919.)

The radiating and receiving conductors of a wireless signalling system are placed on, or beneath, the surface of the earth, or water, and in electrical contact therewith. For directive or multiplex working it is proposed that several such conductors should be used arranged in different directions with the provision of suitable switches for using one or more of these aerials as requisite.

378. UNDERGROUND RADIO MADE POSSIBLE FOR AMATEURS. E. T. Jones. (*Radio Amateur News*, 1, pp. 274—275, December, 1919.)

The arrangement described aims at eliminating the long trenches required for the usual type of "ground aerials." The two horizontal aerial wires which are normally stretched out along or under the ground surface are in the arrangement described wound up into two coils of from 2 to 4 feet diameter each. The coils are sunk in water from 4 to 15 feet or buried in damp earth. One end of each coil is insulated and the other brought up to the ordinary valve receiving set. In the experiments described good signals were apparently received from a number of stations at a considerable distance and working on various wavelengths. The signal strength increased with the distance between the coils up to about 30 feet. About fourteen turns of cable were used on the 4-foot coils, and it is stated that practically no signals were received on them until they were lowered into the water or buried in the damp soil. When using the ordinary straight wire ground aerials, receiving on short wavelengths requires the use of a critical length of wire to obtain best results, but with the coils used in these experiments the length of wire did not materially affect the reception unless it was greater than about 500 feet on each coil.

379. THE WIRELESS EQUIPMENT OF EX-GERMAN SUBMARINES. E. Harper. (*Post Office Electrical Engineers' Journal*, 12, pp. 155—169, October, 1919.)

An illustrated description of the Telefunken apparatus installed in those vessels. In the standard sets a quenched spark transmitter with zincite-bornite crystal receiver was used. The discs of the quenched spark were an alloy of 80 per cent. silver and 20 per cent. copper.

In some sets two or three valve low-frequency amplifiers were added to the above to increase the range. A few of the submarines were provided with an additional box of apparatus containing three valves. These could be used for heterodyne reception or for short-range C.W. transmission. Some particulars of the windings, etc., are given in the paper together with characteristic curves of the valves and photographs of the apparatus.

380. GREAT WIRELESS STATIONS: TOWYN. (*Wireless World*, 7, pp. 433—437, November, 1919.)

An illustrated description of the Towyn Trans-Atlantic Receiving Station.

381. THE NEW BRUNSWICK RADIO STATION. (*Radio Amateur News*, 1, p. 276, December, 1919.)

A short description with illustrations of some of the machines.

382. THE LARGE FRENCH WIRELESS STATIONS DURING THE WAR. (*La Nature*, 47, pp. 374—384, December, 1919.)

This article is divided into five sections describing in a general way the war-time work and developments of the wireless stations at the Eiffel Tower, Lyons, Nantes, Bordeaux, and in the French Colonies. The first arc sets installed at the Eiffel Tower yielded 40 kw. in the aerial. Later this was increased to 100 kw. An extensive scheme of listening stations was arranged around Paris for the interception of all messages sent from enemy or neutral stations. Throughout the war these stations intercepted some 50,000,000 words, while the Eiffel Tower station itself sent about 1,500,000. It was even found possible to decipher messages from German stations when these were sent with a Hughes transmitter, by running an appropriate receiver in synchronism. The Lyons station was entirely erected during the war, and commenced work with a 150-kw. spark-set putting 50 kw. into the aerial. Later an arc was installed giving 70 kw. in the aerial, which was subsequently increased to 100 kw. by improvements in the arrangements. The eight 400 feet towers first installed were increased in height (two to 675 feet and six to 600 feet) to ensure reliable communication with America. This station has been heard in Central Africa, Shanghai, the Philippines, and New Zealand. Arcs giving 200 kw. are also to be installed. A 200-kw. 20,000 $\sim$ alternator was installed in July, 1919, and gives better signals in America than the 200-kw. arcs. The Nantes station erected by the French naval authorities has 30- and 150-kw. spark sets and three arc sets similar to that at the Eiffel Tower. The Bordeaux station is to contain a 300-kw. arc, a 500-kw. arc, and two 500-kw. alternators, to work on 20,000 metres wavelength. The aerial is 820 feet high and 5,000 feet long. A station is to be erected in Indo-China having similar equipment.

