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The Kallirotron, an Aperiodic Negative-Resistance Triode Combination.*

By L. B. TURNER, M.A.

1. Introduction.

In wireless telegraphy it is common practice to exalt the amplifying action of a triode by introducing magnetic or electric retroaction between the oscillatory circuits connected to the grid and anode. It is well understood that the most important effect of such retroaction is the reduction of the ohmic resistance of the circuits; and this may be conveniently, if more abstractly, expressed as the introduction of a negative resistance into the circuit. Since the circuits comprise inductance and capacity, their impedance cannot be reduced indefinitely towards zero as their resistance is decreased, except for sustained alternating currents of the particular frequency (or frequencies) to which they are tuned.

In a recent triode invention known as the "Dynatron," † by virtue of the phenomenon of copious emission of secondary corpuscles from a plate under sufficiently violent bombardment by primary corpuscles, the same negative resistance effect is obtained in quite another way. And the dynatron, being applicable to circuits containing resistance only, as well as to oscillatory circuits, is competent to reduce indefinitely the impedance of a circuit for currents of any frequency, including even steady currents.

The arrangement to be described here consists of a combination of circuits, which may be aperiodic, including two ordinary triodes in which secondary emission plays no part, whereby electrical resistance is annihilated—the result achieved in the dynatron by dependence on secondary emission. Some reference name being necessary, the arrangement has been termed the "Kallirotron." ‡ It will be best understood by examining the device in some detail as an amplifier of electromotive force of any frequency.

2. Theory of Kallirotron.

Consider the circuits shown in Fig. 1. Here two ordinary triodes, with

* Paper received in final form December 24th, 1919.

† "The Dynatron. A Vacuum Tube possessing Negative Electric Resistance." A. W. Hull, *Proc. Inst. Radio Engineers*, February, 1918.

‡ Second syllable accented, vowel short. From καλλιροος = easy flowing.

their filaments joined and heated by a battery not shown, are connected by batteries and resistances disposed in a kind of vicious circle; and at two points small E.M.Fs. e_1 and E_1 may be introduced.

Let the condition of the triodes be given by the equation

$$\delta I = a \,.\, \delta V + g \,.\, \delta v \quad \ldots \ldots \ldots \quad (1)$$

expressing the relation between small changes of anode current, and anode

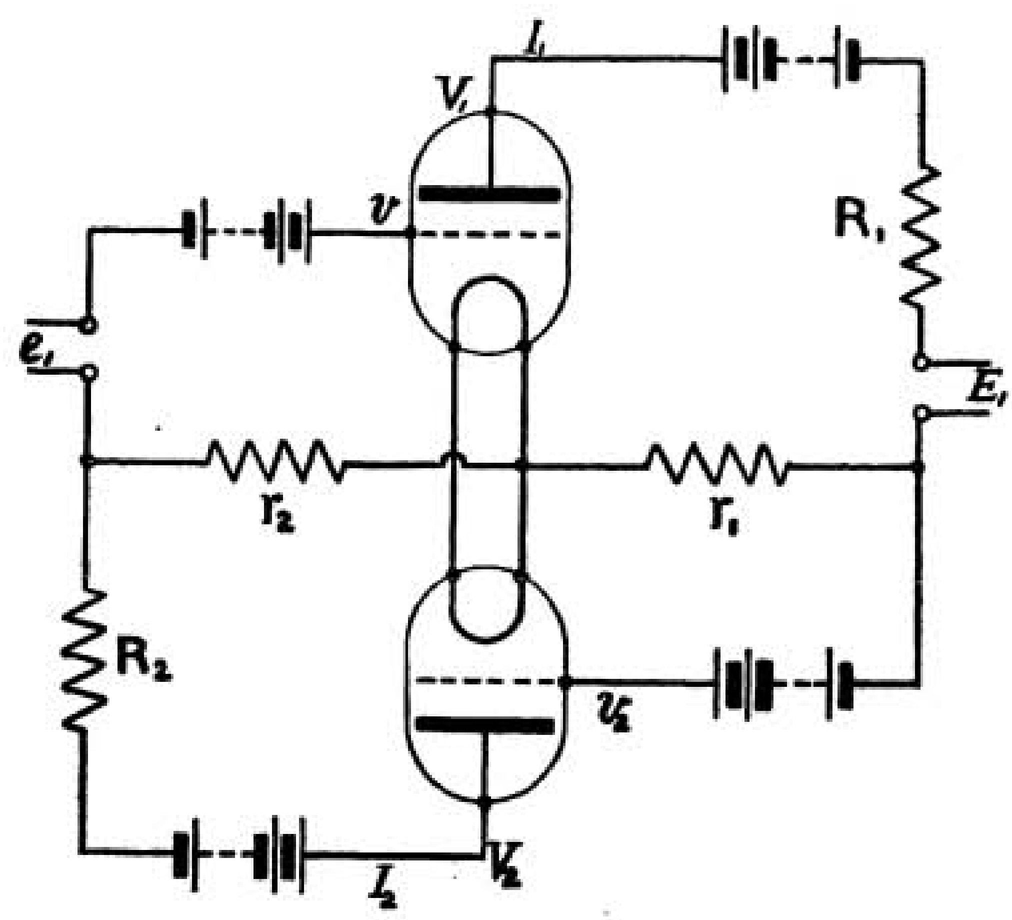

FIG. I.

and grid potentials; a and g being the familiar conductance parameters of the two anode current characteristics.*

Assuming that changes of grid current are negligible in comparison with changes of anode current, the effect of the small E.M.Fs. e_1 and E_1 is given by

$$\delta I_1 = a_1 [E_1 - (r_1 + R_1)\, \delta I_1] + g_1 \,.\, \delta v_1$$

i.e.,

$$\delta v_1 = \frac{1}{g_1}\Big[\delta I_1 \Big\{1 + a_1 \Big(r_1 + R_1\Big)\Big\} - a_1 E_1\Big] \quad \ldots \ldots \quad (2)$$

Also

$$\delta v_2 = -r_1 \,.\, \delta I_1 \quad \ldots \ldots \ldots \ldots \quad (3)$$

Also

$$\delta I_2 = -a_2 (r_2 + R_2)\, \delta I_2 + g_2 \,.\, \delta v_2,$$

* a and g are the conductance slopes k_2 and k_1 of Professor C. L. Fortescue's paper, "The Design of Multi-Stage Amplifiers," read before the Institution of Electrical Engineers on November 19th, 1919. (See RADIO REVIEW, I., pp. 178—181.)

$a \equiv \frac{\partial I}{\partial V}$; $g \equiv \frac{\partial I}{\partial v}$. The graphical significance of a and g, and an idea of their magnitude in the pattern of triode most used in the war, are given at a glance by Fig. 2.

i.e.,
$$\delta I_2[1 + a_2(r_2 + R_2)] = g_2 \,.\, \delta v_2$$
$$= -g_2 r_1 \,.\, \delta I_1 \quad . \; . \; . \quad \text{from (3)} \quad . \; . \; . \; . \; . \; . \qquad (4)$$
Also
$$\delta v_1 = e_1 - r_2 \,.\, \delta I_2$$
$$= e_1 + \frac{r_2 g_2 r_1 \delta I_1}{1 + a_2(r_2 + R_2)} \quad . \; . \; . \quad \text{from (4)} \quad . \; . \; . \; . \; . \qquad (5)$$

Equating (2) and (5) we obtain

$$\delta I_1 \frac{[1 + a_1(r_1 + R_1)][1 + a_2(r_2 + R_2)] - g_1 g_2 r_1 r_2}{1 + a_2(r_2 + R_2)} = a_1 E_1 + g_1 e_1 \,. \qquad (6)$$

If we make $e_1 = 0$, we get from (6)

$$\frac{E_1}{\delta I_1} = \frac{[1 + a_1(r_1 + R_1)][1 + a_2(r_2 + R_2)] - g_1 g_2 r_1 r_2}{a_1[1 + a_2(r_2 + R_2)]} \quad . \; . \; . \; . \; . \; . \qquad (7)$$

This expression is the effective resistance of the I_1 circuit for small changes

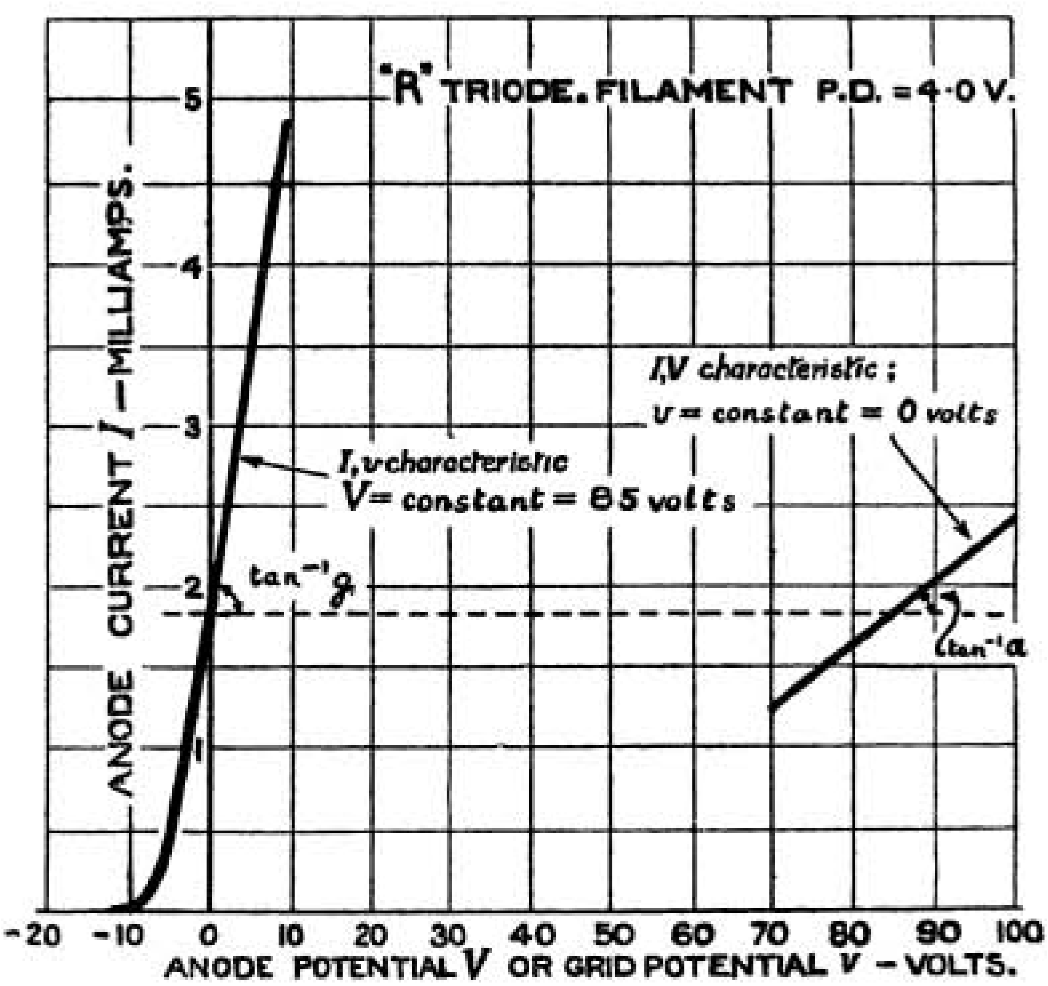

FIG. 2.

of I_1; it may be re-written

$$\rho_{1e} \equiv \frac{E_1}{\delta I_1}$$
$$= \rho_1 - \frac{g_1}{a_1} \cdot \frac{g_2}{a_2} \cdot \frac{r_1 r_2}{\rho_2} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \qquad (8)$$

where $\rho_1 \equiv \left(\frac{1}{a_1} + r_1 + R_1\right)$ and $\rho_2 \equiv \left(\frac{1}{a_2} + r_2 + R_2\right)$ are the intrinsic (non-retroactive) resistances of the anode circuits.

It is thus seen that the effect on the I_1 circuit of the retroaction between the two triodes is to introduce a negative resistance of magnitude

$$\frac{g_1}{a_1}\cdot\frac{g_2}{a_2}\cdot\frac{r_1 r_2}{\rho_2} \quad \ldots\ldots\ldots\ldots\ldots \quad (9)$$

where $$\rho_2 \equiv \frac{1}{a_2} + r_2 + R_2.$$

Under suitable conditions this negative resistance introduced by the retroaction may be made to approximate as closely as may be desired to the intrinsic positive resistance ρ_1, thus reducing the effective resistance to a vanishingly small value.

To examine the arrangement as an amplifier of E.M.F., let us make $E_1 = 0$, and find the magnification ratio m between the applied small E.M.F. e_1 and the resulting change of P.D. $(\delta V_1 - \delta V_2)$ between the anodes. The magnification is

$$m = \frac{(r_1 + R_1)\,\delta I_1 - (r_2 + R_2)\,\delta I_2}{e_1}$$

$$= \frac{\frac{g_1}{a_1}\left(r_1 + R_1\right)\left(\frac{1}{a_2} + r_2 + R_2\right) + \frac{g_1}{a_1}\cdot\frac{g_2}{a_2}\cdot r_1\left(r_2 + R_2\right)}{\left(\frac{1}{a_1} + r_1 + R_1\right)\left(\frac{1}{a_2} + r_2 + R_2\right) - \frac{g_1}{a_1}\cdot\frac{g_2}{a_2}\cdot r_1 r_2}$$

$$\ldots \text{ from (4) and (6)} \ldots\ldots \quad (10)$$

If we take the simple and practical case of a_1, a_2, g_1, g_2 all approximately constant, it is clear that by increasing r_1 and (or) r_2 we can make the denominator as nearly zero as we like, and therefore the magnification as nearly infinite as we like. If the denominator becomes less than zero, the system passes irreversibly into a widely different equilibrium with different values of a and g. The practical limit to m is imposed by the inconstancy of resistances, batteries, and triodes, particularly the last; and by the necessity of avoiding the instability which may accompany the slight changes in a and g set up by the signal to be amplified. In cases where the incoming signal e_1 may be of either sense, instability has to be carefully guarded against if high amplification is to be obtained. If instability is not avoided, the device behaves like the "trigger relay" of Eccles and Jordan,* the connections of which are substantially those of Fig. 1 with R_1, R_2 and E_1 omitted.

3. MEANS OF OBTAINING STABILITY.

In order to obtain an amplifier at once sensitive and stable, that is an amplifier in which a small signal produces a large change continuing only as

* "A Trigger Relay utilising Three-Electrode Thermionic Vacuum Tubes." British Association Meeting, 1919. See Vol. I., No. 3 of this REVIEW. The Kallirotron was devised subsequently to, but independently of, the "trigger relay." In its theory the trigger relay is a particular case of the unstabilised Kallirotron.

long as the signal continues, the expression for m (10), must be large but must not become infinite under the action of the signal. That is

$$\frac{g_1}{a_1}\cdot\frac{g_2}{a_2}\cdot r_1 r_2 \overset{\approx}{\not>} \left(\frac{1}{a_1}+r_1+R_1\right)\left(\frac{1}{a_2}+r_2+R_2\right) \quad . \quad . \quad . \quad (11)$$

The effect of the signal on these expressions is to alter, if only very slightly, the quantities a_1, a_2, g_1, g_2. But the ratio g/a in a triode changes very much less rapidly with changes of grid and anode potential than do a and g separately. We may therefore regard the L.H.S. of (11) as unaffected, but the R.H.S. as affected, by the signal e. Hence m will vary only slightly with e if we make the external resistance $(r + R)$ of the anode circuit much greater than the internal anode resistance $1/a$. This is the familiar condition for making the magnification ratio $\frac{\delta V}{\delta v}$ of a single triode approximate to its limiting value g/a. The only practical difficulty in meeting it is that higher values of $(r + R)$ necessitate anode batteries of higher voltage. For example, if we wish to work on a fairly steep portion of the I,v characteristic without appreciable grid current, we need an anode potential of (say) 85 volts and current about $1\frac{1}{2}$ milliamps. So that with $(r + R) = 4(1/a) = 80{,}000$ ohms (say), the battery could not be less than 200 volts. Even then the change in each of the terms on the R.H.S. of (11) would still be as much as 20 per cent. of the change produced in a.

But the R.H.S. of (11) contains both a_1 and a_2, and if the product of the two terms $(1/a_1 + r_1 + R_1)$ and $(1/a_2 + r_2 + R_2)$ remains constant, changes in the individual terms do not matter. If there is any approach to symmetry between circuits 1 and 2, it is clear that when a_1 increases a_2 will decrease, since the potential and current changes are opposite in the two triodes. A convenient course is to make the two triodes and their circuits roughly similar; and if in addition we arrange to work over nearly straight portions of the I,v characteristic (*i.e.*, a and g nearly constant), we can obtain a fairly constant magnification (10) over a wide range of signal strength.

Stability may, however, be ensured without imposing any conditions of symmetry or rectilinearity of characteristic, merely by working always with that grid potential v which gives maximum magnification for the particular values of the resistances r and R, and controlling the amount of this magnification by adjusting the values of the resistances.* This process of adjustment, which is quite easily carried out, entirely prevents any signal, however strong, from producing the trigger effect; *i.e.*, ensures that the conditions after the cessation of any signal shall be the same as before its arrival. Magnification must then fall off as the strength of signal increases; it can be made to fall off slowly by providing the symmetrical and rectilinear condition described above, or rapidly to emphasise the limiter effect as described in section 7 below.

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* See No. 3 of the working instructions for a particular Kallirotron amplifier, Fig. 6 of this paper.

4. Symmetrical Circuits.

The symmetrical case is of practical importance, and is specially easy to deal with theoretically. Putting

$$a_1 = a_2 = a$$
$$g_1 = g_2 = g$$
$$r_1 = r_2 = r$$
$$R_1 = R_2 = R$$

expressions (8) and (10) become

$$\rho_e = \rho - \left(\frac{g}{a}\right)^2 \cdot \frac{r^2}{\rho} \quad \dots\dots\dots \quad (12)$$

where $\rho \equiv 1/a + r + R.$

$$m = \frac{g}{a} \cdot \frac{r + R}{\rho - \frac{g}{a} \cdot r} \quad \dots\dots\dots \quad (13)$$

The value of m (when large) can be significantly expressed in terms of the ratio between the external anode-circuit resistance $(r + R)$ and the effective resistance ρ_e. From (12) we have

$$\rho_e = \frac{1}{\rho}\left(\rho + \frac{g}{a} \cdot r\right)\left(\rho - \frac{g}{a} \cdot r\right)$$
$$= 2\left(\rho - \frac{g}{a} \cdot r\right) \text{ approx.}$$

$$\therefore \quad m = 2\frac{g}{a} \cdot \frac{r + R}{\rho_e} \quad \dots\dots \text{ from (13) } \dots\dots \quad (14)$$

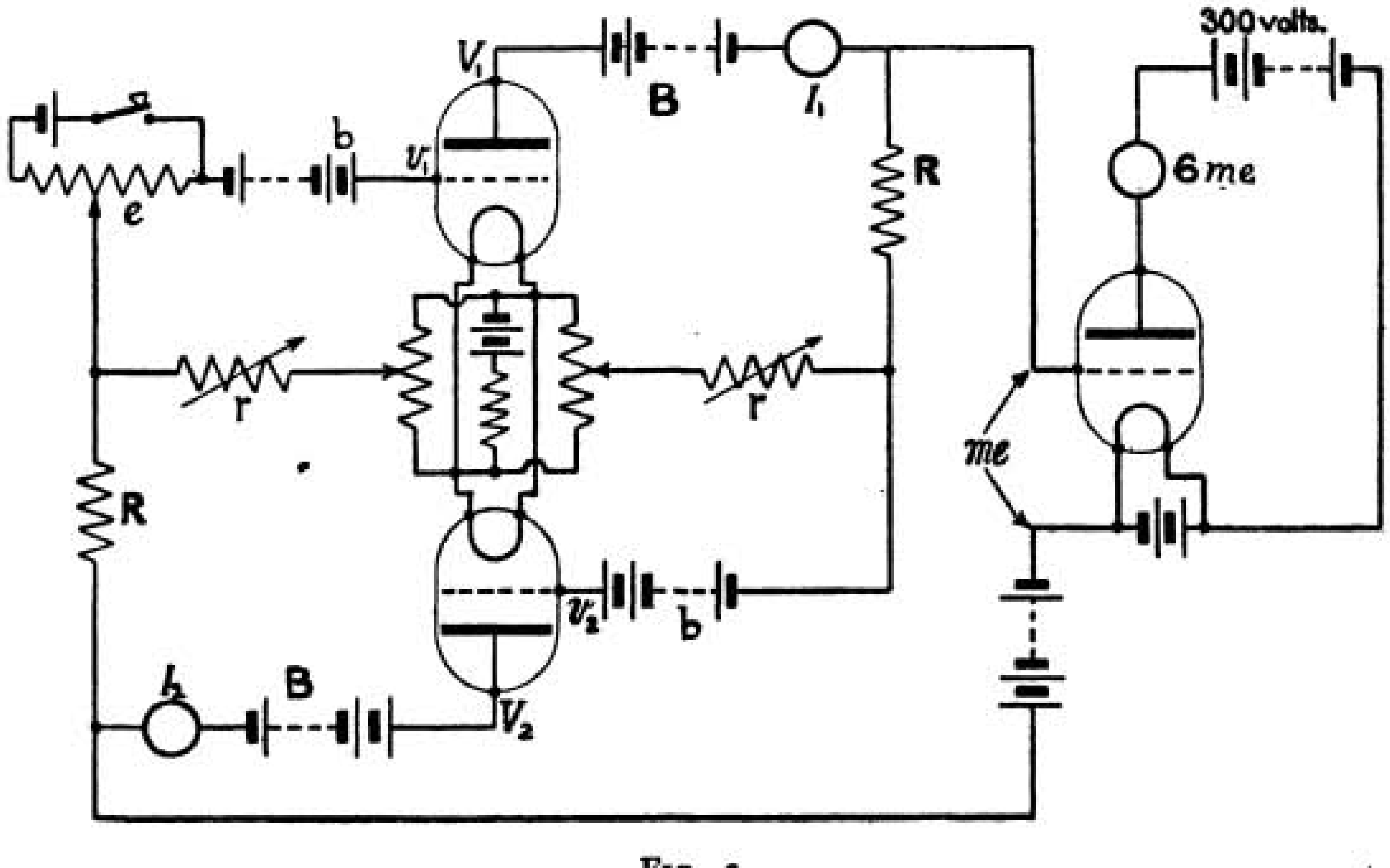


Fig. 3.

Thus, for example, if it were feasible to keep the effective resistance of the whole anode circuit at 1 per cent. of its part $(r + R)$, we should have a magnification 200 g/a. With the pattern of triode of Fig. 2, this would be about 1,600.

5. EXPERIMENTAL RESULTS WITH KALLIROTRON AS AMPLIFIER.

The only Kallirotrons so far made up have been for low-frequency signals. This is the easiest form with which to experiment, since small stray capacities are innocuous, and the resistances may be ordinary wire bobbins wound non-inductively as for wire telegraphy. Stable magnifications up to 2,000 were obtained without difficulty. In order to measure the changes of P.D. between the anodes, a high-resistance voltmeter consisting of a microammeter with a few megohms in series was sometimes used. But a more convenient arrangement is shown in Fig. 3, where the P.D. between the two anodes of the Kallirotron is applied to the grid-filament of a third triode, in whose anode circuit any convenient instrument may be inserted. In the tests quoted below, this instrument was a moving-coil voltmeter of 65,000 ohms reading to 500 volts. The change of voltmeter reading then indicated about six times the change of P.D. $(V_1 - V_2)$ between the Kallirotron anodes, and is shown as $6me$, where m is therefore the Kallirotron magnification.

In Table 1 below, three tests are fully quoted, to show the sort of values which may be worked with and the magnifications obtainable. The magnifications given are the highest which could be obtained with tolerable ease and certainty.

TABLE 1.

Test.	Filmt. P.D. volts.	r ohms.	R ohms.	B volts.	b volts.	I_1 mA.	I_2 mA.	V_1 volts.	V_2 volts.	v_1 volts.	v_2 volts.	e volts.	$6me$ volts.	m
1	4·0	10,850	50,000	150	0	0·8	0·7	101	108	−4·5	−5·6	·002	25	2,000
2	3·5	11,040	50,000	150	0	0·8	0·7	101	108	−4·2	−5·3	·002	10	900
3	4·0	7,600	30,000	150	8	1·4	1·4	97	97	−2·2	−2·4	·002	20	1,700

The figures of Table 1 may be used roughly to check the theory set forth earlier in this paper. The triodes used were a pair whose characteristics were nearly identical and had been determined, and the approximate values of a and g have been computed from the curves. Expression (13) shows that

TABLE 2.

Test.	r ohms.	R ohms.	a mA/volt.	g mA/volt.	$1/(a + r + R)$ ohms.	$(g/a)r$ ohms.
1	10,850	50,000	0·030	0·25	94,000	90,000
2	11,040	50,000	0·0275	0·23	96,000	92,000
3	7,600	30,000	0·034	0·29	67,000	65,000

instability should occur when

$$1/a + r + R = (g/a)r \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (15)$$

In Table 2 these quantities are tabulated for the tests shown in Table 1. The agreement between the last two columns is quite as close as could be expected from the rather rough computations of a and g, in which the errors might well be as much as 10 per cent.

Another experiment may be quoted for the benefit of those who feel difficulty in regarding the conception of negative resistance as anything but a fantastic mathematical artifice. In place of the resistances R_1 and R_2 were placed the two magnet bobbins of a post-office relay, re-wound with finer copper wire (S.W.G. 47). The time constant of the relay actuated directly from a battery was, of course, quite small—probably a fraction of 1/100 second. But when inserted in the anode circuits of the Kallirotron, the relay became more and more sluggish as the magnification was increased, and with large magnifications it would not respond quickly enough for even the slowest practicable hand-speed Morse signalling. The inductance L of the relay being constant, the time constant L/ρ_e became greater and greater as the negative resistance $(\rho - \rho_e)$ (section 2) was increased. The relay, at any rate, was able to appreciate the reality of the negative resistance.

A Kallirotron amplifier constructed after the principle of Fig. 3 is shown in the photographs, Figs. 4 and 5, and by the diagram of connections and instructions, Fig. 6.* The circuits only differ from those of Fig. 3 in that grid batteries are dispensed with, and that a small capacity is bridged across from grid to grid of the Kallirotron combination for the purpose of preventing the occurrence of high-frequency oscillations determined by the accidental inductances of connections between grids and anodes and the other portions of the circuits. The resistances are bifilar bobbins of the form used in ordinary telegraphy. Their self-capacity provides the only limit of frequency (viz. an upper limit) for which the instrument is suitable. It can be used for currents of Morse signalling frequency, the output circuit being then (presumably) an electromagnetic telegraph relay; or for currents of low acoustic frequency, the output circuit being a telephone or any galvanometer or recording instrument; or even for speech frequencies. It is, in fact, a remarkably powerful telephone amplifier, although the efficiency as such is believed to be far short of what it would be if the resistances were wound for low self-capacity as is customary in telephonic work.

With this instrument it is possible to operate a Post Office "B" relay (re-wound with finer wire) with a signal of no more than $\pm$ 1 millivolt—*i.e.*, much less than the weakest signal encountered in submarine telegraphy; and of course it faithfully reproduces a quasi-permanent signal (*e.g.*, a prolonged spacing current in double-current Morse work), which no transformer or condenser circuit can do. As a telephone amplifier, if A. speaks in an ordinary conversational voice 10 or 20 feet from an ordinary pair of

*** This instrument was designed and constructed at the Signals Experimental Establishment, Woolwich. I am indebted to Lieut.-Colonel Cusins, C.M.G., R.E., for permission to reproduce the photographs.**

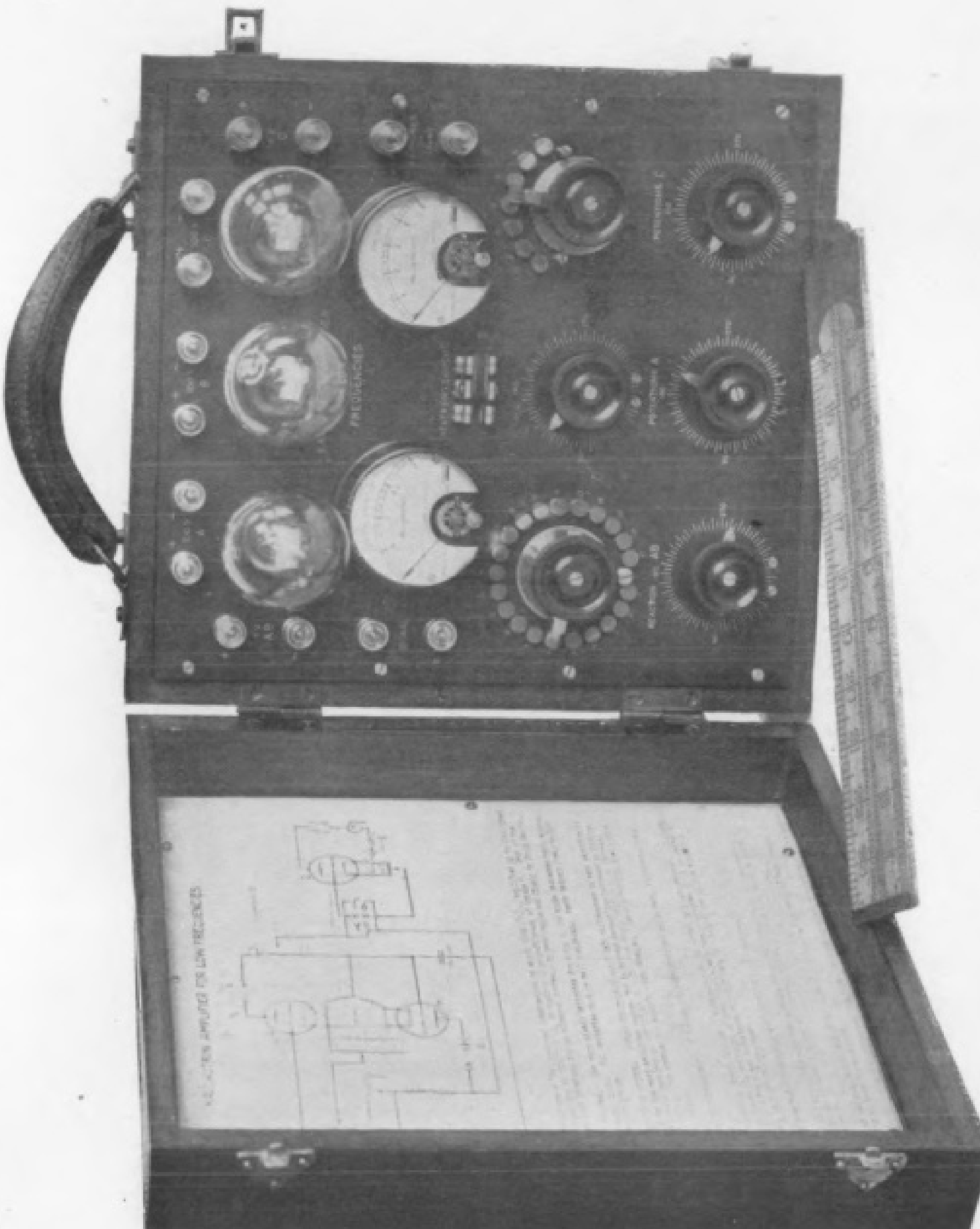


FIG. 4.—THE KALLIROTRON, GENERAL VIEW.

(To face p. 324.)

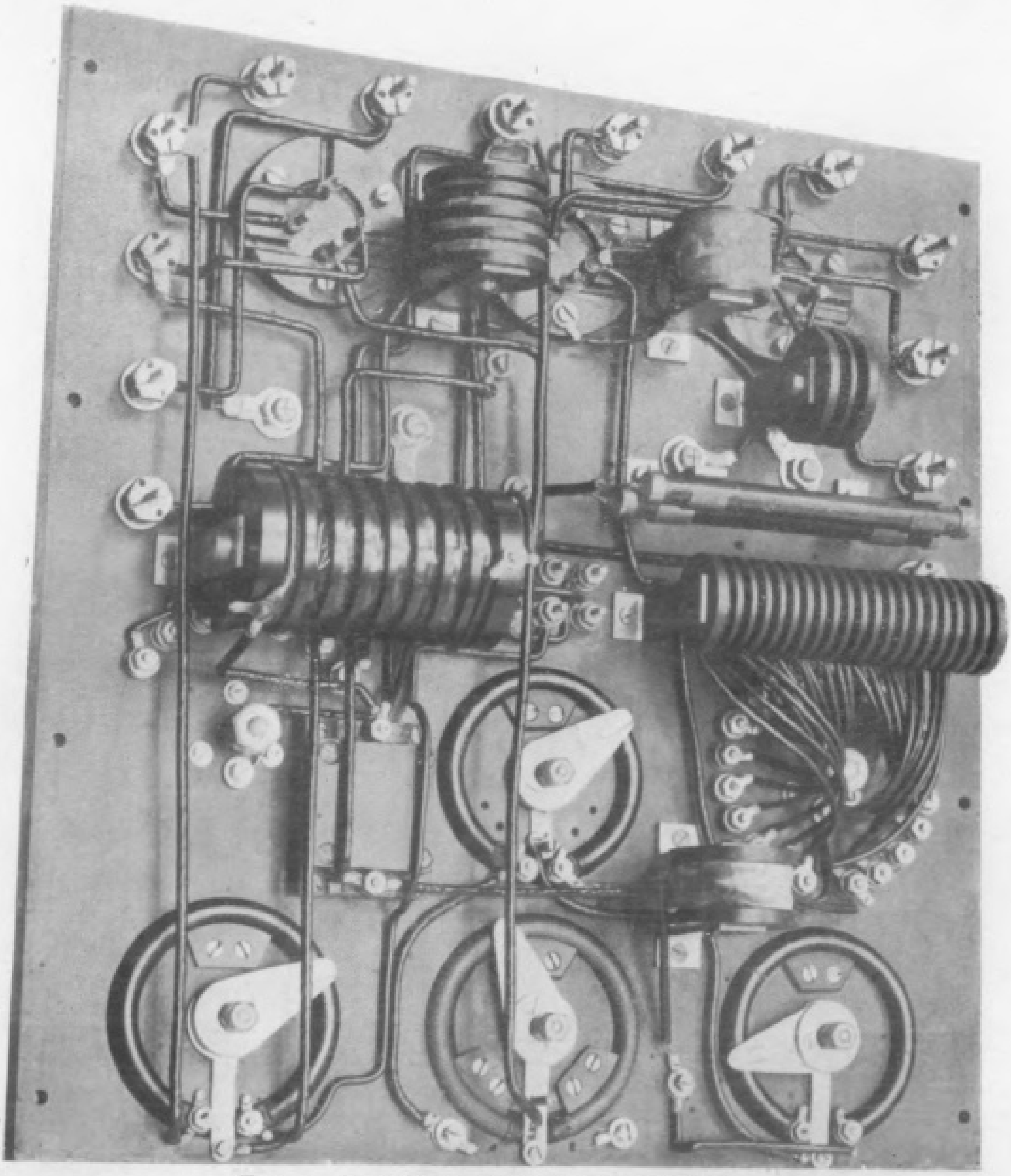
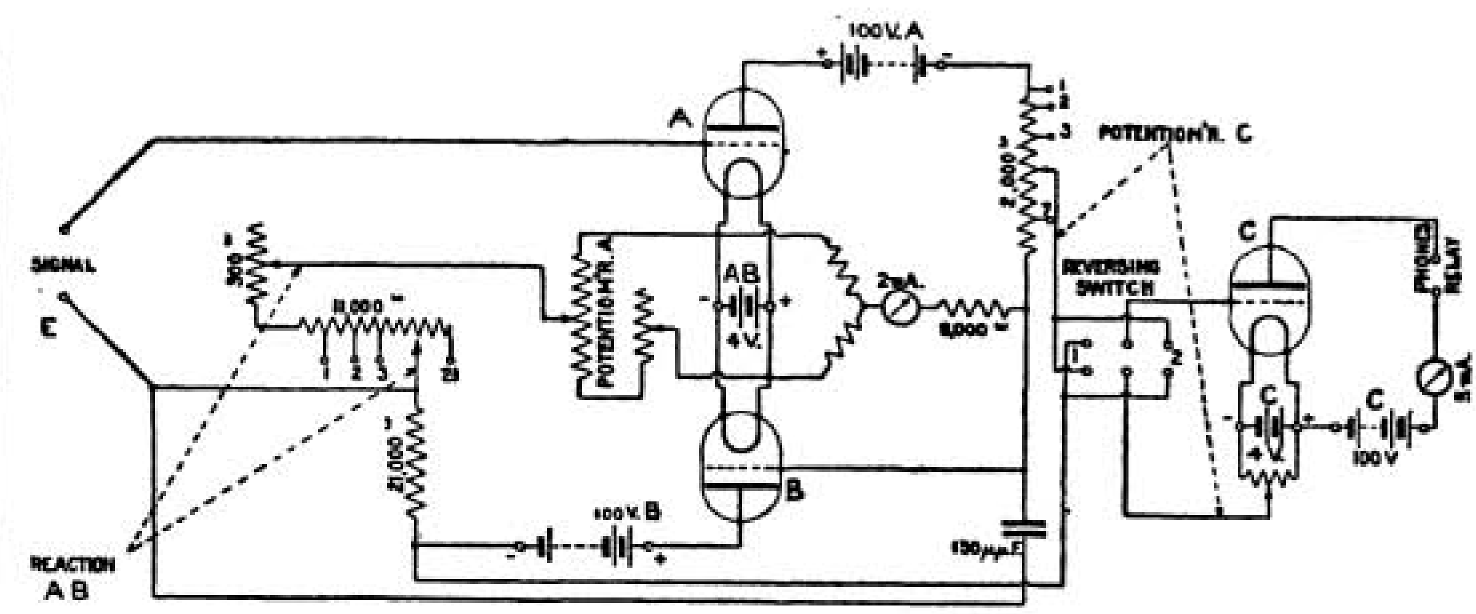


Fig. 5.—The Kallirotron Inside View



1. Circuits AB are a "Kallirotron" combination by which signal P.D., amplified up to 2,000 times according to setting of reaction AB, is applied to grid-filament of triode C. Each of the three adjustments provided for is effected coarsely by rear handle and finely by front handle.
2. Use "R" triodes. Use very steady batteries for A and B, the anode batteries being approximately equal and roughly 100 V. All batteries must be well insulated. Anode battery C may be 100 V. or any convenient value.
3. Open reversing switch. Adjust reaction AB until left milliammeter is very sensitive to potentiometer A in the most sensitive region; but is without instability indicated by flicking of milliammeter and backlash on potentiometer A. The more nearly reaction AB is increased towards instability, the greater the amplification obtained. Leave potentiometer A at middle of sensitive region.
4. If, owing to dissimilarity of triodes AB, adjustment cannot be made, interchange these triodes.
5. Close reversing switch to 1 or 2, whichever does not affect left milliammeter. In order that C may not upset AB, potential of grid C must always remain negative; it is determined by switch positions 1 and 2 and adjustment of potentiometer C. Adjust last to give about 1 mA. (if 100 V. used) in right milliammeter.
6. Slightly re-adjust potentiometer A and potentiometer C if necessary.
7. Signals of 1 mV. or less will then produce changes of current (right milliammeter) in phones or relay up to about ½ mA. per mV. Earthy part of signal circuit should be joined to terminal marked E.
8. Beware of bad insulation, and of batteries AB changing voltage owing to large changes of temperature or to becoming exhausted.

FIG. 6.

high-resistance headgear telephones lying on a table and connected to the input terminals of the instrument in another room, B. hears loud speech in another pair of phones connected across the output terminals.

6. KALLIROTRON AS TELEPHONE AMPLIFIER.

The Kallirotron as a very sensitive amplifier for speech currents is of considerable interest; for in telephony there must be approximately equal amplification over a very wide range of frequencies (such as 200 to 4,000 periods per second), and low-decrement oscillatory circuits of the telephonic frequencies must not be used. Either of these conditions alone rules out the periodic form of retroactive amplifier. In the Kallirotron, the amount of amplification is independent of frequency, and there are no oscillatory circuits.

7. KALLIROTRON AS LIMITER-AMPLIFIER.

We have seen in section 3 that if

$$r + R >> 1/a,$$

the mean value of m is only slightly affected by the strength of the signal e. Conversely, to get a powerful limiter effect, we should make

$$r + R << 1/a.$$

This is most fully accomplished by making $R_1 = R_2 = 0$, as in Fig. 7.