383. THE TECHNICAL PROGRESS IN LARGE WIRELESS STATIONS. (*La Nature*, 47, pp. 387—389, December, 1919.)

A brief description is given of the mode of operation of the Goldschmidt alternator, and of the various means of producing undamped waves. The chief lines of progress have been the substitution of undamped for damped wave transmission, the use of automatic transmitters, the use of amplifiers enabling reception to be effected with frame aerials, improvements in anti-atmospheric devices, automatic reception, and the use of frame aerials for duplex working. A brief account is also given of Levy's anti-atmospheric arrangement using a double heterodyne—the first to 10,000 ~ and the second to an audible note.*

384. NAUEN AND COUNT ARCO. (*Elektrotechnische Zeitschrift*, 40, p. 653, December, 1919.)

The high-power station at Nauen is being rebuilt and fitted with new equipment. The history of Nauen is described in a special number of the *Telefunken Zeitung* issued in honour of Count Arco's fiftieth birthday. The articles deal with the various branches of the wireless plant, including duplex working.

385. SOME FOREIGN APPARATUS. F. M. Gill. (*Radio Amateur News*, 1, p. 282, December, 1919.)

Circuit diagrams are given of the various French amplifier, wireless telegraph and telephone, and aeroplane sets also of a French spark transmitter for trench use and the French wavemeters which were supplied to the U.S. Signal Corps.

386. TRANSMITTERS. H. Thuret and L. Louvel. (*French Patent* 497299, March 19th, 1919. Published December 2nd, 1919.)

The invention described in this specification consists of an automatic keyboard sender which may be used in sending Morse or other signals in wireless telegraphy. For each key a rotating shaft, whose speed may be regulated, is disposed transversely to and above the keys. A disc of insulating material is loosely mounted on the shaft and carries conducting segments. Two conducting members arranged to bear against the disc are connected to the transmitting circuit and means are provided to connect each disc automatically to the shaft by depressing its controlling key, whereby the said disc rotates and signals are produced.

387. NEW RADIO DYNAMIC CONTROLLING SYSTEM. W. R. Coventry. (*Radio Amateur News*, 1, p. 293, December, 1919.)

Two synchronously rotating contact drums are used and the contacts are controlled by signals sent at the appropriate instant.

388. OSCILLATORY MERCURY "MAKE AND BREAK" APPARATUS FOR WIRELESS TELEGRAPHY. M. Compare. (*British Patent* 134297, October 29th, 1918. Patent accepted, October 29th, 1919.)

The relay described is for use in wireless control systems and is arranged to be responsive only to impulses of a particular frequency. It consists of a vertical column of mercury or other liquid partly filling a tube having a sealed upper end with a magnetic float on the surface of the mercury. This float is

* See also RADIO REVIEW Abstracts Nos. 190 and 191.

under the influence of a solenoid which encloses the tube and through which the received currents are passed. The lower end of the tube dips into a containing vessel in which two contacts are mounted above the surface of the mercury. When impulses of the correct frequency are passed through the solenoid winding an oscillation is set up in the mercury column which increases in amplitude until the contacts are closed.

389. RADIO PROBLEMS IN AVIATION. E. R. Doyle. (*Electrical Experimenter*, 7, p. 543, October, 1919.)

The problems considered are: (1) Directional control of transmitted signals; (2) wavelength adjustment of incoming and outgoing signals; and (3) transmitting ranges and sensitivity of receiving apparatus.

390. ON THE FORM OF THE TRAILING AERIAL. H. C. Plummer. (*Philosophical Magazine*, 38, pp. 732—736, December, 1919.)

A mathematical treatment of the form taken up by a wire aerial hung from an aeroplane in flight.

391. ELECTRIC SWITCHES SPECIALLY SUITABLE FOR USE IN WIRELESS SIGNALLING. M. D. Scott and P. P. Eckersley. (*British Patent* 134590, October 26th, 1919. Patent accepted, November 13th, 1919.)

This relates to electromagnetic switches specially suitable for use on aircraft for changing over from wireless reception to transmission and *vice versa*. The switch is particularly adapted for use with thermionic valve transmitters, and is arranged to dim the filaments of the transmitting valves when the receiver is connected to the aerial. The generation of oscillations by the transmitting valves is thus stopped during reception. By this means the complete change over from transmission to reception can be effected with a small local switch or push button.

392. A METHOD OF DEMONSTRATING THE EDISON EFFECT. (*Annales des Postes, Télégraphes et Téléphones*, 8, p. 551, September, 1919.)