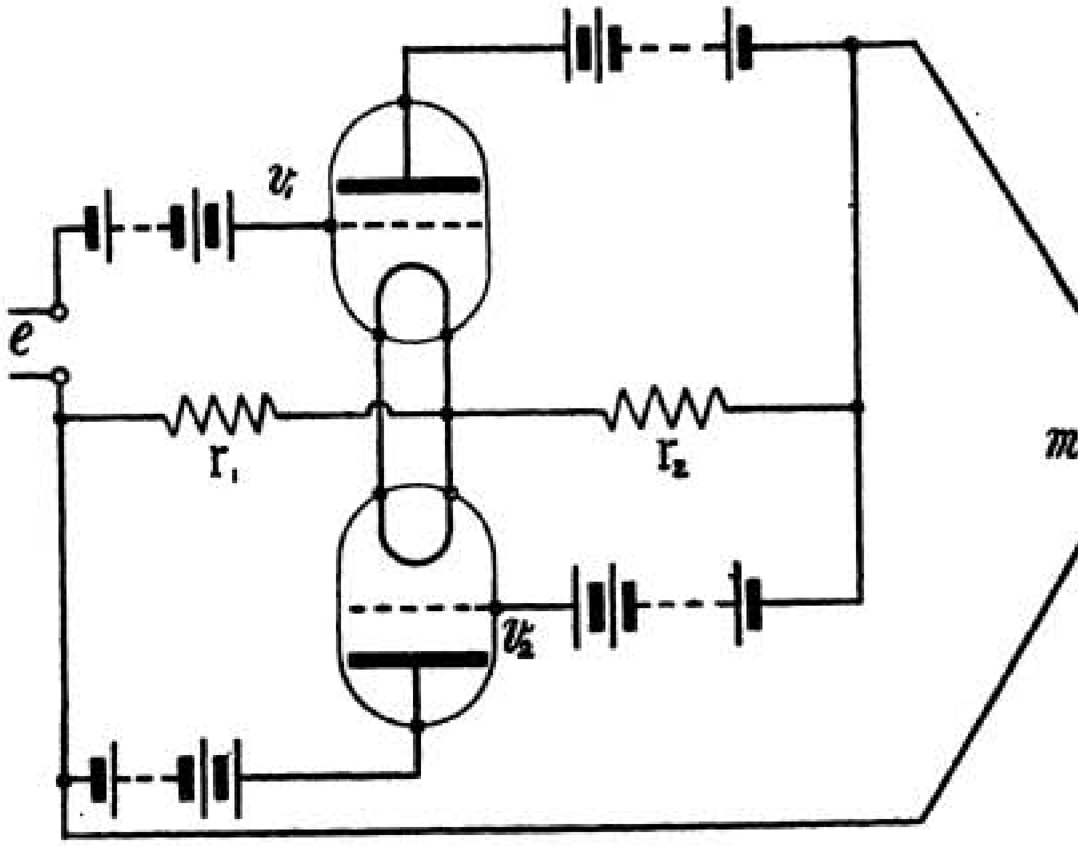


FIG. 7.

Expression (10) then becomes approximately

$$m = \frac{\frac{g_1}{a_1} \cdot r_1 \left(\frac{1}{a_2} + r_2\right) + \frac{g_1}{a_1} \cdot \frac{g_2}{a_2} \cdot r_1 r_2}{\left(\frac{1}{a_1} + r_1\right) \left(\frac{1}{a_2} + r_2\right) - \frac{g_1}{a_1} \cdot \frac{g_2}{a_2} \cdot r_1 r_2} \quad . \quad . \quad . \quad . \quad . \quad (16)$$

As a close enough approximation for our present purpose, let us simplify the algebra by taking

$$r_1 << 1/a_1$$
$$r_2 << 1/a_2.$$

We may then write in place of (16)

$$m = \frac{\frac{g_1 r_1}{a_1} \left(\frac{1}{a_2} + \frac{g_2}{a_2} \cdot r_2\right)}{\frac{1}{a_1 a_2} - \frac{g_1}{a_1} \cdot \frac{g_2}{a_2} \cdot r_1 r_2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (17)$$

In this expression, provided that m is large, the change produced by the signal is substantially confined to the first term of the denominator; and the more rapidly $1/(a_1 . a_2)$ increases, the more rapidly does m decrease, as the signal e increases.

Now an examination of the enlarged foot of an I, v characteristic such as that in Fig. 2 shows that over a suitable portion of the curve (*e.g.*, around $v = -8$ volts in the case of Fig. 2) g, and therefore also a, is approximately doubled by a 1-volt increase of grid potential. Let us then write

$$a_1 = \alpha_1 (1 + e)$$
$$a_2 = \alpha_2 (1 - e),$$

where α_1, α_2 are the values of a_1, a_2 with indefinitely weak signals. Then

$$\frac{1}{a_1 a_2} = \frac{1}{\alpha_1 \alpha_2 (1 - e^2)}$$
$$= \frac{1 + e^2}{\alpha_1 \alpha_2} \text{ approx. if } e^2 << 1.$$

Hence from (16)

$$m = \frac{\frac{g_1 r_1}{a_1} \quad \left(\frac{1}{a_2} + \frac{g_2}{a_2} . r_2\right)}{\left(\frac{1}{\alpha_1 \alpha_2} - \frac{g_1}{a_1} . \frac{g_2}{a_2} . r_1 r_2\right) + \frac{e^2}{\alpha_1 \alpha_2}}$$

$$\therefore \quad \frac{1}{m} = \frac{1}{\mu} + \frac{e^2}{g_1 r_1 (1 + g_2 r_2)} \quad \text{. . . . . (18)}$$

where μ is the value of m with indefinitely weak signals.

The significance of (18) is best seen from a numerical example. For simplicity we will take the symmetrical arrangement. Suppose $V_1 = V_2 = 85$ volts, $v_1 = v_2 = -8$ volts; then approximately $g_1 = g_2 = 0{\cdot}08$ mA./volt $= 8 \times 10^{-5}$ mho, and $a_1 = a_2 = 1 \times 10^{-5}$ mho. The approximate values of $r_1 = r_2 = r$ are calculable from (15), putting $R = 0$; thus

$$\frac{1}{10^{-5}} + r = 8 r$$
$$\therefore \quad r = \frac{10^5}{7} \text{ ohms.}$$

With these numerical values (18) becomes

$$\frac{1}{m} = \frac{1}{\mu} + \frac{e^2}{\frac{8}{7}\left(1 + \frac{8}{7}\right)}$$
$$= \frac{1}{\mu} + \frac{e^2}{2{\cdot}4}$$

Hence output is

$$me = \frac{2{\cdot}4\,\mu e}{2{\cdot}4 + \mu e^2}.$$

This quantity increases as e increases; passes through a maximum value when $e = \sqrt{\frac{2{\cdot}4}{\mu}}$; and falls asymptotically to zero. In Table 3 the values of the output me are tabulated against values of the input e between 0 and 1 volt, for the two zero-signal magnifications μ of 1,000 and 100.

TABLE 3.

Input volts.	Output volts.	
	$\mu = 1{,}000$	$\mu = 100$
Zero.	Zero.	Zero.
0·0001	0·10	0·01
0·001	1·0	0·10
0·01	9·6	1·0
0·049	24·0 (max.)	—
0·1	19·4	7·1
0·155	—	7·7 (max.)
1·0	2·4	2·4

The table shows that we have produced a limiter-amplifier in which, when the signal reaches 0·049 (or 0·155) volt, any increase of strength actually reduces the output. Thus if this limiter-amplifier were applied to an antenna (nearly aperiodic or slightly mistuned to the signal) receiving a continuous-wave signal of something (say) between 1 and 10 millivolts, it should be possible, with proper precautions, by the ordinary tuning processes applied after the limiter, to select the desired signal and reject atmospherics and spark signals however strong.

Owing to the difficulty of devising suitable finely adjustable resistances for high-frequency currents, a good deal of experimental work is likely to be necessary before a satisfactory Kallirotron for wireless signals is constructed; but the urgent need of an effective limiter, as providing one method—probably the simplest—of overcoming jamming, seems to make the attempt well worth while. It may be convenient to use thermionic circuits (of independent thermionic tubes) as the resistances r_1, r_2.

8. KALLIROTRON AS OSCILLATOR.

Any negative-resistance device can obviously be used to produce sustained oscillation. One simple arrangement is that shown in Fig. 8, where the circuit LC begins to oscillate with approximately its own independent frequency as soon as the retroaction has been increased sufficiently to reduce the resistance of its anode circuit below zero. Where such an oscillator is

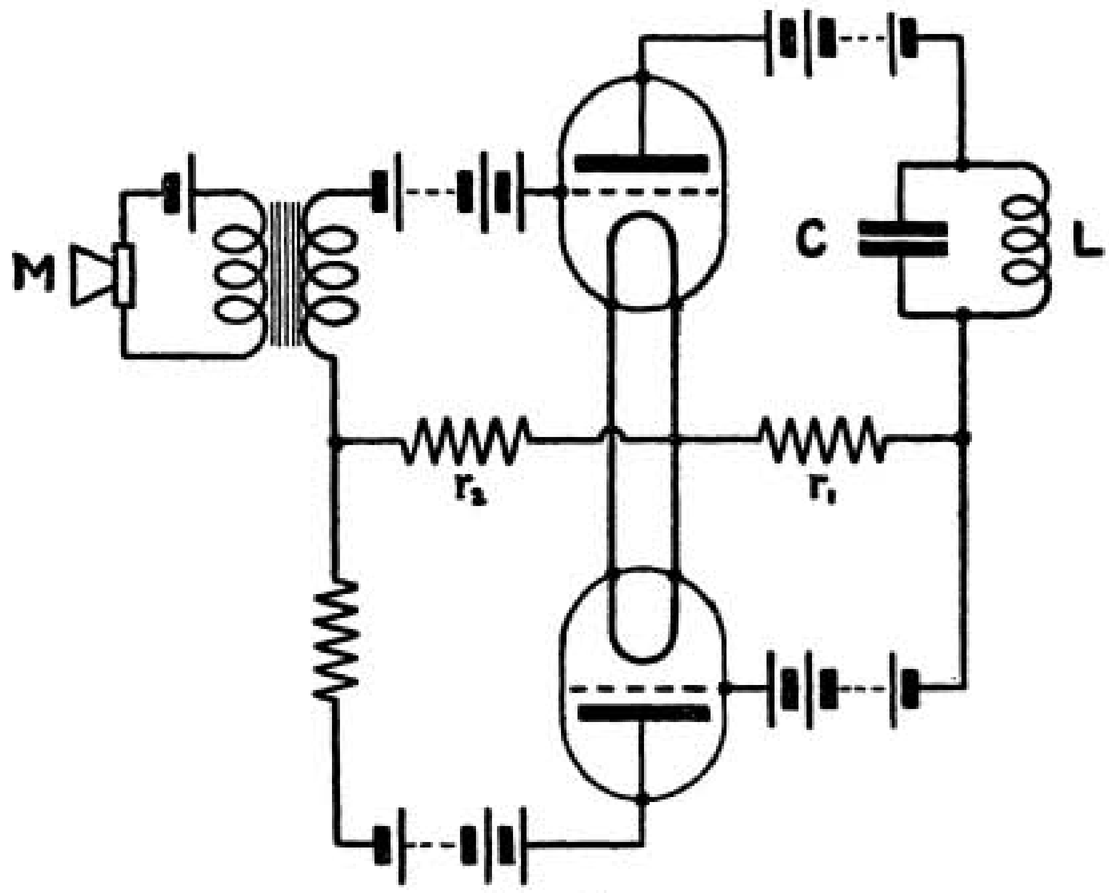


FIG. 8.

to be used for wireless telephony, speech control can be effected by a microphone M and transformer, the secondary of the latter being conveniently inserted between either grid and its resistance *r*.

Damped Oscillations in Coupled Circuits.

By G. BRAMWELL EHRENBORG.

(*Continued from page* 224.)

It will appear in what follows that α, β, p and q are the most important of the constants which occur in equations (9), and in Figs. 1 to 4 a graphical representation has been given of the ratios $\frac{\alpha}{p}$ and $\frac{\beta}{q}$ for various values of $\frac{R_1C_1}{R_2C_2}$ and of k. Each curve has been calculated on the supposition that R_1C_1, R_2C_2 and u_2 are kept constant and that u_1 alone varies. The quantity a which appears in the scale of ordinates is the ratio $\frac{R_2C_2}{\sqrt{u_2}}$. It is known that if circuit 1 is removed altogether, so that circuit 2 oscillates by itself, the logarithmic decrement per semi-period of these oscillations is $\frac{\pi}{2}\frac{R_2C_2}{\sqrt{u_2}}$,

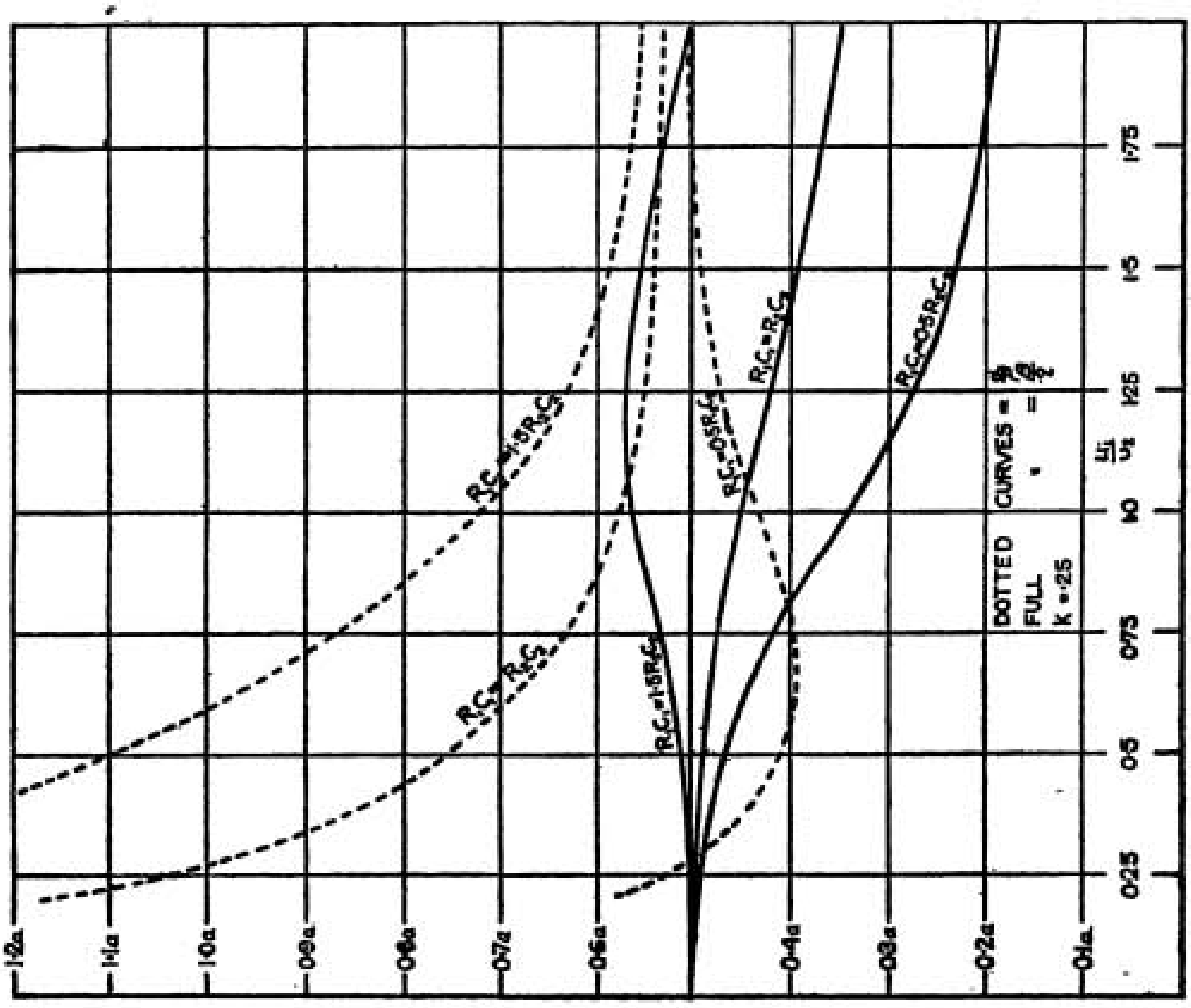

1·2a
1·1a
1·0a
0·9a
0·8a
0·7a
0·6a
0·4a
0·3a
0·2a
0·1a
0·25
0·5
0·75
1·0
1·25
1·5
1·75
DOTTED
FULL
K = ·25
CURVES

FIG. 2.

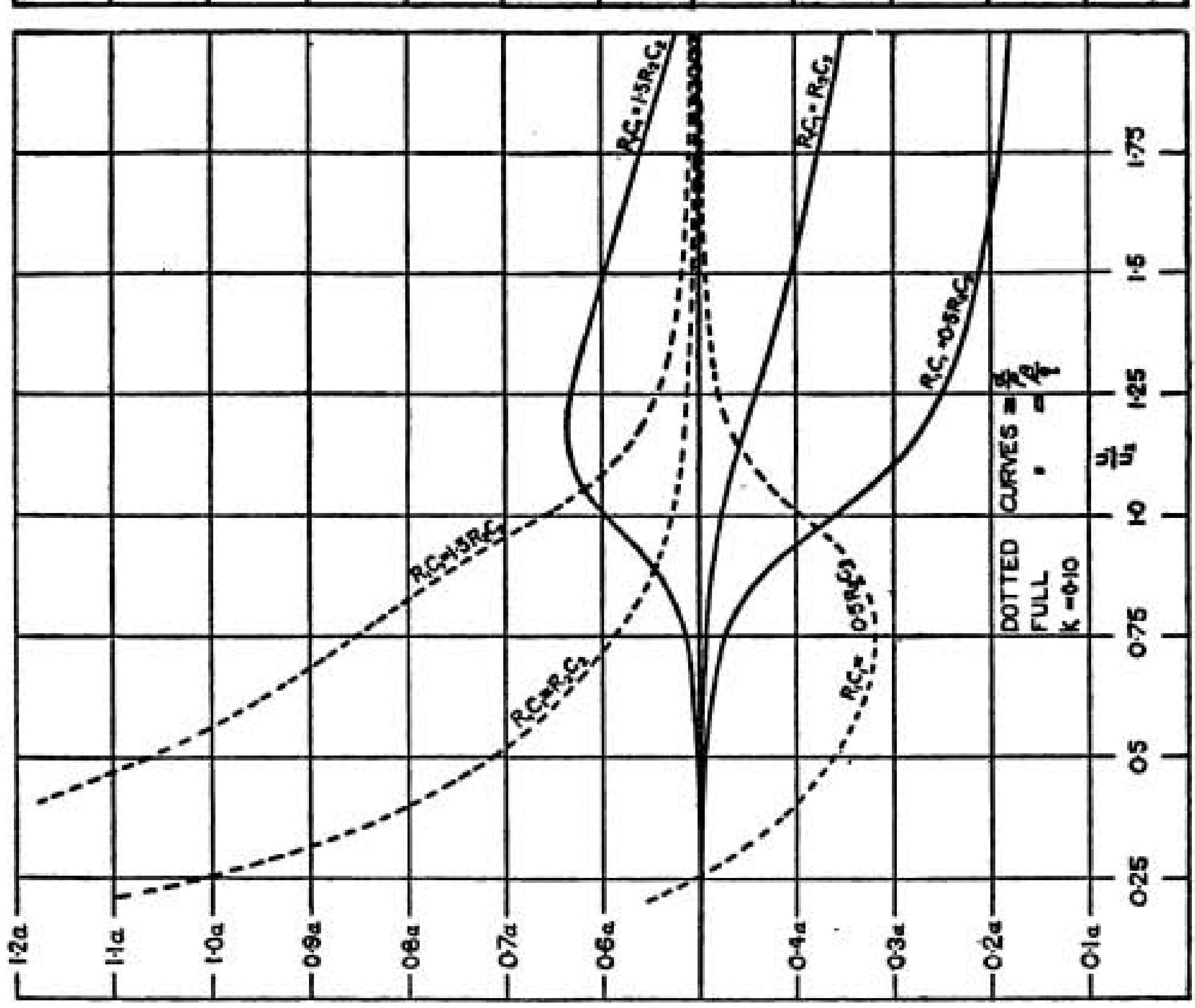

1·2a
1·1a
1·0a
0·9a
0·8a
0·7a
0·6a
0·4a
0·3a
0·2a
0·1a
0·25
0·5
0·75
1·0
1·25
1·5
1·75
DOTTED
FULL
K = 0·10
CURVES

FIG. 1.

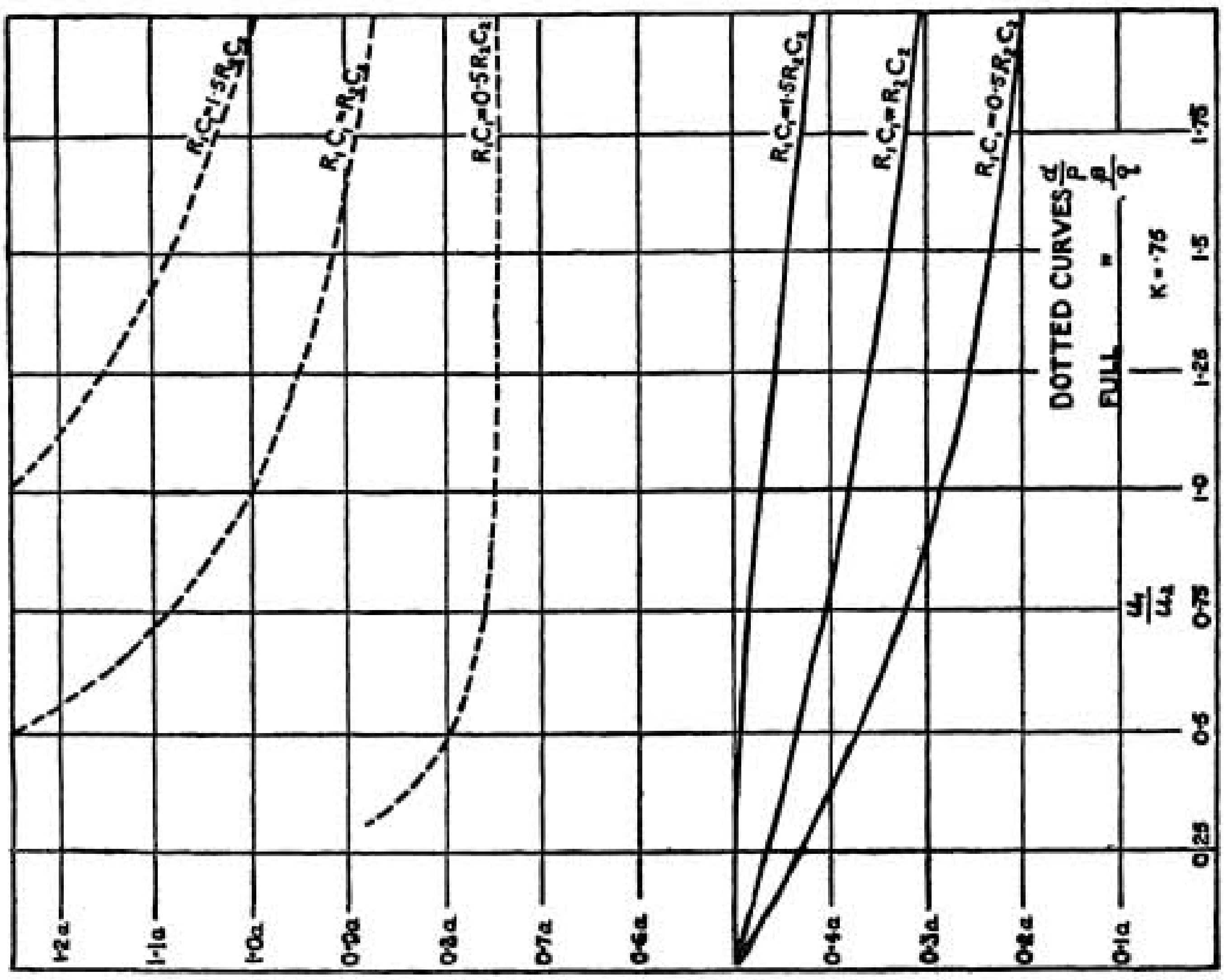

1·2a
1·1a
1·0a
0·9a
0·8a
0·7a
0·6a
0·4a
0·3a
0·2a
0·1a
0·25
0·5
0·75
1·0
1·25
1·5
1·75
$\frac{\omega_1}{\omega_2}$
$R_1C_1=1·5R_2C_2$
$R_1C_1=R_2C_2$
$R_1C_1=0·5R_2C_2$
DOTTED CURVES $\frac{\alpha}{p}$
FULL " $\frac{\beta}{q}$
K = ·75

FIG. 4.

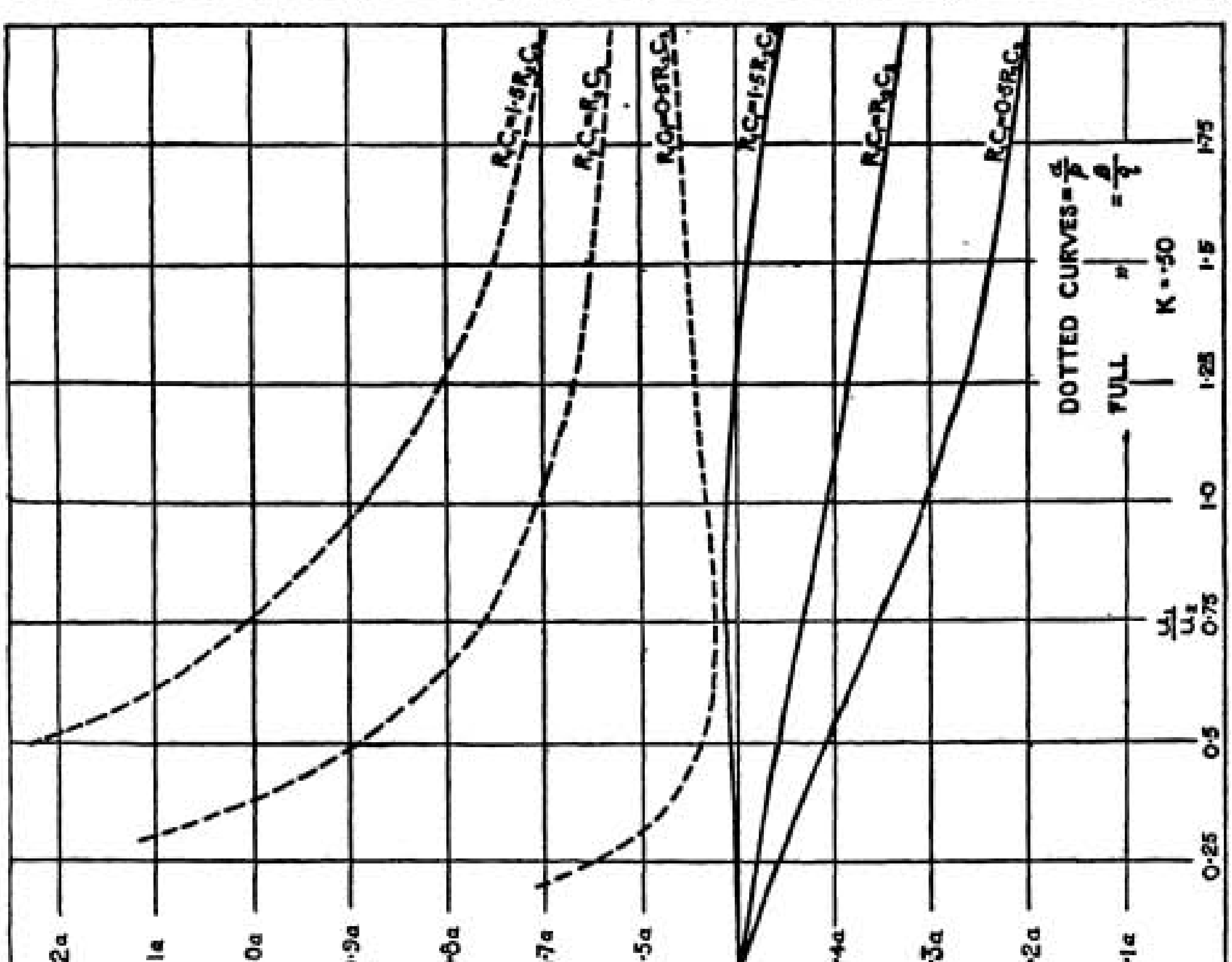

1·2a
1·1a
1·0a
0·9a
0·8a
0·7a
0·5a
0·4a
0·3a
0·2a
0·1a
0·25
0·5
0·75
1·0
1·25
1·5
1·75
$\frac{\omega_1}{\omega_2}$
$R_1C_1=1·5R_2C_2$
$R_1C_1=R_2C_2$
$R_1C_1=0·5R_2C_2$
DOTTED CURVES = $\frac{\alpha}{p}$
FULL " = $\frac{\beta}{q}$
K = ·50

FIG. 3.

so that $a = \frac{2}{\pi} \times$ logarithmic decrement in circuit 2 when isolated. As in practice one rarely encounters logarithmic decrements greater than 25 per cent., a will seldom exceed 0·16.

When $R_1C_1 = R_2C_2$ we see by (12) that $\frac{a}{p} = \frac{R_2C_2}{2}p$; hence, if we give the value $\frac{2}{\sqrt{u_2}}$ to a, we see that the curve showing $\frac{a}{p}$ when $R_1C_1 = R_2C_2$ may be used as a representation of p. Accordingly the numerical values of all the constants a, β, p, q can be found from the curves in question.

We now have to integrate equations (9). If D stands for the operator $\frac{d}{dt}$, and if we operate on the first equation with $D^2 + 2\beta D + q^2$ and on the second with fD and then subtract, the result will be in symbolical form

$$\{(D^2 + 2aD + p^2)(D^2 + 2\beta D + q^2) - fgD^2\}\, x = 0 \quad . \quad . \quad (13)$$

We have $fg = \dfrac{\left(u_1 - \frac{1}{p^2}\right)\left(\frac{1}{q^2} - u_1\right)}{\left(\frac{1}{q^2} - \frac{1}{p^2}\right)^2}(R_1C_1 - R_2C_2)^2\, p^2q^2$, and by applying equations (5) this easily reduces to

$$fg = \frac{k^2}{1-k^2}\,\frac{(R_1C_1 - R_2C_2)^2}{\left(\frac{1}{q^2} - \frac{1}{p^2}\right)^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (14)$$

On account of the presence of the factor $(R_1C_1 - R_2C_2)^2$ this is quite a small quantity, so as a first approximation we may take as particular solutions of (13) the quantities $\epsilon^{(-at + it\sqrt{p^2 - a^2})}$, $\epsilon^{(-at - it\sqrt{p^2 - a^2})}$, $\epsilon^{(-\beta t + it\sqrt{q^2 - \beta^2})}$, and $\epsilon^{(-\beta t - it\sqrt{q^2 - \beta^2})}$. Before going any further it is necessary to examine how these solutions are affected when fg is taken into consideration. We will suppose that the effect of this is to change the first solution to $\epsilon^{\{-(a + \Delta a)t + it\sqrt{(p + \Delta p)^2 - (a + \Delta a)^2}\}}$. We will assume that Δp and Δa are so small that their squares and product may be neglected, an assumption that will be justified when we have found the actual values. On this assumption we find

$$\sqrt{(p + \Delta p)^2 - (a + \Delta a)^2} = \sqrt{p^2 - a^2} + \frac{p\,\Delta p - a\,\Delta a}{\sqrt{p^2 - a^2}},$$

so that the second approximation to the solution is

$$\epsilon^{\{-a + i\sqrt{p^2 - a^2} - \Delta a + i(p\,\Delta p - a\,\Delta a)/\sqrt{p^2 - a^2}\}t}$$

By substituting this quantity for x in (13) we can determine the values of Δp and Δa. If we neglect $2fg\left(-a + i\sqrt{p^2 - a^2}\right)\left(-\Delta a + i\frac{p\,\Delta p - a\,\Delta a}{\sqrt{p^2 - a^2}}\right)$

in comparison with $fg(-\alpha + i\sqrt{p^2 - \alpha^2})^2$ and if we notice that $(-\alpha + i\sqrt{p^2 - \alpha^2})^2 + 2\alpha\,(-\alpha + i\sqrt{p^2 - \alpha^2}) + p^2 = 0$, we get as the result of the substitution

$$\left[2i\sqrt{p^2-\alpha^2}\left\{\left(-\alpha + i\sqrt{p^2-\alpha^2}\right)^2 + 2\beta\left(-\alpha + i\sqrt{p^2-\alpha^2}\right) + q^2\right\} \times \left(-\Delta\alpha + i\,\frac{p\,\Delta p - \alpha\,\Delta\alpha}{\sqrt{p^2-\alpha^2}}\right) - fg(-\alpha + i\sqrt{p^2-\alpha^2})^2\right] \times \epsilon^{\{-\alpha + i\sqrt{p^2-\alpha^2} - \Delta\alpha + i(p\,\Delta p - \alpha\,\Delta\alpha)/\sqrt{p^2-\alpha^2}\}t} = 0.$$

If this equation is to be satisfied, the real and imaginary parts of the expression inside the square brackets must be separately equal to zero, so we find

$$\{(p^2 - q^2) - 4\alpha\,(\alpha - \beta)\}\;\Delta\alpha + 2p\,(\alpha - \beta)\,\Delta p = -fg\alpha$$
$$\{4(p^2 - 2\alpha^2)(\alpha - \beta) + 2\alpha\,(p^2 - q^2)\}\;\Delta\alpha - \{2p\,(p^2 - q^2) - 4\alpha p\,(\alpha - \beta)\}\,\Delta p = fg\,(p^2 - 2\alpha^2).$$

It is quite sufficient for us to know the order of magnitude of $\Delta\alpha$ and Δp, accurate values not being required, so we will neglect α^2 and β^2 in comparison with p^2 and q^2; the above equations then become

$$(p^2 - q^2)\,\Delta\alpha + 2p\,(\alpha - \beta)\,\Delta p = -fg\alpha$$
$$\left\{\frac{\alpha}{p}(p^2 - q^2) + 2p\,(\alpha - \beta)\right\}\Delta\alpha - (p^2 - q^2)\,\Delta p = +\frac{1}{2}fgp$$

of which the approximate solutions are

$$\left.\begin{aligned}\Delta\alpha &= \frac{fg}{(p^2 - q^2)^2}(\alpha q^2 - \beta p^2) = -\frac{k^2u_1u_2(R_1C_1 - R_2C_2)^3}{2\left(\frac{1}{q^2} - \frac{1}{p^2}\right)^5}(u_1 - u_2)\\ \Delta p &= -\frac{fg}{2\,(p^2 - q^2)}\,p = -\frac{k^2u_1u_2(R_1C_1 - R_2C_2)^2}{2\left(\frac{1}{q^2} - \frac{1}{p^2}\right)^3}\,p\end{aligned}\right\}. \quad (15)$$

If we investigate the solution $x = \epsilon^{(-\alpha t - it\sqrt{p^2 - \alpha^2})}$ the same values of $\Delta\alpha$ and Δp will be arrived at, and in the case of the two remaining solutions the corresponding quantities are

$$\left.\begin{aligned}\Delta\beta &= -\frac{fg}{(p^2 - q^2)^2}(\alpha q^2 - \beta p^2) = +\frac{k^2u_1u_2\,(R_1C_1 - R_2C_2)^3}{2\left(\frac{1}{q^2} - \frac{1}{p^2}\right)^5}(u_1 - u_2)\\ \Delta q &= +\frac{fg}{2(p^2 - q^2)}\,q = +\frac{k^2u_1u_2(R_1C_1 - R_2C_2)^2}{2\left(\frac{1}{q^2} - \frac{1}{p^2}\right)^3}\,q\end{aligned}\right\}. \quad (16)$$

We notice that $\Delta\alpha = -\Delta\beta$ and $\dfrac{\Delta p}{p} = -\dfrac{\Delta q}{q}$.

D D

The numerical values of $\frac{\Delta q}{q}$ are exhibited in Fig. 5, where the constant a has the same meaning as in Figs. 1 to 4. It is seen that when $R_1C_1 = 0{\cdot}5\,R_2C_2$ (or $1{\cdot}5\,R_2C_2$), $\frac{\Delta q}{q} = 0{\cdot}004$ if $k = 0{\cdot}10$ and $a = 0{\cdot}16$, so under these circumstances Δq (and Δp) can evidently be neglected. As the writer has no

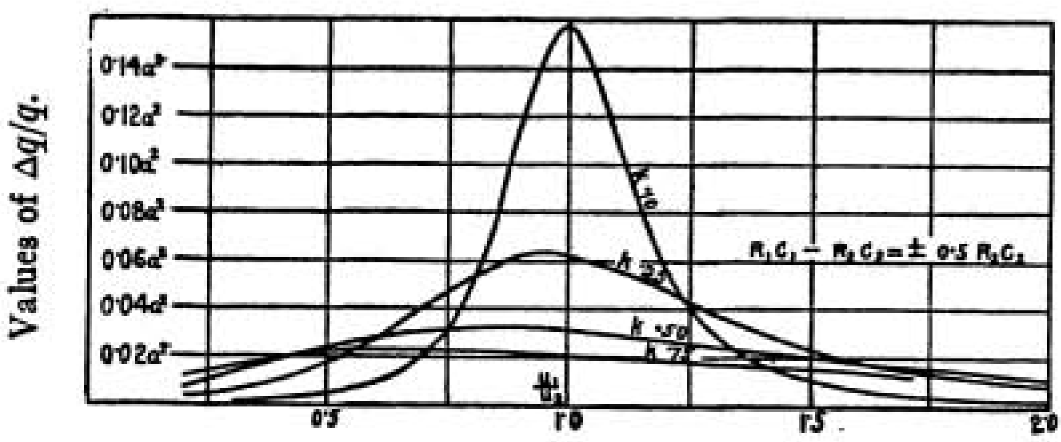


FIG. 5.

numerical data which would enable him to say what values of the ratio $\frac{R_1C_1}{R_2C_2}$ are likely to be encountered in practice, he has chosen the values 0·5 and 1·5 in a purely arbitrary manner for the purpose of calculating curves in connection with this paper. It is, however, a simple matter to modify the curves from the formulæ when other values of the ratio have to be considered.

The logarithmic decrement per semi-period of $\epsilon^{(-at + it\sqrt{p^2 - a^2})}$ is $\frac{\pi a}{\sqrt{p^2 - a^2}} = \pi \frac{a}{p} \frac{1}{\sqrt{1 - a^2/p^2}}$, so it is of importance to know what $\frac{a}{p}$ becomes in the second approximation. It evidently takes the form

$$\frac{a + \Delta a}{p + \Delta p} = \frac{a}{p} + \frac{\Delta a}{p} - \frac{a}{p}\frac{\Delta p}{p} = \frac{a}{p} - \left(\frac{a}{p} - \frac{(R_1C_1 - R_2C_2)(u_1 - u_2)}{p\left(\frac{1}{q^2} - \frac{1}{p^2}\right)^2} \right) \frac{\Delta p}{p}.$$

Similarly, $$\frac{\beta + \Delta\beta}{q + \Delta q} = \frac{\beta}{q} - \left(\frac{\beta}{q} - \frac{(R_1C_1 - R_2C_2)\,(u_1 - u_2)}{q\left(\frac{1}{q^2} - \frac{1}{p^2}\right)^2} \right) \frac{\Delta q}{q}.$$

The expressions $\frac{(R_1C_1 - R_2C_2)\,(u_1 - u_2)}{p\left(\frac{1}{q^2} - \frac{1}{p^2}\right)^2}$ and $\frac{R_1C_1 - R_2C_2)(u_1 - u_2)}{q\left(\frac{1}{q^2} - \frac{1}{p^2}\right)^2}$ which we shall call $\tan\theta$ and $\tan\phi$ respectively, in anticipation of the final results, where θ and ϕ appear as integration constants, are shown graphically in Fig. 6. On referring to Figs. 1—4 we see that $\tan\theta$, $\tan\phi$, $\frac{a}{p}$ and $\frac{\beta}{q}$ are all of the same order of magnitude, so if we can neglect Δp and Δq in comparison with p and q, we are equally justified in neglecting Δa and $\Delta\beta$ in comparison with a and β. It is evidently fairly safe to assert that if k is not less than 0·1 it is unnecessary to proceed to the second approximation, and that when integrating equations (9) we may neglect the product fg. On the other hand the maxima of the quantities in Figs. 5 and 6 grow very rapidly as k diminishes, so it is clearly necessary to proceed with caution when k is less than 0·1, unless $R_1C_1 - R_2C_2$ is small.