A telephone joined between the earth and a band of tinfoil wrapped round an ordinary electric lamp indicates the passage of a current due to the Edison effect. This current passes *through the warm* glass.

393. WIRELESS RAILWAY SIGNALS. (*Electrical Review*, 85, p. 721, December, 1919.)

Brief mention of an apparatus operated by radio to give a warning in the engine cab when a train passes a danger signal.

394. WIRELESS STATIONS AS COMPETITORS WITH LINE TELEGRAPHY AND TELEPHONY. E. Nesper. (*Jahrbuch der Drahtlosen Telegraphie*, 15, pp. 69—72, January, 1920.)

An article drawing attention to the advantages of wireless telegraphy and the possibility of relieving the present congestion and cheapening communication.

395. WIRELESS PRESS SERVICE. Communicated by the Gesellschaft für Drahtlosen Telegraphie (*Jahrbuch der Drahtlosen Telegraphie*, 15, pp. 72—76, January, 1920.)

A plea to the German authorities for the establishment of a system of distribution of news from wireless stations.

2. Books.

LA THÉORIE ET LA PRATIQUE DES RADIOCOMMUNICATIONS. Vol. I. INTRODUCTION À L'ÉTUDE DES RADIOCOMMUNICATIONS. By Léon Bouthillon. (*Paris: Librairie Delagrave* Pp. ix. + 193. Price 20 fr. paper covers; cloth, 25 fr.)

This volume is the first of a series of eight dealing with the whole subject of radiotelegraphy, both in its theoretical and its practical aspects. The author states in his preface that he has come to the conclusion that it is more satisfactory to publish such a work in a series of volumes, each dealing with one particular branch of the subject, than to attempt to include everything in a single volume, unwieldy in size and prohibitive in price.

He also expresses a doubt whether such a book is needed when there are already so many in existence; but this volume seems to show that there should be a place for his work which is not quite filled by any author. During the war, owing to the necessities of the case, the practical side of radiotelegraphy made enormous advances; but these advances were hardly paralleled on the theoretical side, and the urgent need of the moment is a consideration of the more abstract side of the subject, in order to obtain the full value of the practical results already obtained.

For the ordinary operator or erecting engineer, the mathematical side of the subject is not of such great importance, and for men of this type there are many small handbooks in existence suitable to their particular needs; but it is absolutely indispensable for any worker who wishes to deal with fundamentals. In many books on radiotelegraphy there is a tendency to sacrifice either the theoretical or the practical side, generally the theoretical, as this is the side which appeals to fewer readers. Hence anybody who wishes to study first principles is usually obliged to refer to original papers dealing with the mathematics of the subject, or to a condensed edition of them.

In such editions, not only in books on this subject but in many others, portions of a mathematical discussion are frequently left out, and this renders it very difficult for the argument to be followed. "Hence it follows" may be made to cover several pages of close mathematical reasoning, and one is at times driven to the conclusion that such cuts have been made with greater vigour than discrimination. Even ordinary papers require editing in view of the special requirements of their subject which may not have appeared of immediate importance to the author at the time he wrote his work. For instance, Maxwell knew nothing of, and had no direct interest in radio communications. He was entirely concerned in the development of his theory of electrical actions in material space. Consequently, when his work is applied to radio communications, the relative order of importance of his results may differ considerably from that in which he placed them himself. Such editing has been particularly well carried out in this work; the mathematical reasoning, without being prolix, is presented in a form which makes the argument very easy to follow, and gives the definite impression that the author is fully at home with the mathematics of his subject.

He himself would probably be the last to claim originality for most of the work in this volume. He has taken the results of the classical researches on the subject, and has arranged and prepared them to form a continuous whole leading directly to the results he has in view. This particular volume, of course, demands of its readers considerable familiarity with the mechanical processes involved in the handling of differential equations, and immediate recognition of the standard forms of equations dealing with wave-motion, and the physical interpretation of the symbols that occur. This amount of mathematical skill is unfortunately very infrequent among radio engineers in this country and the subject suffers considerably therefrom. Experimental work of the "hit and miss" type is far too common, and the idea of basing it on a mathematical foundation is looked on as impracticable by many experimenters.