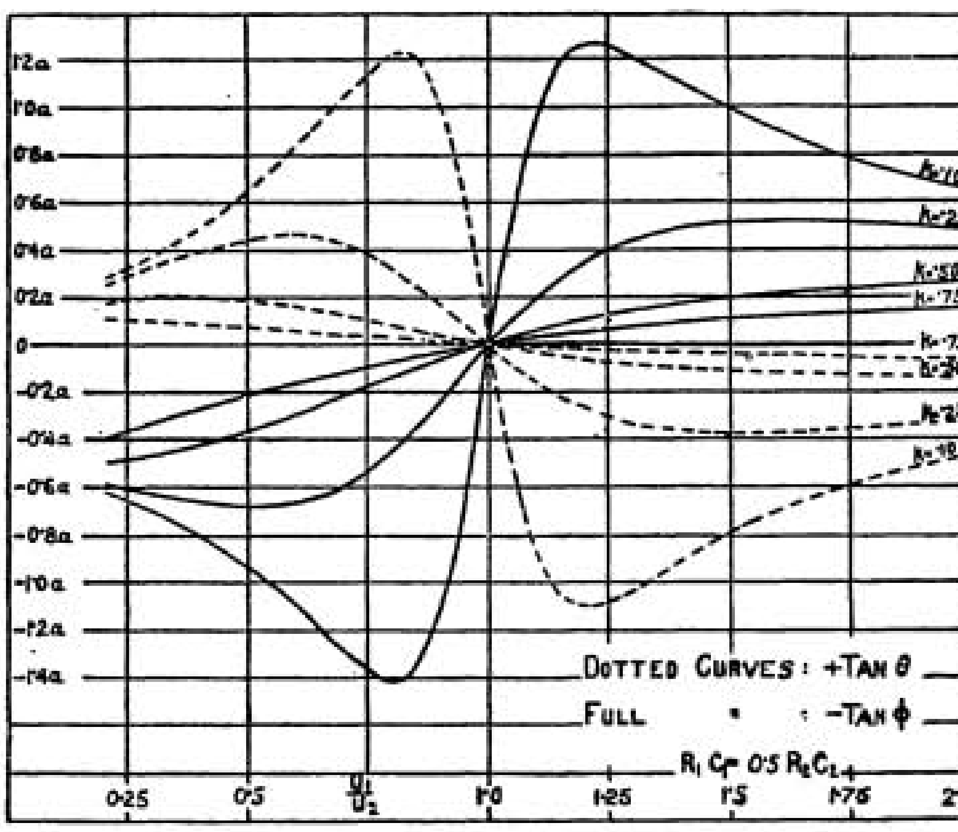


FIG. 6.

There is a further reason to exercise care when the coupling is very loose. From Figs. 1 to 4 we find that the variation in the values of $\frac{\alpha}{p}$ and $\frac{\beta}{q}$ when u_1 is nearly equal to u_2 becomes more and more rapid as k diminishes. The variation is due to the presence of the factor $\dfrac{u_1 - u_2}{\dfrac{1}{q^2} - \dfrac{1}{p^2}}$ in the second terms of $\frac{\alpha}{p}$ and $\frac{\beta}{q}$. (See equations (12).) By (6) this factor, which we shall call Z, may be expressed in the form $\dfrac{X}{\sqrt{X^2 + Y^2}}$, where $X = \dfrac{u_1 - u_2}{\sqrt{u_1u_2}}$ and $Y = 2k$. If $X, Y, Z,$ are looked upon as rectangular co-ordinates, Z may be represented graphically by the surface $Z = \dfrac{X}{\sqrt{X^2 + Y^2}}$. Now transform to cylindrical co-ordinates, *i.e.* $X = \rho \cos \phi$, $Y = \rho \sin \phi$, $Z = Z$; then we have $Z = \cos \phi$. A little consideration will show that the surface is generated by the motion of a straight line which intersects the axis of Z perpendicularly and rotates round it, rising and falling as it rotates in such a way that its height above the XY plane is equal to $\cos \phi$. The surface can easily be visualised if one looks upon it as a spiral staircase where the height of the steps is not constant;

in fact, for the first half of a complete circuit round the central pillar the staircase leads downwards, and then upwards during the second half. The point that should be grasped is that near the axis of Z the slope of the surface is very steep. Suppose that we are experimenting with two circuits which are very loosely coupled; suppose further that we have adjusted u_1 to be almost equal to u_2 but slightly less. From any one of a number of causes u_1 may now alter slightly so as to exceed u_2, and owing to the steep slope of the surface this is enough to change Z from -1 to $+1$, nearly. Hence, unless $R_1C_1 = R_2C_2$, the values of $\frac{\alpha}{p}$ and $\frac{\beta}{q}$ are practically speaking indeterminate under the circumstances considered.

This indeterminateness of $\frac{\alpha}{p}$ and $\frac{\beta}{q}$ for small values of k is a question of considerable practical importance, as is also the fact that $\Delta\alpha$, Δp, etc., increase very quickly as k decreases, for when making measurements with decremeters and cymometers one usually works with very weak couplings. As the readings taken on such instruments are not in general themselves the quantities one seeks to discover, but are intermediary quantities which have to be interpreted by formulæ derived from theory, it is doubly necessary to arrange that $R_1C_1 = R_2C_2$ if consistent results are desired.

(*To be concluded.*)

The Production of a Single Frequency in Spark Transmitters.

By THE EDITOR.

From time to time methods are described and patents are taken out for the production of a single frequency in the aerial of a spark transmitter. When an aerial is coupled to a tuned oscillatory circuit containing an ordinary open spark-gap, the coupling cannot exceed a certain small value without causing the aerial to radiate waves of two different frequencies. This way of describing the effect is based upon the result of mathematical analysis. If one could actually see the current in the antenna or the waves being radiated one would certainly describe the phenomenon in a different manner; they would see an alternating current of one definite frequency but with a variable amplitude. Up to a certain value of the coupling these surges or beats in the amplitude of the aerial current do not appear; below this value of the coupling the amplitude grows to a maximum and then gradually decreases to zero. If the coupling is increased, energy is transferred more rapidly to the aerial with the result that the transfer is complete before the damping due to radiation and various losses has sufficiently reduced the amplitude of the current to prevent the E.M.F. induced by it in the primary circuit maintaining the spark. The energy is then transferred back from the aerial to the primary circuit, and so on until the amplitude is sufficiently reduced to allow the spark to be extinguished. As Max Wien first clearly showed, a gap of the

Lepel type has such a pronounced tendency to extinction that the coupling can be considerably increased without causing this surging backward and forward of the energy.

As was stated above methods are continually being devised for giving a single frequency in the aerial whilst using an ordinary spark-gap. Let us examine this claim a little more closely. The ordinary coupled aerial gives a single frequency if the coupling is suitably adjusted. In what then does the advantage of the proposed methods consist? Although not always explicitly stated, it is implied that the proposed arrangements allow of a closer coupling without introducing beats. If this is not so, it is difficult to see their *raison d'être*. In some cases it is definitely stated that the method allows of closer coupling. This was so in the system "*à onde unique*" which we showed to be based on a fallacious method of calculating the coupling.

The only safe and reasonable measure of the coupling is the rate at which energy is transferred from one circuit to the other and—excluding quenching effects due to special types of spark-gaps—this rate of energy transfer is a measure of the frequency of the surges or beats. If the coupling is really closer, the energy will be transferred more rapidly backward and forward between the spark-gap circuit and the aerial, and the greater will be the divergence between the component frequencies.

It would appear then that, apart from improvements in the spark-gap, closer coupling while maintaining a single frequency is a contradiction in terms.

In a paper published in *The Electrician* of August 6th, 1915, we showed that the two frequencies occurring in the solution of the equations of two coupled oscillatory circuits could be merged into a single frequency for a definite value of the coupling. If the circuits have no damping two frequencies are always present except for zero coupling, but actual circuits always have damping and it was shown that the coupling can therefore have a certain small but definite value without introducing two frequencies. That is to say, that apart from the initial building-up period the oscillation can be regarded as a damped sine-wave of one frequency.

It may have been noticed, however, that some of the proposed systems employ a combination of magnetic and electric coupling, *i.e.* energy is transferred both by coils and condensers. In these systems the aerial is partly precharged. Now in a precharged aerial, *e.g.* Marconi's original plain aerial, when the gap breaks down, the damped oscillatory current in the aerial has its maximum amplitude at the initial moment, whereas in a coupled aerial, the amplitude is gradually built up from zero as the energy is transferred from the primary circuit. By combining these two processes it is possible to precharge the aerial to a certain degree and then to supply energy to it by magnetic coupling at a rate sufficient to compensate for the decrease in amplitude which would ordinarily take place in a simple precharged aerial. In this way the amplitude could be maintained at its initial value for a considerable time. This appears to be the idea underlying some of the suggested arrangements, but one must not overlook the fact that they involve precharging the aerial, the disadvantages of which are well known.

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

By Captain P. P. ECKERSLEY.

(1) Introduction.

This paper deals with experiments on duplex wireless telephony for aircraft carried out at the Wireless Experimental Establishment of the R.A.F.

With true duplex telephony sets the operator should be able to send and receive simultaneously, using the wireless telephone exactly as he uses the ordinary wire telephone. The chief problem of simultaneous reception and transmission is to protect the receiver from the powerful oscillations in the aerial when sending, without detriment to its sensitivity. To indicate the magnitude of the problem it may be noted that the standard aircraft transmitter deals with energies some million times greater than those dealt with by the receiver. The systems using a switch to change over from sending to receiving may be referred to as *switched wireless telephony* in contradistinction to *duplex-wireless telephony*. True duplex wireless telephony has great practical advantages over the switching method and by its use a subscriber to any ordinary telephone line could be put into communication with an aeroplane in flight or with a ship at sea.

A number of solutions of the problem have been suggested. For use on the ground two aerials, one for transmission and one for reception, may be employed, placed at right angles and spaced more than one-quarter wavelength apart. This is obviously not applicable to aircraft. Frames at right angles have also been suggested but it is questionable whether this would be very practical for aircraft.

Balancing systems with two aerials, one receiving and the other transmitting in which the effect of the transmitting aerial on the other is balanced against some equal and opposite effect purposely communicated through circuits under the operator's control, have given considerable success for ground work. This method is difficult of application to aircraft on account of varying antenna constants when non-rigid aerials are used. There is another general method of protecting the receiver in which the earth lead is split into two paths and it is arranged that all the transmitter currents pass through one path and all the received currents through the other.

To overcome the criticality of the balancing system a compromise is possible wherein the transmitter only oscillates when the operator is actually speaking. Such *quiescent aerial transmitters*, however, have to be rather complicated in order that they may transmit good speech, but by arranging them so that there is a small permanent oscillation in the antenna they give very much better articulation. This last type of transmitter has been given the name of *augmented oscillation transmitter* and when it is used with a partially protected receiver it constitutes a *partial duplex system.*

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* **Abstract of paper read before the Institution of Electrical Engineers (Wireless Section) on March 17th, 1920.**

(2) AUTOMATIC DUPLEX WIRELESS TELEPHONY SYSTEMS.

The quiescent aerial arrangement has little superiority as regards the user's point of view over the switching system, as it is still impossible for "chipping in" by the other station to be effected. The quiescent aerial transmitter was first proposed by the General Electric Company of America and later was developed independently by Major Whiddington. It is a direct outcome of the choke control system recently described by Major Prince.* Instead of modulating by the voice the intensity of a continuous source of power supplied to the oscillator as with choke control, power is only supplied when speaking. For this purpose the transmitting microphone is inductively coupled to the plate circuit of the oscillating valve so that the only source of voltage in that circuit is the E.M.F. derived from the secondary of the transformer influenced by the transmitting microphone. In an improved arrangement the microphone may control an amplifying valve, the plate circuit of which is used to feed the plate circuit of the oscillating valve. The arrangement is indicated in Fig. 1. In this diagram the microphone M controls the output of the valve V_1 through the grid circuit transformer T_1. The plate circuit of V_1 includes the primary winding of transformer T_2 and the high tension battery B_2. The only source of high tension current in the anode circuit of the main oscillating valve V_2 is the induced E.M.F. in the secondary winding of T_2. The quality of the radiated speech

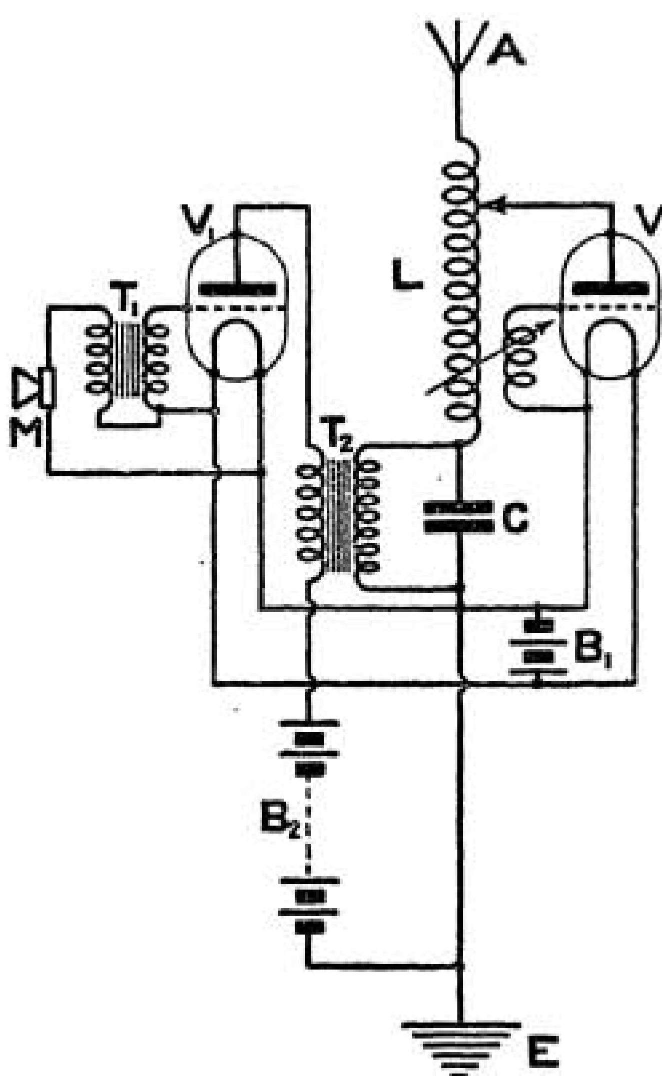

FIG. 1.

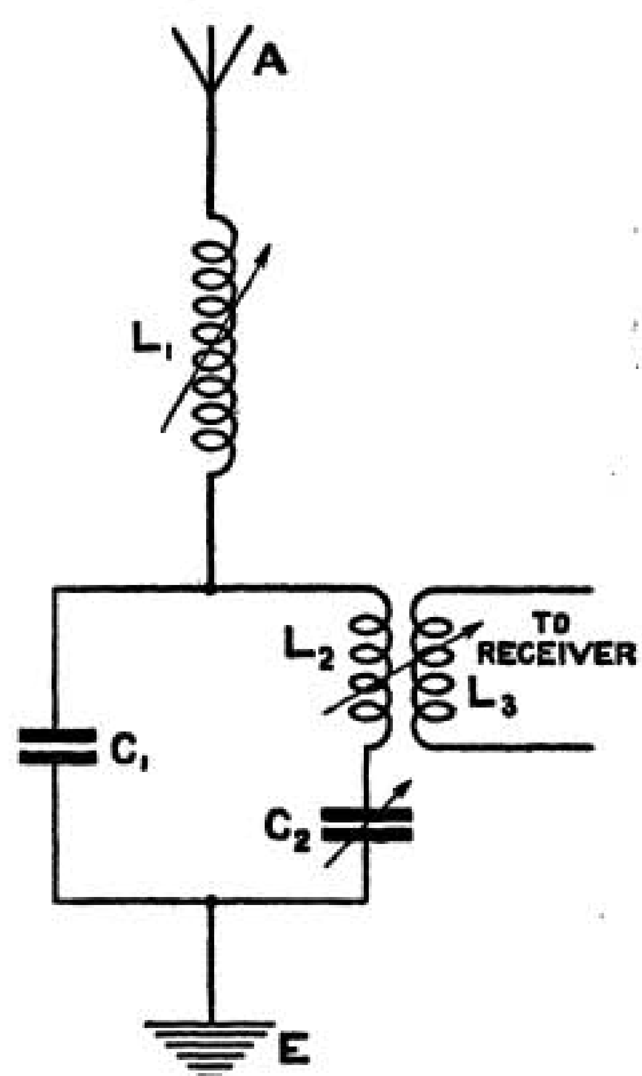

FIG. 2.

* See RADIO REVIEW, 1, pp. 281—283, March, 1920.

was much worse on the whole than that given by transmitters using the choke control method. It lacked a certain mellow roundness, and was sometimes broken and peaky. It was found, however, that by the application of a small steady voltage in series with the secondary of the transformer T_2 (Fig. 1) of just sufficient value to keep the system oscillating feebly, the speech quality was at once changed from bad to good.

Various theories to account for this effect are set out in the paper.

An alternative arrangement was subsequently investigated by the author in which the grid of the oscillating valve was continually varied in potential from an outside source at a frequency corresponding to the natural period of the aerial circuit. This was achieved by coupling the grid circuit to a closed oscillating circuit tuned to the frequency of the aerial oscillations.

The general trend of these experiments was to show that the quiescent aerial system fails owing to the non-instantaneous response of the oscillating valve to the short high tension pulses applied to it—in other words, that the high frequency oscillation does not build up as soon as the H.T. voltage is applied, while it also persists for a short time after the voltage is removed. With all these arrangements it was also found difficult to prevent the receiver from picking up high and low frequency disturbances from the transmitter, while the latter was active. This resulted in deafening noises in the receiving telephones when speaking into the microphone, and it was therefore necessary to protect the receiver from such disturbances. When this is done it is no longer necessary to use a truly quiescent aerial transmitter and a truer duplex telephone system becomes possible.

(3) True Duplex Wireless Telephone Systems.

In these arrangements any type of transmitter may be employed that will ensure the production of good speech quality. The main problem of the arrangement was to ensure that the receiver was not suffering any great loss of sensitivity due to the presence of relatively large alternating currents generated by the transmitter.

The first suggested method embodied the use of two aerials separated by a few feet from one another and using different wavelengths for transmitting and receiving. At the receiver a rejector circuit was included to bye-pass the induced oscillations of the transmitter frequency and to provide a path for the proper received signals. The arrangement used is indicated in Fig. 2. The condenser C_1 provides a bye-path for the oscillations of the transmitter frequency and should have as large a capacity as possible consistent with sensitivity. Its value may be increased by the use of the series inductance L_1. The shunt circuit L_2 C_2 is tuned to the frequency of the received signals, and the receiver is coupled to this circuit by the loose coupling L_2 L_3. A safe value for C_1 is 0·003 mfd. Using an aerial of capacity 0·00025 mfd., C_2 can be made to vary between 0·0005 and 0·001 mfd., depending upon the wavelength, and L_2 may be adjusted to suit the wavelength. It is claimed that this circuit is an improvement upon the simple rejector circuit, and that it reduces the number of necessary adjustments. The circuit will work with a difference of 20 per cent. between the two wavelengths.

(To be concluded.)

Wireless Telephony on Aeroplanes.

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

(*Continued from p.* 283.)

It was intended to replace the receiver of Fig. 2 which used only low frequency amplification, by one including high frequency magnifying stages, and for this purpose a five valve receiver was designed by Major Whiddington but it was not manufactured in sufficient quantities in time to play a large part in the war. As compared with the early three valve receiver however it was about ten times as sensitive for strong signals and thirty times for weak ones. It had two high frequency magnifications, and two low, and a detector valve.

The normal working range between machines with the apparatus that was generally in use was about four miles, though this was often very much exceeded. The range to a ground station was from twenty to fifty miles or more. A trailing aerial wire 120 feet in length was used in the transmitting machines with an aerial current of the order of 0·4 ampere.

When larger and more powerful ground stations were put up—as in the case of the home air raid defence stations—a machine could speak or be spoken to at distances of from 70 to 100 miles.

With the signing of the Armistice the Cologne postal service was equipped with these sets and some remarkable results were obtained. The Central Station on this route handled 5,000 messages during the five months that it was in operation.

At the conclusion of the paper a very brief outline was given of the most recent apparatus which the author is developing.

DISCUSSION.

Captain FURNIVAL referred briefly to the greater reliability obtained when using high-frequency magnification at the receiver than when using only detecting and low-frequency magnifying valves. In the construction of suitable transmitting microphones for use in aircraft a great deal was found to depend upon the material of the diaphragm as well as upon its thickness and size. Mica was found to give the best results but aluminium was also good.