The first chapter deals almost entirely with Maxwell's equations and their derivatives, special attention being given to the case in which the electromagnetic field is symmetrical about one axis, *i.e.*, a field of revolution; and to the case in which the frequencies involved are of the order used in radio work. In particular, a full discussion is given of vector potential. This is probably one of the most difficult points in the mathematics of the subject. From the purely mathematical standpoint, the vector potential appears as an abstract arbitrary function, whose chief purpose is to effect a symbolic reduction of the equations to a more workable form. It is thus primarily defined by a mathematical substitution in the original equations, but the conditions it has to satisfy for this purpose do not define it uniquely, and so there is one other independent condition available. By postulating this condition differently, Maxwell, Hertz and Lorenz have each arrived at a different function to suit the particular case they had under consideration. Poynting's theorem and the problem of the diffusion of electromagnetic effects into a conductor are also briefly discussed.

The second chapter occupies most of the book. The first part of it deals with the form taken by Maxwell's equations for a perfect dielectric, and is, therefore, of primary importance in radiotelegraphy. Throughout the chapter only two cases are considered in detail, first the field of revolution, in order to deal with the radiation from a source on the axis, and the effects in its immediate neighbourhood; and secondly the case of a plane wave front, which is the condition that holds for reception at a considerable distance from the source. The method of Hertz for obtaining the graphs of the lines of force radiating from an undamped oscillator at various phase times is given in detail with a great many diagrams, and there are also full references to the works of Professor Karl Pearson and Miss Lee, and also to that of A. E. H. Love dealing with damped oscillations.

In the latter part of the chapter the problems of transmission and reception from both closed and open aerials are discussed. The special object in the case of transmission is to obtain an expression for the power radiated under given conditions, and the efficiency of such radiation; and in the case of reception to determine the power absorbed from the dielectric by the receiving system and its efficiency. The results are given in two tables, which give these efficiencies both for the general case and also for cases in which special relations exist between the various constants of the aerial. The results for reception are based on the assumption that the atmosphere is a perfect dielectric; and a table is given showing for different wavelengths the power which must be radiated to give a power of four microwatts in the receiver. Of course, on this assumption, no account is taken of the actual conditions which arise in practice, such as reflection from an ionised upper layer of the atmosphere or losses due to the resistance of the surface of the earth. Hence the results are very different from actual results which would be obtained in practice. For example, the table shows that with a radiated power of 16 kw. at a wavelength of 2,000 metres, the power mentioned above, 4×10^{-6} watts can be received at a distance of 15,040 km. Experience, especially with continuous waves, tends to show that these distances are excessive and also that it is probable that the power received is not proportional to the inverse square of the distance, as is assumed in these calculations, so that care should be used in applying them to a practical case.

The third chapter discusses the mathematics of radiation over a plane perfectly-conducting surface; the ideal case of transmission over the surface of the earth. A few special cases of simple aerial forms are discussed; but as the author himself says this is approaching the practical side of the question, and so a full discussion of it is left to a later volume. This is the only weak point of the system by which a different volume is allotted to each branch of the subject, namely, that it is difficult to draw a sharp line of distinction between the theoretical and the practical side of the problem. This disadvantage is, however, far outweighed by the advantages of the system.

A comparative table is given of the reception of the same signal by open aerials and closed coils of various dimensions, showing the range and the efficiency obtained in each case. These are, of course, open to the same objections as the table referred to above, namely that these figures would probably not be substantiated in actual working, although the relative values may be correct.

In the fourth chapter the results of the rest of the volume are summarised and at the end of each chapter a bibliography is given of the references to the original papers from which the results have been taken.

J. HOLLINGWORTH.

MESURES PRATIQUES EN RADIOACTIVITÉ. W. Makower and H. Geiger. Translated from the English by E. Philippi. (Paris: *Gauthier-Villars et Cie.* 1919. Pp. vii. + 181. Price 12 fr.)

We welcome the translation of Makower and Geiger's "Practical Measurements in Radioactivity" as an earnest of the resumption of Anglo-French publishing relations, rudely arrested by the war. Doubtless owing to the difficulties of the times, the translation bears no marks of any attempt to incorporate the results of work published subsequent to 1912—the date the book first appeared in this country.

Radioactivity, as a subject, has now been added to the syllabus of instruction of most of the physical laboratories in this country—certainly in the case of students contemplating a medical career. The authors of the present volume can fairly claim a large share of the credit for bringing this about. They clearly demonstrate that a laboratory course in radioactivity requires only simple and inexpensive apparatus. With the assistance of many excellent diagrams they set out the main points which are likely to worry the novice or for the matter of that the more knowledgeable student. Here and there the treatment is perhaps meagre, and now and again unexpectedly complete, probably owing to the fact that the authors have not been able to fall back on the crop of graded text-books common to other branches of physics.

The French edition follows precisely the English one in its sequence of chapters dealing in logical order with electrometers and electroscopes (string-electrometers should receive better treatment), the *alpha*, *beta* and *gamma* rays of radium, methods of measuring ionisation as the basis of standard measurements, etc.

We notice a small slip on p. 101 where in equation 39, P should read Q. The book concludes with some useful tables of constants and an index which leaves a good deal of room for improvement. The translator appears to have done his work well.

We know of no other work which seeks to impart the technique of radioactivity to the student. The book may fairly be recommended to the reader who wishes to know some of the details of the methods employed in a subject which has profoundly affected the fundamentals of physics.

G. W. C. KAYE.

Books Received.

LEÇONS DE PHYSIQUE GÉNÉRALE. By J. Chappuis and A. Berget. Vol. II. ELECTRICITY AND MAGNETISM. Revised by J. Chappuis and M. Lamotte. (Paris: *Gauthier Villars et Cie.* Third Edition. 1920. Pp. 623. Price 45 fr.)

MANUAL OF RADIOTELEGRAPHY. By Captain S. Robison, U.S.N. Revised by Captain D. W. Todd and Commander S. C. Hooper. (Annapolis, U.S.A.: *The United States Naval Institute.* London: *S. Rentell & Co.* Fifth Edition. 1919. Pp. 307. Price 10*s.* net.)

TELEPHONIC TRANSMISSION, Theoretical and Applied. By J. G. Hill. (London: *Longmans, Green & Co.* 1920. Pp. xvi + 398. Price 21*s.* net.)

ANNUAIRE POUR L'AN 1920. By Le Bureau des Longitudes. (Paris: *Gauthier Villars et Cie.* 1920. Pp. viii + 708 + A. 27 + B. 64 + C. 70. Price 4 fr. 50 net.)

This Annual contains in addition to extensive astronomical information, physical and chemical particulars arranged mostly in tabular form for reference purposes, as well as a number of electrical constants, etc. An appendix contains an article by C. Lallemand setting out full particulars of the new metric system units legalised in France.

LA TELEFONIA SENZA FILO. By Umberto Bianchi. (Milan: *Ulrico Hoepli.* 1920. Pp. viii + 296. Price L. 10.)

REPORT OF THE CHIEF SIGNAL OFFICER (General G. O. Squier) TO THE SECRETARY OF WAR, U.S.A., 1919. (Washington: *Government Printing Office.* 1919. Pp. 547.)

RADIO ENGINEERING PRINCIPLES. By H. Lauer, B.S., and H. L. Brown, B.E.E. (New York: *McGraw-Hill Book Co., Inc.* London: *Hill Publishing Co., Ltd.* 1920. Pp. xv + 300. Price 21*s.* net.)

THE "PRACTICAL ENGINEER" ELECTRICAL POCKET BOOK AND DIARY, 1920. (London: *The Technical Publishing Co., Ltd.* Pp. clxiv + 592 + 56 (Diary). Price 1*s.* 6*d.* net; best cloth binding, 2*s.* net.)

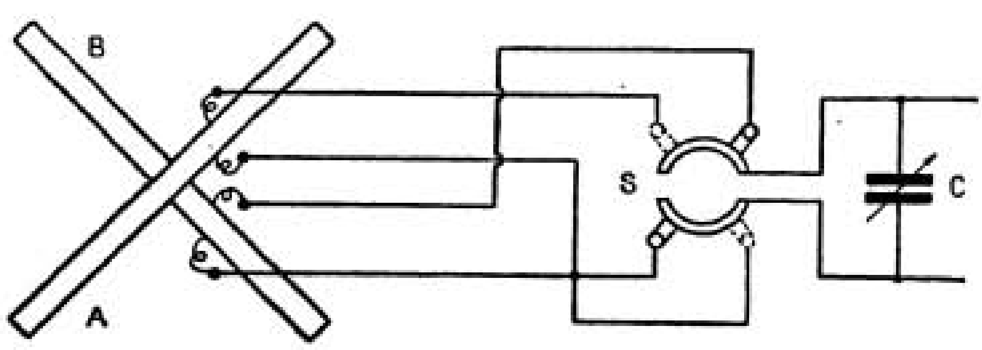
Correspondence.