Captain ROUND stated that the grid control modulation method becomes a type of choke control when the same valve is used both for generating the oscillations and for the modulation. The earlier circuit described in which the microphone was directly in series with the aerial circuit is a more useful one when larger powers are used, but, in that case, the microphone could not be directly inserted in the aerial circuit but must be arranged to influence it by a suitable coupling.

Mr. L. B. TURNER also dealt with the choke modulation control and outlined its mode of operation. He preferred to regard the choke more as maintaining constant the output current from the high-tension battery or generator, in place of the explanation given in the paper. Looking at the problem from this point of view, there should be no optimum value for the choke inductance as it would tend to maintain the current steadier the larger its value. When however the impedance of the choke coil at the frequency used becomes equal to the internal resistance of the oscillating valve, little advantage is gained by further increasing the inductance. In the example quoted in the paper in which an inductance of 5 henries was said to be required for a sound frequency of 750 per second, the impedance of such a coil at that frequency would be about 25,000 ohms. This is rather larger than but of the same order as the internal resistance of the valve. He also showed a diagram illustrating another suggested arrangement. In this case the microphone was inductively coupled to the plate circuit of a valve arranged to generate feeble oscillations only. The output from this feeble oscillator was amplified by a second valve, or by a bank of valves in parallel, and then transferred to the aerial circuit in the usual manner. Such an arrangement reduces the difficulty of two-way work.

It has been suggested that the unmodulated residuum of the radiation from the transmitter may have some useful effect at the receiver in stimulating the efficiency of the rectifier there used. Such an arrangement, however, is extremely inefficient, and it is much preferable to provide this steady component at the receiver itself rather than at the transmitter. The whole of the transmitted energy should then be modulated, or preferably matters should be so arranged that radiation only takes place when speech is being transmitted. At the receiver a local heterodyne may be used, tuned dead on to the incoming waves.

Major WHIDDINGTON. One fundamental feature of radiotelephony should not be forgotten in discussing any arrangement of transmitting or receiving circuits, and that is the change of wavelength which is inseparable to voice control of the radiation. If the modulated current is in the form of a uniform sine wave of frequency Q, the resultant output frequency which was originally P, varies between $P + Q$ and $P - Q$, hence it is impossible at the receiver to tune to all of the waves, and as a consequence the articulation becomes imperfect if strong reaction is used.

Captain P. P. ECKERSLEY stated that with the apparatus at present used in aircraft shorter wavelengths give better results than longer ones. It had been shown that 300 metres was preferable to 450 and therefore the wavelength fixed by the International Convention for use in aircraft, namely, 900 metres, was not at all a good one. It should be possible to find a more advantageous shorter wavelength which would be free from disturbances. With reference to the advantages and disadvantages of the choke control method it was surely better to so arrange the control that the modulation was both above and below the normal intensity of transmission instead of merely to modulate below the maximum. He thought that the quiescent aerial systems that had been mentioned by Major Whiddington did not give very good speech, and their only advantage was that one got rid of the changeover switch for changing from transmission to reception. With the choke control method, however, articulation was very good. The articulation obtained at the receiver was as much dependent upon the receiver as upon the transmitter. Breaking of the speech sometimes occurred even with the choke control method, but not so frequently as when grid control is used. The most serious problem in aircraft work was the elimination of magneto noises.

Major VINCENT-SMITH pointed out the enormous advantages of the remote control unit as applied to the apparatus described. One of the most important, in fact the most important, application of wireless telephony was to inter-machine work. The question of jamming of the wireless telephones was also an important one, but it was found that such jamming was never a very serious item on the Western Front.

Captain McDOUGAL stated that the main early work was concerned with reducing the size, weight and number of adjustments of the instruments. With the soft valves that were at first used in these sets adjustments were extremely difficult in the air as it was sometimes necessary to warm the valves to obtain the best results. The variations of the wavelength caused by changes in the configuration of the trailing aerial had been overcome by the use of fixed frame aerials on the machines. Small wavelength variations might also be caused by variations in the high-tension voltage. Magneto noises were, however, rather worse on the frame aerials than on the trailing aerials.

A few remarks were also contributed by Major ORME, Mr. DOWSETT and Professor FORTESCUE.

Major PRINCE in reply stated that the whole subject of wireless telephony covered a very wide field and that he had not intended to deal with all the various problems connected with it, but merely its application to aircraft work. He had not intended to imply that there was a definite optimum value for the inductance of the choke coil, but merely that the results improved as the choke was increased up to a point, but after that there was very little further gain. As to the power loss in the control valve this could be reduced to a very small quantity under normal conditions, but as soon as the microphone is spoken to the control valve absorbs more power. He thought that the idea of choke control originated in America.

Review of Radio Literature.

1. Articles and Patents.

269. FURTHER DISCUSSION ON "ELECTRIC OSCILLATIONS IN ANTENNAS AND INDUCTION COILS," BY J. M. MILLER. J. H. Morecroft. (*Proceedings of the Institute of Radio Engineers*, 7, pp. 652—654, December, 1919.)

A further contribution to the discussion on the paper with the above title * pointing out that what the effective inductance and capacity of an antenna are when it is oscillating in its fundamental mode, is largely a matter of the view point. It is pointed out that the formulæ obtained for the capacity and inductance depend upon whether the electromagnetic or the electrostatic energy is considered first in deriving the formulæ. In the latter case the relations $L_e = 8L_0/\pi^2$ and $C_e = C_0/2$ would have been obtained, instead of the relations given in the original paper.

270. ON THE PHENOMENA PRODUCED BY THE INTERRUPTION OF A STEADY CURRENT IN AN OSCILLATORY CIRCUIT. G. Zickner. (*Jahrbuch der Drahtlosen Telegraphie*, 14, pp. 478—498, October, 1919.)

The theory of the oscillation produced by the cessation of a steady current through the inductance of an oscillatory circuit is discussed mathematically. Experimental observations in support of theory are given, including Braun tube oscillographs.

271. DIFFICULTIES IN THE TRANSMISSION AND RECEPTION OF SUSTAINED WAVES. M. Wien. (*Jahrbuch der Drahtlosen Telegraphie*, 14, pp. 442—451, October, 1919.)

A non-mathematical discussion of the following points: (*a*) difficulties in the production of oscillations, (*b*) alteration of wavelength, (*c*) difficulties in distinguishing between sending stations, (*d*) harmonics, (*e*) radiation from receiving antenna, (*f*) interference from spark stations, (*g*) production of anode voltage, (*h*) difficulties in manufacture of military C.W. sets.

272. THE CALCULATION OF THE SELF-INDUCTANCE OF RECTANGULAR FLAT COILS. A. Esau. (*Jahrbuch der Drahtlosen Telegraphie*, 14, pp. 386—394, September, 1919.)

The calculation follows the same lines as his previous paper on rectangular solenoidal coils.† It is not a current sheet method but sums up the effect of the separate turns. The result is given in the same form as before, viz., $L = 8\,a\,n\,(S_1 + S_2)$ where a is the mean radius and n the number of turns. Tables and curves are given for the constants S_1 and S_2 which are functions of n, a and the pitch of the turns.

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* See RADIO REVIEW Abstract No. 2, October, 1919.

† RADIO REVIEW Abstract No. 73.

273. Stranded or Solid Wire? W. Rogowski. (*Archiv für Elektrotechnik*, 8, p. 269, 1919.)

A mathematical investigation of the conditions under which a coil wound with solid wire has a lower high-frequency resistance than if a stranded wire were used; also of the relation between the resistance and the number of wires in the stranded conductor.

274. Skin Effect in Iron. L. Truxa. (*Archiv für Elektrotechnik*, 8, pp. 137—144, August 28th, 1919.)

A theoretical investigation of the apparent resistance and equivalent permeability taking the hysteresis loss into account.

275. An Oscillation Source for Radio Receiver Investigations. J. Weinberger and C. Dreher. (*Proceedings of the Institute of Radio Engineers*, 7, pp. 584—602, December, 1919.)

Describes a triode generating source of sustained oscillations suitable for laboratory experiments in which it is necessary that stray electric and magnetic fields be reduced to a minimum. Multilayered coils are used to reduce the stray magnetic field and the whole apparatus is enclosed in copper or brass shields connected to one terminal of the filament battery. The source described provides an E.M.F. rather than a current thus simulating closely the effect of electric waves on an antenna.

276. Apparatus for High-frequency Measurements E. Nesper and P. Floch. (*Physikalische Zeitschrift*, 20, pp. 371—375, August, 1919.)

An arrangement of vacuum tubes for a variety of H.F. measurements as well as for radio-transmission and reception.

277. Oscillographic Study of Thermionic Generators. K. Mühlbrett. (*Archiv für Elektrotechnik*, 8, pp. 188—190, September 15th, 1919.)

Grid and anode current and voltage waves at a frequency of 50, both as an amplifier and as a generator, using a standard Siemens oscillograph.

278. Harmonic Oscillations in Directly Excited Antennas used in Radiotelegraphy. L. Lombardi. (*Proceedings of the Institute of Radio Engineers*, 7, pp. 636—647, December, 1919.)

Deals with the author's measurements of the frequencies, decrements and relative amplitudes of the fundamental and harmonic oscillations of a directly excited artificial antenna. Marconi, brass and Boas spark gaps were used.

279. REINFORCED HARMONICS IN HIGH-POWER ARC TRANSMITTERS. F. A. Kolster. (*Proceedings of the Institute of Radio Engineers*, 7, pp. 648—651, December, 1919.)

A discussion of Lombardi's paper (see previous abstract). Some experiments on the directly excited antenna system of the arc station at San Francisco showed that an arc generating at 7,200 metres fundamental gave a very strong harmonic at 1,100 metres. The effect is explained in terms of reactance diagrams, and a method of eliminating the interference effects of the harmonic suggested. This consists in coupling to the antenna a closed circuit including an energy absorbing resistance, and tuned to the undesired harmonic.

280. SPARK GAPS. A. Marino. (*British Patent* 129700, November 29th, 1917. Patent accepted, July 24th, 1919.)

Various forms of multiple quenched spark gaps are described. The complete group of electrode plates is clamped together by bolts external to the electrode surfaces, and may be mounted upon a rotating shaft.

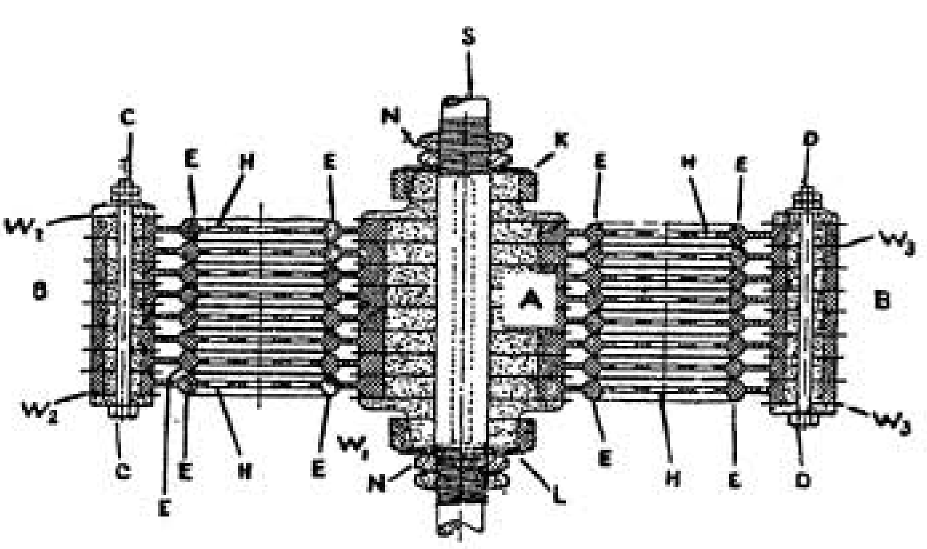

FIG. 1.

One of the forms is illustrated in Fig. 1. S is the shaft upon which the electrode plates are clamped by the nuts NN. The central portion A of the electrode plates is circular and provided with two or more extension parts BB, on which the electrode surfaces EE are formed. The separate electrode plates are kept apart by the insulating washers W_1 W_2 W_3, etc., and are also bolted together, insulated from one another, at their edges as indicated at C, D, W_2, and W_3. The spaces enclosed by the annular electrode surfaces are provided with ventilating holes HH. The electrodes are usually of silver or silvered copper, but for use on direct current the adjacent electrode surfaces may be of different shape and material. Slip rings KL are provided on the shaft and arrangements are also made for connecting the rings to any one of the plates, thus enabling the number of gaps in the circuit to be varied.

281. MODERN RADIO TRANSMITTERS OF UNDAMPED OSCILLATIONS. G. von Arco. (*Jahrbuch der Drahtlosen Telegraphie*, 14, pp. 558—569, November, 1919.)

A comparative discussion of the arc, the high-frequency alternator and the vacuum tube generator.

282. SPARK GAPS. A. Marino. (*French Patent* 496118, November 23rd, 1917. Published October 28th, 1919.)

The invention relates to spark gap apparatus used in wireless telegraphy. For particulars, see the British Patent No. 129700.*

283. IMPROVEMENTS RELATING TO RADIO TELEGRAPHIC APPARATUS. M. Latour. (*British Patent* 132118, November, 1916. Patent accepted, September 11th, 1919.)

The same valve is used both for amplifying the modulation currents and also for generating the high-frequency oscillations. The microphone M, Fig. 2, is coupled through the transformer T to the grid circuit of the valve V as shown. This grid circuit also includes the coil L_1 of the reaction coupling L_1 L_2. The plate circuit of the valve includes the choking inductance L_0. The amplified modulation current produces low frequency potential variations

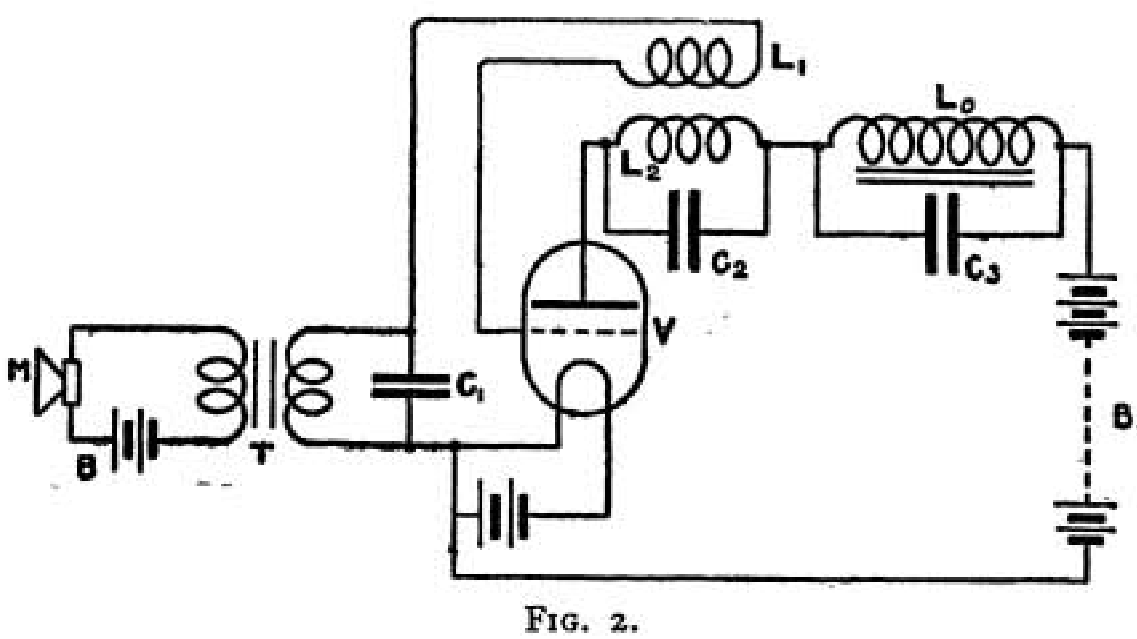

FIG. 2.

across this inductance. It therefore varies the effective plate voltage for the valve V and hence modulates the oscillations set up by reason of the reaction coupling L_1 L_2. Condensers C_2 C_3 serve to bye-pass high-frequency current across the inductances L_2 L_0. Alternatively the secondary of T and coil L_1 may be joined in parallel instead of in series and likewise L_2 and L_0 may be in parallel instead of in series if preferred.

284. IMPROVEMENTS IN POWER MODULATORS FOR RADIO TRANSMISSION. Western Electric Company, U.S.A. (*British Patent* 132058, September 19th, 1918. Patent accepted, September 11th, 1919.)

Acircuit of the high-frequency oscillation generator G (Fig. 3) is arranged to include the plate filament circuits of the valves V_1 V_2 connected in opposite directions as well as the coil L_2 for coupling to the aerial circuit A L_1 C_1 E.

* RADIO REVIEW Abstract No. 280.

The grid circuits of these two valves are supplied with high frequency P.D's derived from the same oscillation generator G through the transformers L_3 L_4 and L_5 L_6 L_7. The intermediate circuit connecting these two transformers is tuned by the condenser C and includes the transmitting microphone M. The position of the slider on R is adjusted to bring the potentials applied to the grids of the valves into phase with the potentials in their plate circuits.

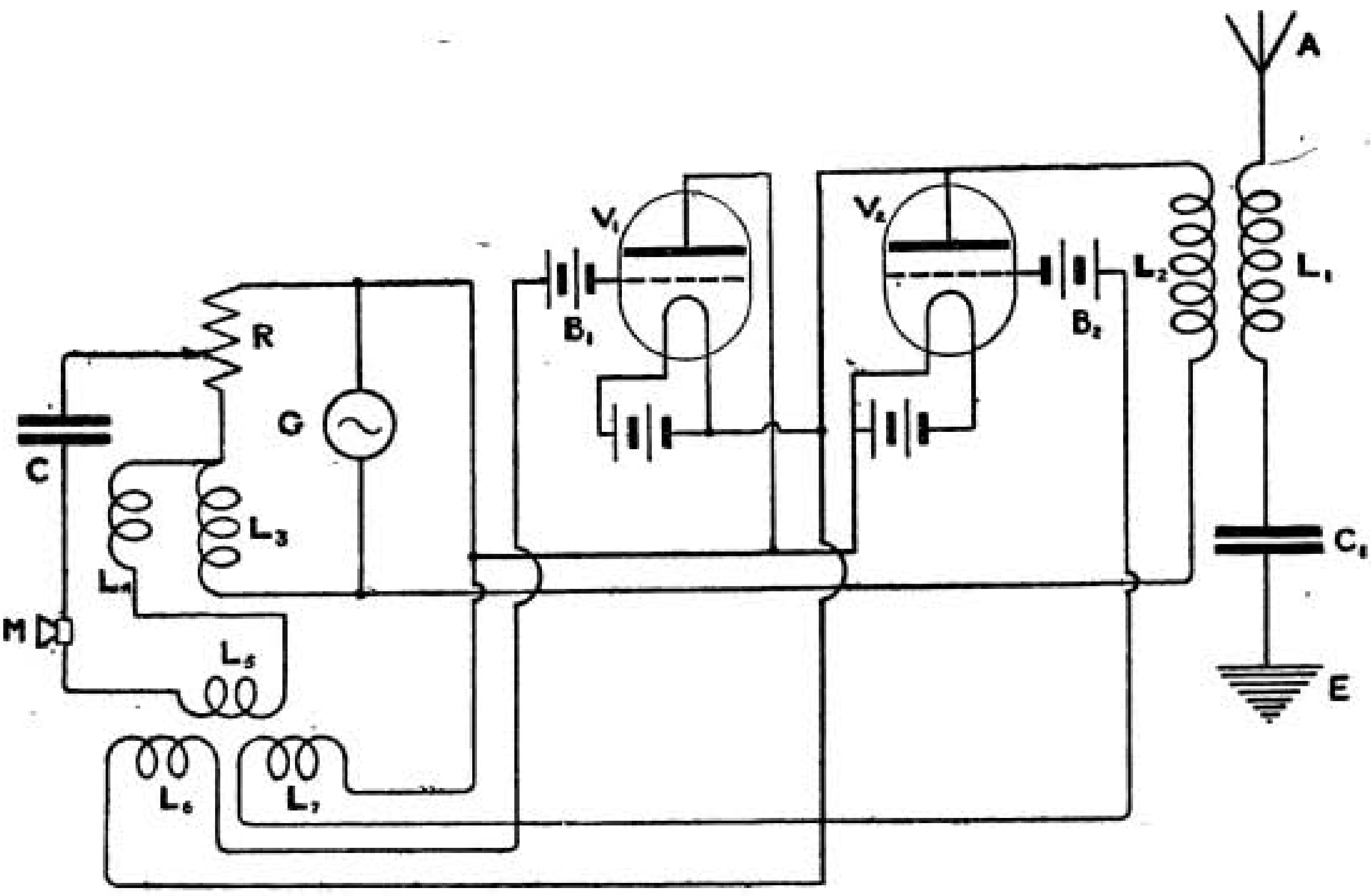

FIG. 3.