WIRELESS DIRECTION FINDING.

To the Editor of the "Radio Review."

SIR,—In No. 5 and 6 of the RADIO REVIEW Captain Robinson describes a maximum method of direction finding with crossed coils.

Methods of direction finding using crossed coils were experimented with and developed at the National Physical Laboratory in the winter of 1914, and it may be of interest to describe two of these methods. In one method two direction finder coils A and B are wound at right angles to each other



and are capable of being rotated together about a vertical axis. The coils are similar and are used independently, each in turn being placed in circuit with the tuning condenser C by means of the switch S. If the coils A and B are exactly at 45° to the direction of the incoming signals the intensities of the received signals will be equal.

If the coil A be at an angle $45° + d\theta$ to the incoming signals then the ratio of the E.M.F.'s in the two coils is equal to $1 - 2 \sin d\theta$, and the ratio of the difference of E.M.F. to the mean E.M.F. is $2 \sin d\theta$. This ratio is identical with that obtained with Captain Robinson's system if he uses two similar coils.

It may be urged that this 45° system is nevertheless at a disadvantage, for apparently the maximum intensity of the received signals is less. In practice, however, this is not the case. In Captain Robinson's method the two coils are in series; in the 45° method each coil is used independently, and for the same values of the capacity and diameter of coils the inductances must be the same. That is, there will be approximately $\sqrt{2}$ times as many turns on each of the coils A and B as on a Robinson coil, with a corresponding increase in the E.M.F. However, in the one case a coil is at 45° to the direction of the incoming signals and in the other case at 0° which results in the E.M.F.'s for similar coils being in the proportion $1 : \sqrt{2}$. Allowing for the difference of turns the final result is therefore that the E.M.F.'s are equal. The effective resistance of the circuit of an A or B coil will however be less than for the Robinson coils which is a slight advantage.

Obviously it is not possible with this method as it is with Captain Robinson's to vary the diameter of one of the coils and so obtain a greater ratio of the difference of E.M.F. to the mean E.M.F. In practice, however, it must be possible to rotate the coil systems and hence whatever the size may be of Captain Robinson's auxiliary coil it is possible for each of the coils A and B to be of equal diameter. It follows therefore that with the auxiliary coil system it is not possible to obtain a greater *difference* of E.M.F. for a small variation $d\theta$ from the desired position but it is possible to add this difference to a smaller E.M.F. than in the method of 45°. Two questions immediately arise:—(1) What is the smallest change of intensity which the ear can detect? and (2) Is the ear *more* or *less* sensitive to a change of intensity when the change is superposed on another note of the same frequency? In general I believe the ear is more sensitive when there is no added note. Assuming this to be so, the most sensitive coil system is that of a single coil and the writer has obtained some remarkably consistent results when the signals were of sufficient intensity to necessitate an angular movement of a few degrees only. One disadvantage lies in the necessity to rotate the coil to compare the two notes, and it was with a view to overcoming this difficulty that the second method of crossed coils, now to be described, was devised. In practice the system is not equivalent to that of a single coil but in sensitiveness it appears to be equivalent to the Robinson method with a main and an auxiliary coil. If arrangements are made to alter the angle between the coils it appears to be equivalent to the Robinson system plus the advantage which would result if the main coil of the latter could be arranged to have its "area-turns" varied without altering the inductance.

The two coils are equal and similar as before but instead of being crossed at 90° the angle between the coils is smaller, for example 20°. Observations can be made with the system when its mean plane (each coil being 10° from the plane) is (*a*) at right angles to the direction of the incoming signals and (*b*) in the direction of the signals. A switch similar to that employed in the previous method may be used to compare the intensities.

In the case where the angle is 20°, and the displacement from the correct minimum position is $d\theta$ the ratio of the E.M.F.'s in the two coils is equal to $1 - 11{\cdot}4 \sin d\theta$, and the ratio of the difference of E.M.F. to the mean E.M.F. is $2 \tan 80° . \sin d\theta = 11{\cdot}4 \sin d\theta$. The latter ratio depends on the angle between the coils and may be varied to suit special cases.

With such a crossed coils system the intensity of the incoming waves may not be sufficiently great for the latter to be detectable when the plane of a coil is 80° from the maximum position and in such a case the method would fail. It may be pointed out, however, that for similar signals and for a similar ratio of difference of E.M.F. to mean E.M.F. the Robinson system of small main coil and auxiliary coil would also fail. To obtain the ratio of $11{\cdot}4 \sin d\theta$ the ratio of the area turns of the auxiliary coil to those of the main coil would have to be 5·7 (this is $b/a = k$ in Captain Robinson's notation) and since the area turns of each of the 80° coils can be equal to the area turns of the auxiliary coil it follows that the E.M.F. produced in such a coil 80° from the maximum position is $5{\cdot}7 \cos 80° (= 1)$ times that of Captain Robinson's main coil in the maximum position. That is, the E.M.F.'s are equal and if one system fails to pick up signals the other will also. The obvious remedy is to use the auxiliary coil as the main coil and work in the maximum position. This of course sacrifices sensitiveness. Similarly with such a system as I have termed an 80° system; when the mean plane is near the "maximum" position the displacement being $d\theta$, the ratio of the E.M.F.'s in the two coils will be equal to $1 - 0{\cdot}35 \sin d\theta$ and the ratio of the difference of E.M.F. to the mean E.M.F. is $2 \tan 10° \sin d\theta = 0{\cdot}35 \sin d\theta$.

It will I hope be clear that in designing any D.F. coil system the all-important question is that of the intensity of the received signals. The 80° system as I have called it was experimented with but little, but I did observe some slight interaction between the coils. This interaction did not influence the accuracy of the results but there was evidence of a small reduction in the intensity. For general work I am inclined to prefer two equal coils crossed at right angles used either independently or as a Robinson maximum system. In aircraft work it is essential to have considerable intensity, and the minimum method using a single coil, is therefore disadvantageous. I would like to point out that the disadvantages of a single coil were brought to my notice by an officer of the R.N.A.S. (there was no R.A.F. then) in 1916. At this time what I believe to be the first D.F. coil ever taken in the air in this country was being made at the National Physical Laboratory and I proceeded at once to devise "intensity and difference" methods instead of minimum intensity methods. These methods I am now at liberty to describe and I hope they will be of some interest to your readers.

F. E. SMITH.

The National Physical Laboratory,
Teddington, Middlesex,
March 11th, 1920.

TRIODE NOMENCLATURE AND SYMBOLS.

TO THE EDITOR OF THE "RADIO REVIEW."

SIR,—With reference to Mr. L. B. Turner's letter in your last number, I am very glad to see that the question of symbols and nomenclature for use with thermionic valves and the associated circuits is being discussed.

The k_1, k_2, k_3, and k_4 of my paper were chosen provisionally in 1915, after careful consideration of other possibilities. The letter g being in very general use for conductance was naturally the first suggestion. But there were certain objections to this choice. In the first place the slopes of the characteristics are not exactly conductances. Again, there are in the associated circuits true conductances, for which the g is required in its usual sense.

With regard to the use of k, this was to some extent justified by the fact that the slopes of the characteristics are constants in most problems. The values are only altered by alterations of the batteries or controlling resistances. They are not affected by the functioning of the valve itself.

For each of these reasons therefore the choice of the letter k seemed to be justified.

The question of distinguishing subscript numbers or letters then arose. If letters were to be used it would have meant that two subscript letters would have been required if they were to have indicated the particular slopes referred to. Consequently the numbers 1, 2, 3, and 4 were chosen and applied to the slopes in the order of their respective importance.

This notation has proved quite satisfactory in practice.

The letter k without subscript could be used for the slope of the "lumped characteristic," if this is required.

For the voltage ratio of the tube, *i.e.*, the ratio k_1/k_2 in my notation, the letter m was chosen at the same time as the k_1, etc. There is some risk of confusion here with m or M for mutual inductance and an alternative is desirable. Dr. Eccles' g is not good, as confusion with conductance is likely. Mr. Turner's ν is very inconvenient to write and a change from m to μ might meet the case as confusion with permeability is scarcely possible.

With regard to Mr. Turner's proposals for names for the slopes, these seem to be quite sound and might well be generally adopted.

Dr. Eccles has recently introduced the term "lumped characteristic," used above. Cannot this name be improved upon? Why not simply "*the* characteristic" or the "total characteristic." Or again, would it be a misplaced compliment to call it the "Langmuir characteristic"?

C. L. FORTESCUE.

Royal Naval College,
Greenwich.
March 17th, 1920.