The couplings L_6 L_7 are arranged so that the microphone M produces opposite potential changes upon the grids of V_1 and V_2. Since these two valves are connected in opposite directions both half waves of the radiated energy are controlled by them. In alternative arrangements the two valves connected in opposition in this manner may be joined in shunt with the coil L_2 instead of in series with it.

285. THE "FOG-WARNING" RADIOTELEPHONE. (*Electrical Experimenter*, 7, p. 426, September, 1919.)

Describes the interior mechanism of the wireless telephone fog-warning apparatus installed at the Point Judith Light, near Narragansett Pier, R.I. (U.S.A.).

286. THE MANUFACTURE OF AMPLIFYING VACUUM TUBES. E. Rüchardt. (*Jahrbuch der Drahtlosen Telegraphie*, 14, pp. 619—624, November, 1919.)

An account of the technique of triode tube manufacture.

287. TRANSMITTING AND RECEIVING APPARATUS. The Connecticut Telephone and Electric Company, Inc. (*French Patent* 496240, February 25th, 1919. Published October 30th, 1919.)

The valve described in this specification has a filament within an exhausted bulb and a grid and an anode both mounted outside the bulb. The grid and the anode may be of silver or copper deposited electrolytically.* See also British Patent No. 124721.

288. VALVE CONSTRUCTION. Osram-Robertson Lamp Works, Ltd. (*French Patent* 496479, May 3rd, 1918. Published November 7th, 1919.)

The invention relates to supporting means for the electrodes in ionic tubes, more particularly for use in wireless telegraphy. The filament is maintained in tension by a coiled spring which is attached to a pin in alignment with the filament and the axis of the spring. The pin is carried in a guide whereby thermal expansion is permitted while preventing lateral displacement. The guide may be constituted by a socket opening into an enlargement to receive the head of the pin, which enlargement is attached to the inner end of the re-entrant tube of the bulb. For further particulars, see British Patent No. 116134.

289. VALVE CONSTRUCTION. Osram-Robertson Lamp Works, Ltd. (*French Patent* 496632, May 21st, 1918. Published November 12th, 1919.)

The specification describes means for supporting the electrodes of ionic tubes, more particularly such as are employed in wireless telegraphy. The cylindrical electrode is carried by, for example, three arms on a metal clip or clips which encircle the re-entrant tubular part of the bulb. Conveniently, two clips are employed which are disposed one on each side of a protuberance on the re-entrant tubular part. The conductor is soldered to one of the clips and is also attached to a leading-in wire. The grid may consist of a wire coiled around parallel straight wires attached to the supporting arms and carried on a second re-entrant tube. For further particulars, see British Patent No. 116113.

290. VALVE CONSTRUCTION. Osram-Robertson Lamp Works, Ltd. (*French Patent* 496752, June 20th, 1918. Published November 15th, 1919.)

The invention relates to means for supporting the electrodes in ionic tubes, more particularly such as are used in wireless telegraphy. A substantially cylindrical anode is carried at each end on bars which have divergent ends and which at the said ends are attached to metal collars which fit into annular seatings, one at each end of the bulb. A convenient form of collar

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* *Cf.* RADIO REVIEW Abstracts Nos. 17 and 79.

is an elastic split ring which tends to expand to a greater diameter than the seating, and preferably, one collar is smaller than the other so as to allow it to be inserted into the tube first. For further particulars of the invention, see British Patent No. 117939.

291. AMPLIFIERS. M. Latour. (*Bulletin, Société Française des Electriciens*, 9, pp. 465—484, July, 1919. *Revue Générale de l'Électricité*, 6, pp. 709—718, November, 1919.)

After referring to the American Patents Nos. 921930 and 1041210 of 1907 of Latour and Weintraub in which the negative resistance of a mercury vapour lamp was utilised to give amplification and pointing out that such an arrangement can be adjusted to be on the point of maintaining self-sustained oscillations, the author passes on to the main subject of his paper, viz., the use of the de Forest three-electrode bulb or triode.

He refers to the types due to Lieben and Reiss, the General Electric Co., the Western Electric Co., and the so-called French type due to MM. Biguet and Peri (Brit. Pat. 126658).* He then gives the general theory of the triode amplifier, which although now published by him was incorporated in his 1916 patents. From the four resistances obtained from the plate and grid currents and potentials the amplification is calculated and the optimum value of the load or of the ratio of transformation between the plate circuit and the load. The values of the constants for the standard French valve are given. The calculation is extended to loads of different types, to amplification by retroaction, and by the use of several valves in cascade.

292. THE DESIGN OF TRIODE GENERATOR CIRCUITS. M. Vos and R. Ziegler. (*Jahrbuch der Drahtlosen Telegraphie*, 14, pp. 578—598, November, 1919.)

A discussion of the triode generator under the following headings : (*a*) Case of external excitation with alternator in grid circuit and anode circuit coupled to antenna ; (*b*) Cases of self-excitation, phases of currents and voltages discussed ; (*c*) Simple circuits ; (*d*) Design of above circuits with the aim of combining uniform frequency, high efficiency and long life of triode.

293. QUANTITATIVE STUDY OF TRIODE GENERATORS WITH THE AID OF OSCILLATION CHARACTERISTICS. H. G. Möller. (*Jahrbuch der Drahtlosen Telegraphie*, 14, pp. 326—360. September, 1919.)

If an alternating P.D. is applied to the grid of a triode an alternating current will be produced in the anode circuit with an amplitude and phase depending on the nature of the load in the circuit. Curves having the amplitude of the anode current as ordinates and that of the grid voltage as abscissæ are called oscillation characteristics ; a different curve is obtained for every value of the resistance or other load in the anode circuit. The author uses these curves to study the stability, frequency, wave form, amplitude of harmonics, etc., in a self-sustained oscillating triode.

* RADIO REVIEW Abstract No. 16.

294. ELECTRIC CURRENT AMPLIFIERS. The Western Electric Co. (*British Patent* 130432, April, 1918. Patent accepted, August 7th, 1919.)

An amplifying system comprising two three-electrode valves, and their inter-connected circuits, is connected to two high-frequency current sources, one of which produces opposite potential variations upon the grids of the valves, while the other produces like potential variations on the grids. One of the above variable current sources is a feed-back circuit. A typical arrangement is shown in Fig. 4. The H.F. current to be amplified is applied to the

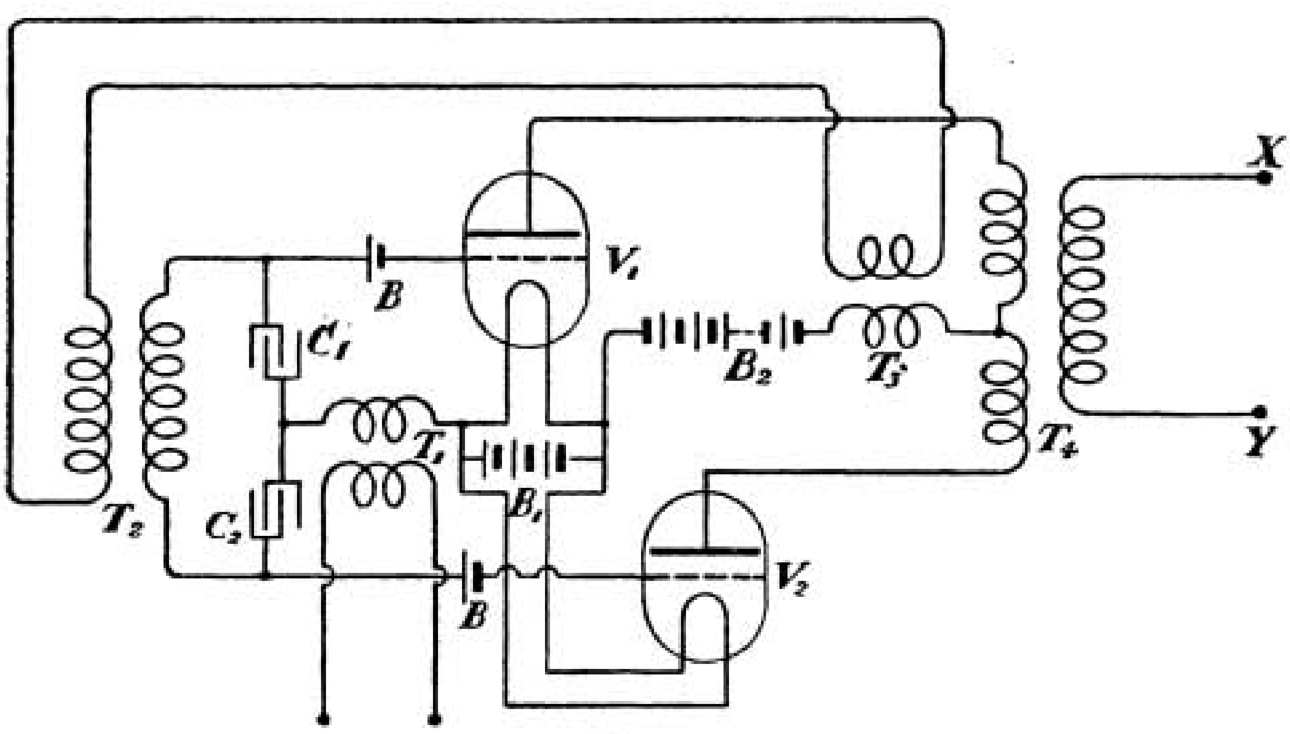

FIG. 4.

transformer T_1, and thus influences the grids of both V_1 and V_2 in parallel through the condensers C_1 C_2. The plate circuits of these valves are in parallel and supplied from the common battery B_2, through the windings of T_3 and T_4. Since equal current variations are impressed upon both windings of T_4 there is no resultant effect upon the output circuit connected to X Y, but transformer T_3 forms part of the " feed-back " circuit, and in conjunction with T_2 impresses opposite potential variations upon the grids of the two valves causing a differential action. The plate currents therefore vary in opposite phase and so produce a resultant effect on the output circuit through T_4. Various modifications are described involving the use of low-frequency fitters in the output circuits. A single valve with double grid and anode can replace the two valves in all cases.

295. TECHNICAL DEVELOPMENT OF THERMIONIC TRANSMITTERS. L. Kühn. (*Jahrbuch der Drahtlosen Telegraphie*, 14, pp. 395—419, September, 1919.)

A description of methods employed by the Erich Huth Co. The grid circuit is tuned to the aerial which is coupled to the anode circuit through an auto-transformer The only coupling between the grid and the anode circuit is that due to the valve itself. The author claims many advantages for this method of coupling. Photographs of the transmitting sets are reproduced. In the larger sizes the anode battery or dynamo is replaced by a rectifier supplied with A.C. which has been transformed up to the necessary voltage. This rectifier has a calcium oxide cathode wound with a platinum heating spiral and the two anodes are of graphite. The author discusses the reduction of the pulsations by means of choking coils and condensers. The voltage varies from 1,000 volts in the valves with 15 watts output, to 5,500 in the 2,000 watt valves. The filament is heated from the A.C. supply through a transformer and an ingenious compensating device is described whereby the heating current is kept constant in spite of the drop of voltage which occurs when the sending key is depressed.

296. ON THE DETECTING EFFICIENCY OF THE THERMIONIC DETECTOR. H. J. van der Bijl. (*Proceedings of the Institute of Radio Engineers*, 7, pp. 603—635, December, 1919.)

Describes a modification of the " audibility method " of testing thermionic detectors for standardising purposes. The relation between the alternating grid voltage e and the alternating component of the anode current J of a triode is expressed by a convergent power series

$$J = a_1e + a_2e^2 + a_3e^3 + \ldots\ldots$$

The second term is only considered effective in detecting and the method is designed to determine the value of a_2 for any tube. Modulated radio frequency oscillations are impressed on the detector at L (Fig. 5) and the input voltages are measured by means of a Duddell thermo-galvanometer G and non-inductive resistance R. The signal produced in the telephones is matched with a known fraction of a known value of auxiliary current of the same audio frequency from the generator U. The switch S is so designed that the total resistance into which the generator works is constant for all adjustments of the shunt.

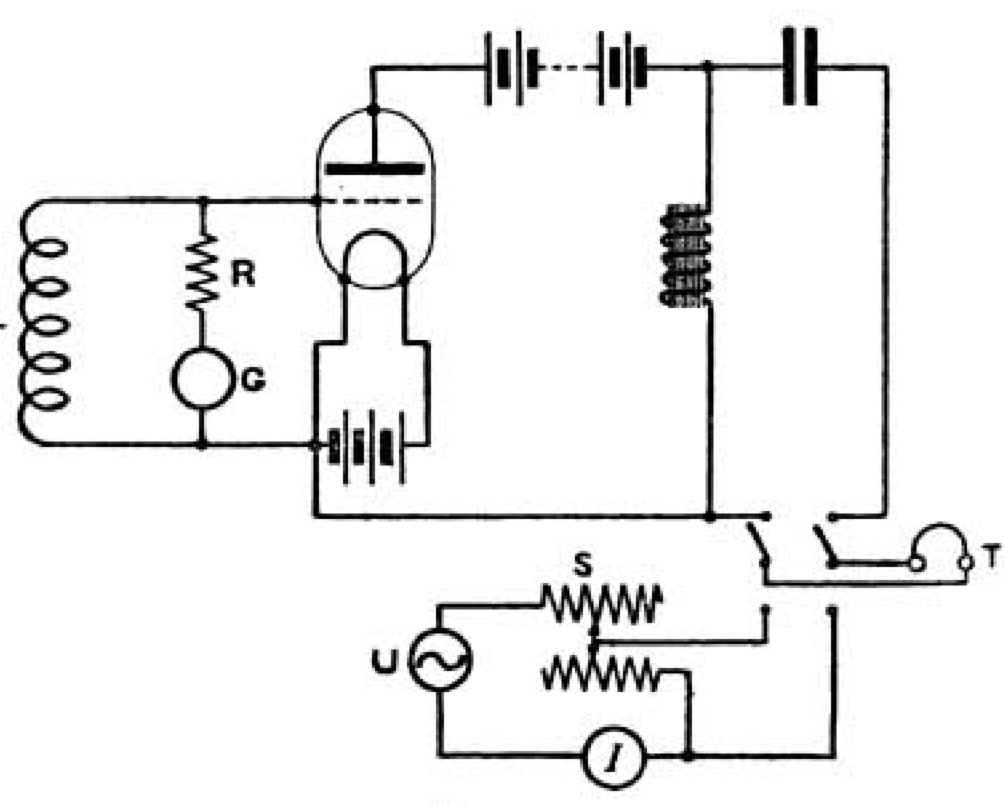

FIG. 5.

For constant input voltages the detection coefficient is a function of the " effective grid voltage " and is a maximum when the latter is equal to the potential drop along the filament. Methods are given for the comparison of detectors and the measurement of the amplification of triodes. In the discussion J. M. MILLER describes the method of measuring the detecting efficiency of a triode tube in use at the Bureau of Standards, Washington.

297. THE DETERMINATION OF CHARACTERISTIC CURVES OF TRIODES. R. Jaeger. (*Jahrbuch der Drahtlosen Telegraphie*, 14, pp. 361—385, September, 1919.)

A discussion of the connections to be employed in determining the various characteristics of a triode. A number of interesting details are discussed, such as the saturation current per watt as a function of the watts per candle, the best current for various sizes of filament. Methods are described for determining directly the slope of the ordinary characteristic curve and the voltage ratio of the triode. The following table gives the results obtained from a number of triodes of various types:

Type of Triode.	Voltage Ratio in per cent.	$\partial i_a/\partial e_g$. Amps. per Volt.
TRANSMITTING TUBES :—		
A.E.G.	5·0	18×10^{-4}
Auer-Studienges. für electrische Leuchtröhren (molybdenum wire mesh anode)	2·4	15×10^{-4}
Ditto. Type W.M. 2 (mesh anode)	1·0	$17—20 \times 10^{-4}$
C.H.F. Müller-Hamburg	2·0	18×10^{-4}
Schott u. Gen.-Jena. Type M. (copper or iron anode)	5·0	18×10^{-4}
Ditto (tantalum anode)	6·0	25×10^{-4}
Type K. (for low power)	5·0	5×10^{-4}
Siemens & Halske	5·0	18×10^{-4}
AMPLIFYING VALVES :—		
Auer-Studienges.	6·0	$1{\cdot}1 \times 10^{-4}$
Deutsche Telephon-Werke (D.T.W.)	9·0	$1{\cdot}8 \times 10^{-4}$
French valve	15·0	$2{\cdot}5 \times 10^{-4}$
Gundelach	6·0	$1{\cdot}1 \times 10^{-4}$
Dr. E. F. Huth	11·0	$2{\cdot}6 \times 10^{-4}$
C.H.F. Müller-Hamburg	5·0	$3{\cdot}6 \times 10^{-4}$
(R.I.W.) Seddig-Würzburg	10·0	$1{\cdot}3 \times 10^{-4}$
Telefunken E.V.E. 173	10·0	$1{\cdot}1 \times 10^{-4}$
Ditto. E.V.N. 171	15·0	$1{\cdot}1 \times 10^{-4}$
Ditto. Type O	5·0	$1{\cdot}5 \times 10^{-4}$
HETERODYNES :—		
Auer-Studienges.	5·0	$2{\cdot}2 \times 10^{-4}$
French valves :—		
Model 53, 4 volts, 251	2·8	$8{\cdot}0 \times 10^{-4}$
„ 53, 4 volts, 215	1·2	$8{\cdot}0 \times 10^{-4}$
Telefunken, Type R.E. 16 ("U")	10·0	$3{\cdot}0 \times 10^{-4}$

The effect of small traces of gas on the characteristic curves is discussed and curves given.

298. ELECTROSTATIC DIRECTION FINDERS. E. Bellini. (*Electrician*, 83, pp. 273—275, September, 1919. *L'Elettrotecnica*, 6, pp. 759—760, December, 1919, Abstract.)