"TEXT-BOOK ON WIRELESS TELEGRAPHY."

TO THE EDITOR OF THE "RADIO REVIEW."

SIR,—A very fair review of my "Text-Book on Wireless Telegraphy," Vol. II., by Dr. Whiddington appeared in your February issue, and I have never before replied to criticism. Dr. Whiddington, however, takes me to task for giving so much credit to the French military service and so little to the work carried on under the auspices of the British services; perhaps you will therefore afford me a little space to explain my attitude.

I was intimately connected with the British Army wireless service for four and a half years and my experience was that our home establishments produced very little of an original nature. For example, right up to the end of the war, the French valve was our favourite at the front, and for all round adaptability nothing better than it was produced by our home department. Apart from the excellent range of valves introduced by the Marconi Co. we must admit that the French service deserves most of the credit for valve work, and it may be noted that even the Germans copied the French arrangement of hard valve in 1918. The valves brought over by the American army service were excellent in robustness of design and in characteristic.

In oscillation amplifiers we in France were acquainted with no design except those of the French service and of the Marconi Co.; if the British establishments discovered any improvements in such apparatus they certainly did not produce anything which could be of service in the field.

In L.F. amplifiers I think the patent records show that most of the honours should go to Latour and the French wireless service. We were using French amplifiers in February, 1916, and for almost two years the home establishment produced amplifiers which were not so flexible as the French ones, and of which the design was more applicable for dressing jewellers' windows than for use in the trenches. It was not until 1918 when the influence of German portable designs had at last penetrated that we obtained amplifiers from home of really serviceable construction.

Of C.W. Sets the less said the better; we in France started clamouring for serviceable Sets in 1916 but it was 1918 before we got a field pattern in which there was nothing original, and in which there was much faulty design.

The only evolutions of real importance and utility from our home establishment were the excellent C.W. Set designed by Mons. Matthieu, a Belgian, and the Loop Set of Captain L. B. Turner; had the war been further prolonged I believe also that Captain Turner's Wireless Telephone Trench Set would have been most useful.

I could not describe Mons. Matthieu's C.W. Set nor Captain Turner's Loop Set in my text-book because they are standard sets in the Army at present.

Dr. Whiddington says that "no one relying entirely on the text-book for information would for a moment suspect that any research or design had been carried out by the British Government along lines *parallel* to the French." If that is so I have been happily successful in my intention, for the difficulty of getting any serviceable design out of our home establishments was heart-breaking to every responsible wireless officer in the field. Far from being on parallel lines the productions of our home establishments were very much behind those of the French service, both in originality and in date.

As regards the Navy my information was that Dr. de Forest's circuits were largely employed; it was impossible to publish details of the Air Service apparatus, and in any case I have not dealt with air radio-practice in the text-book.

I was not aware that the Fullerphone had revolutionised earth signalling; the Fullerphone was employed in the field as an alternative method of line signalling. Dr. Whiddington thinks that in connection with L.F. amplifiers my use of the terms "amplifier" and "relay" may lead to some confusion; I can only say that I have taught some hundreds of operators and found it necessary to call on their previous knowledge of "relay" action in order to get them to really understand the simple theory of amplification.

RUPERT STANLEY.

Municipal Technical Institute,
Belfast.
March 15th, 1920.

The above letter has been submitted to Professor Whiddington, who has replied as follows:—

TO THE EDITOR OF THE "RADIO REVIEW."

SIR,—In a letter to the RADIO REVIEW criticising my review of his book Mr. Stanley conveys an impression which I feel bound to correct.

Far from taking him "to task for giving so much credit to the French military service," I actually commended him most warmly for so doing. I also took the opportunity of recording my own deep appreciation of the great work done by the excellent scientific staff of the French military service.

What I did call attention to was the fact that Mr. Stanley had omitted *all* reference to British official design—an omission which I stated detracted from the value of his book.

It is interesting in this connection to learn from Mr. Stanley's letter that (leaving out of account the Navy and Air Force) there were in his opinion two sets designed in the Army establishment which were definitely useful and a third which might have been, if the war had lasted!

R. WHIDDINGTON.

The University, Leeds,
March 29th, 1920.

(We regret that owing to pressure on our space some correspondence has been unavoidably held over to the next issue.—ED.)

ERRATUM.

Page 318, *footnote*. The expression for a should read: $a \equiv \frac{\partial I}{\partial V}$.