The apparatus described in this article utilises electrostatic coupling between the aerials and the receiving circuits in place of the magnetic coupling customarily employed in direction finding. One of the forms

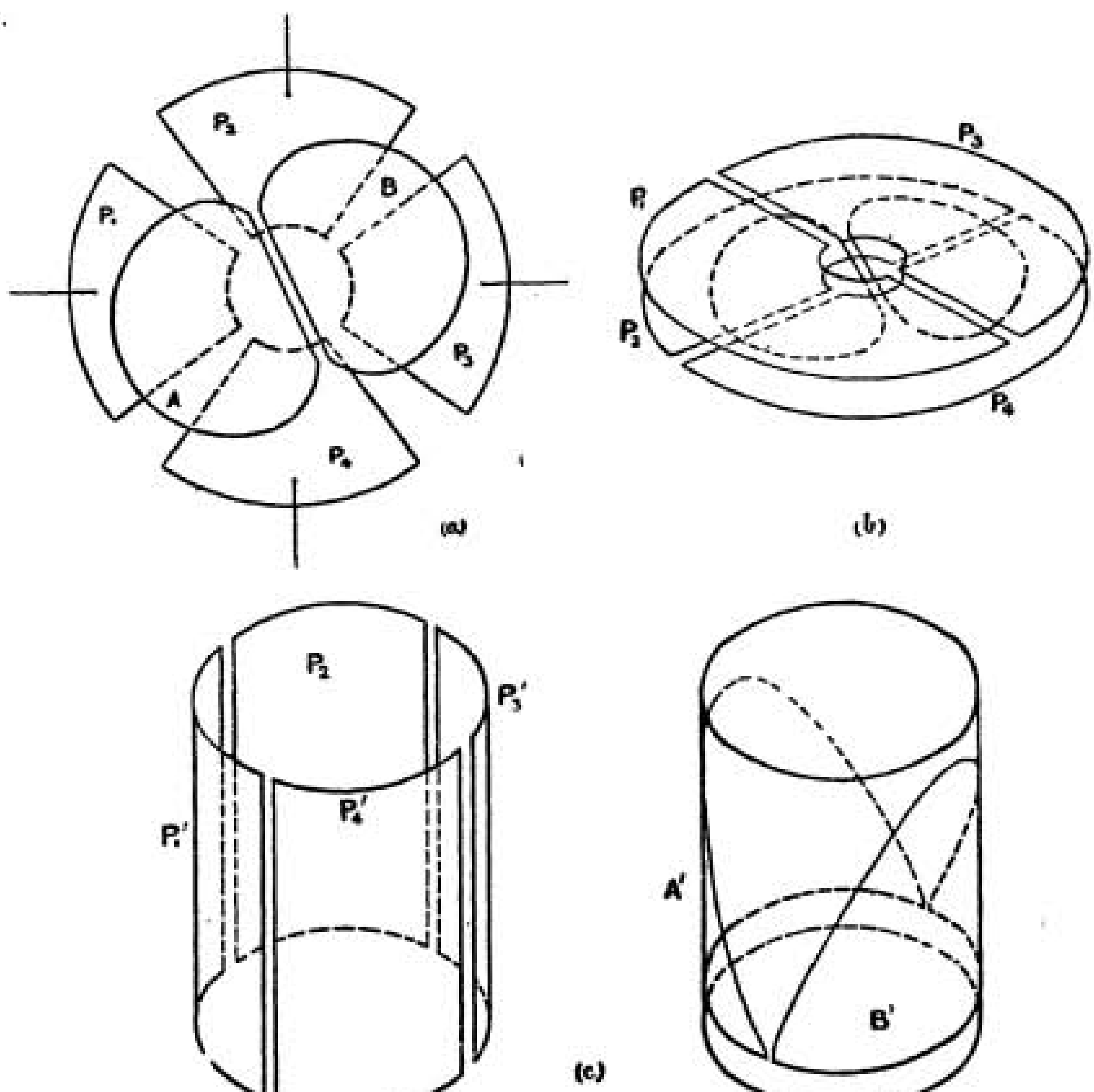

FIG. 6.

described is constituted as a special multicellular electrometer with four systems of fixed plates connected to the directive aerials, and two movable plates connected to the receiver. In Fig. 6 (*a*) and (*b*) two forms of this arrangement are indicated, $P_1P_2P_3P_4$ being the two pairs of fixed plates and A and B the movable ones. In (*b*) the two pairs of fixed plates are on separate planes and overlap.

In the second type of arrangement described in the paper, the fixed plates $P_1'P_2'P_3'P_4'$, Fig. 6 (*c*), are arranged as part of a cylinder, and two specially shaped movable plates (A'B') are arranged concentrically within them.

299. IMPROVEMENTS RELATING TO WIRELESS DIRECTION FINDERS. R. C. Vaughan. (*British Patent* 131963, June, 1918. Patent accepted, September 11th, 1919.)

In wireless receiving apparatus the direction of incoming signals is determined by the use of a composite aerial comprising three coils A, B, B_1 (Fig. 7). The switch S is arranged to connect coil A in series with either coil B or with coil B_1. In using this arrangement the three coils are rotated together round the axis C until equality of signal strength is obtained with the switch in either position. When this is the case the plane of the aerial A indicates the direction of the incoming signals.

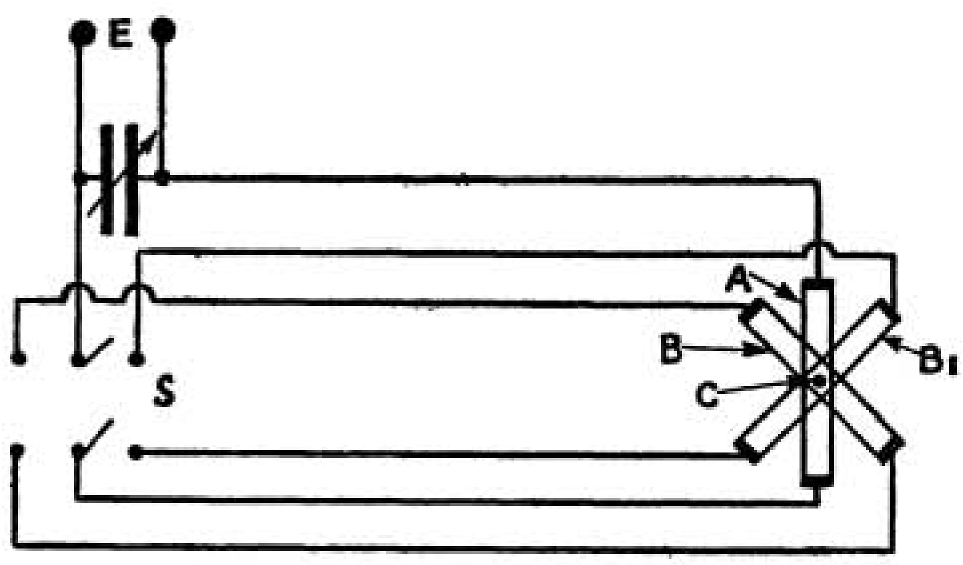

FIG. 7.

300. SHIP RADIOGONIOMETERS—FIXED OR ROTATING AERIALS? (*Le vie del Mare e dell' Aria*, 3, pp. 266—275, 1919.)

A comparison of the Bellini-Tosi and the single rotating coil systems of direction finding.

301. RECEIVING APPARATUS. A. Artom. (*French Patent* 495960, December 1st, 1917. Published October 23rd, 1919.)

The apparatus described in this specification for determining the direction of incident waves consists of two or more coils mounted to turn in a permanent magnetic field. The coils are connected to the directive receiving aerials or are traversed by currents set up by and proportional to the currents in the said receiving aerials. A pointer attached to the coils indicates on a scale the direction of the incident waves. For further particulars, see British Patent No. 124786.

302. WIRELESS TELEGRAPHY AND THE SOLAR ECLIPSE OF MAY 28TH. (*Revue Générale de l'Électricité*, 6, p. 55B, September, 1919. *Technical Review*, 5, p. 28.)

A special receiving station was erected at Meudon for reception from Ascension. This was normally only possible at night. During the eclipse, when the shadow of the moon passed between Ascension and Meudon, the signals were audible at Meudon, and as the shadow passed away the signals became weaker and disappeared completely with the end of the eclipse.

303. ON THE QUANTITATIVE DETERMINATION OF ELECTROMAGNETIC RADIATION FIELD STRENGTH IN WIRELESS TELEGRAPHY. H. R. von Traubenberg. (*Jahrbuch der Drahtlosen Telegraphie*, 14, pp. 569—578, November, 1919.)

Describes a method of measuring the value of the magnetic vector *H* (using a search coil with vacuum thermo-element detector) based on Professor Braun's mathematical treatment of the subject.

304. THE WIRELESS STATION AT BANDOENG (JAVA). (*Elektrotechnische Zeitschrift*, 40, p. 339, July, 1919.)

This station has communicated with San Francisco, 14,000 km. distant in a direction perpendicular to the antenna which is directed towards Amsterdam.

305. IMPROVEMENTS RELATING TO TELEPHONE INSTALLATIONS, PARTICULARLY FOR WIRELESS TELEGRAPHY. L. N. Brillouin. (*British Patents* 131054, 131055, April, 1918. Patents accepted, August 21st, 1919.)

This patent relates to special connections of multivalve "resistance-capacity" amplifiers, with the object of obtaining selective amplification for a given frequency or for a range of frequencies. The apparatus may also operate as an oscillation generator. Fig. 8 shows a system of four valves. The coupling between successive valves is provided by condensers C_2, C_3, C_4, in the well-known manner. (See also British Patent 127014.*) A special

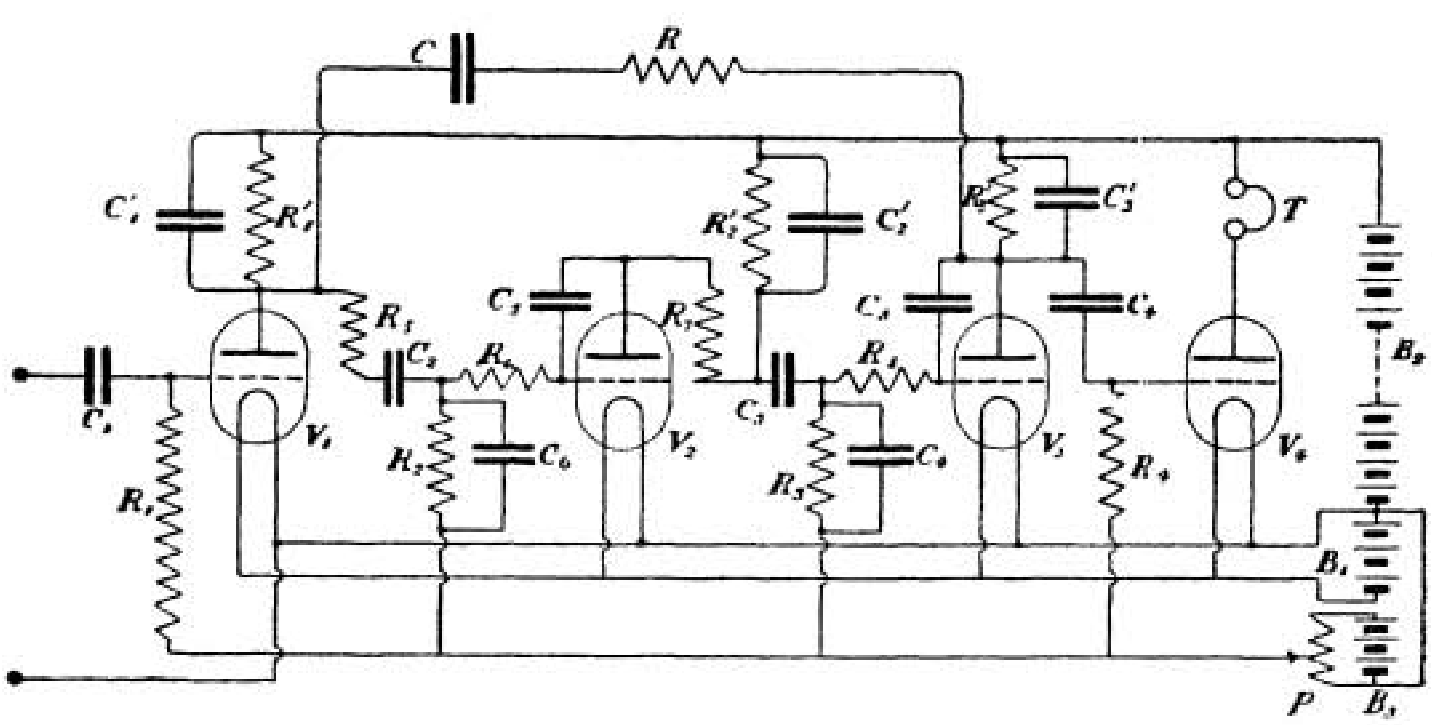

FIG. 8.

connection is made between the anodes of the first and third valves through the condenser C and resistance R. The strength of the amplified oscillations increases as the capacity of C is increased, until sustained oscillations are

* RADIO REVIEW Abstract No. 51.

set up. The wavelength to which the apparatus resonates varies directly with

(1) the value of the resistances R_2 R_3
(2) the capacities of C_5 and C_8
(3) the capacities of C_6 and C_7 shunting R_2 and R_3;
(4) the capacities of C_1', C_2' and C_3' shunting R_1', R_2' and R_3';
(5) the value of the resistances R_5 and R_7;
(6) the value of the resistance R;

and (7) the value of the capacities C, C_2 and C_3.

When more than four valves are used the connection from C, R may be made to other valves than the third, and in that case the resonant wave length is increased by increasing the number of valves in use. The set may be arranged to amplify between certain limits of frequency—the lower limit being determined by the values of C_2 and C_3, and the upper limit by the shunt condensers C_5 and C_8.

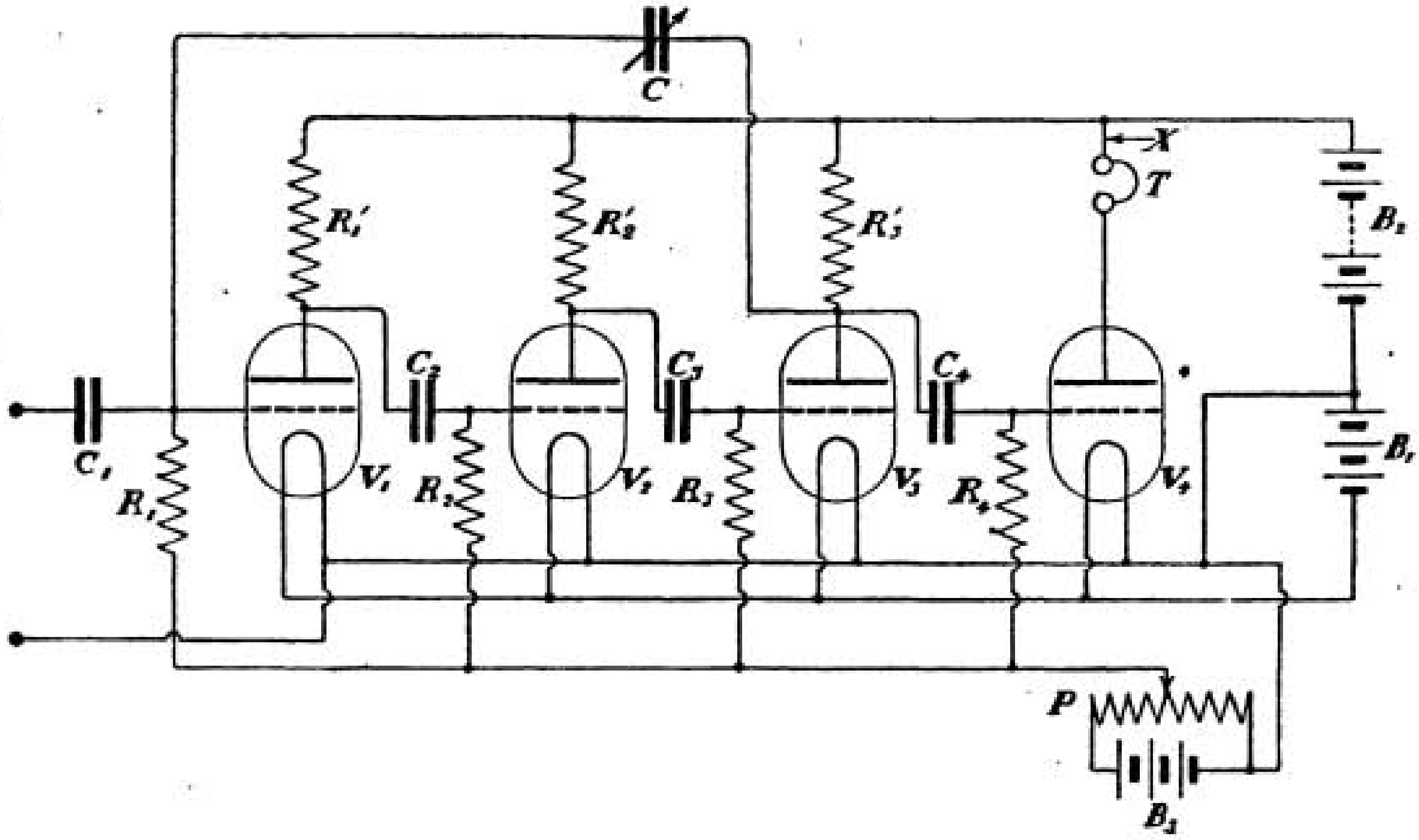

FIG. 9.

In the second of the above patents a simpler circuit is given, using a variable condenser only to couple the first valve with the plate of another one (Fig. 9). The amplification increases as the capacity of C is increased, until sustained oscillations are set up. For short waves the plate of the third valve is connected to this condenser C, but with increasing wavelengths, the connection is made to the valves in the following order: second, fifth, seventh, fourth, sixth, eighth. The resistance R_3 and condenser C_3 connected to the grid of the selected valve are increased in value until maximum amplification is obtained without "howling." In a still simpler arrangement the connection from the reaction condenser C is permanently connected to the plate of the last valve so as to reduce the necessary adjustments, and the receiving instrument T (or transformer supplying that instrument, when one is used) is shunted by a condenser, while a resistance and a choking inductance are placed in series with T, between it and the plate of the valve (at the point marked X in Fig. 9). To avoid stray reactive capacity, the valves are arranged in line and the resistances and capacities are grouped near the valves to reduce the length of connecting wires.

306. IMPROVEMENTS RELATING TO AUDION AMPLIFYING APPARATUS. M. Latour. (*British Patent* 131092, April, 1917. Patent accepted, August 21st, 1919.)

In a multivalve amplifier* the same valves are used for both high and low-frequency amplification. In Fig. 10 the high-frequency current is amplified in V_1 and V_2 (using finely laminated iron-core intervalve transformers),

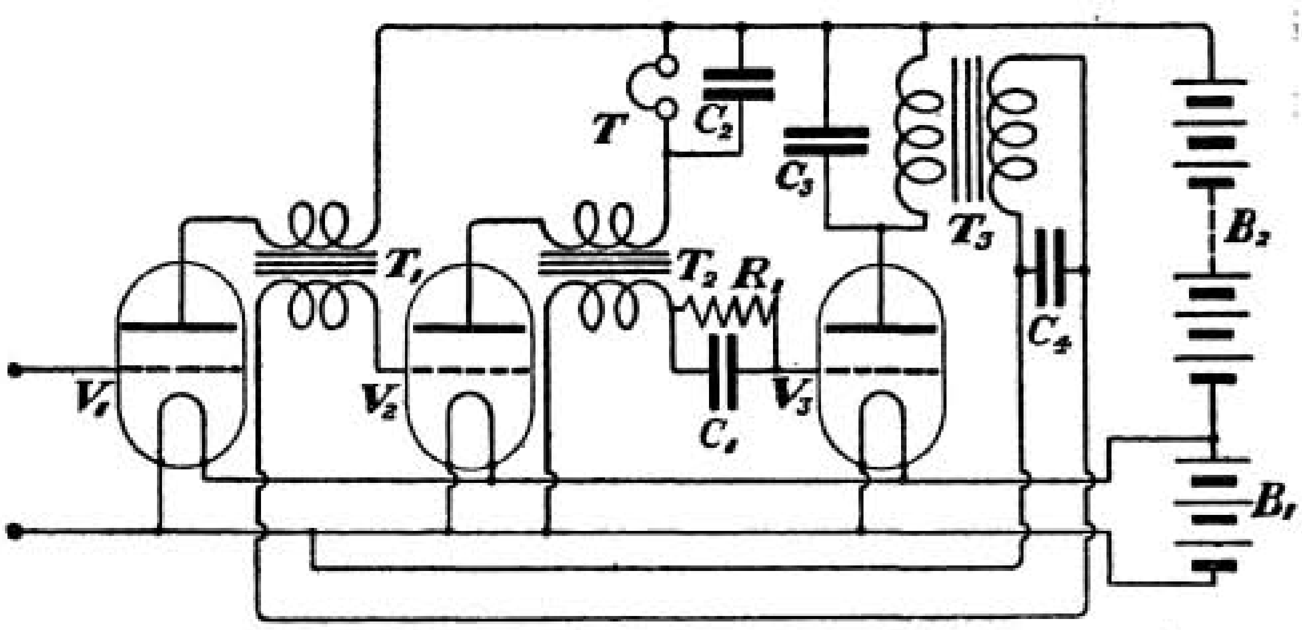

FIG. 10.

and detected in V_3. The rectified (low-frequency) current from this valve is returned through T_3 to V_2 as indicated, and the amplified L.F. current passed to the receiver T which is shunted by C_2 to prevent H.F. currents passing through it. The windings of T_3 are shunted by C_3 and C_4 for the same reason.

307. ON THE USE OF ALTERNATING CURRENT FOR VALVE DETECTORS. E. A. White. (*Electrical Experimenter*, 7, p. 234, July, 1919.) See also L. H. Maertens. (*Radio Nieuws*, 2, pp. 274—278, September, 1919, Abstract.)

An arrangement is described for the use of rectified A.C. for supplying the plate voltage of receiving valves, to eliminate any disturbance in the phones from the A.C. frequency. Fig. 11 is the connection scheme. An essential point is the use of the same A.C. supply for heating the valve filaments, as shown, and making the plate circuit connection to the slider of a potentiometer, P, connected across the filament of the receiving valve. By proper adjustment of this potentiometer the buzzing in the phones can be eliminated.

* See also British Patent 127318. RADIO REVIEW Abstract No. 83.

The transformer must be very well insulated, its iron core should be earthed, and it should be kept at least 5—6 feet away from all parts of the receiving circuit proper.

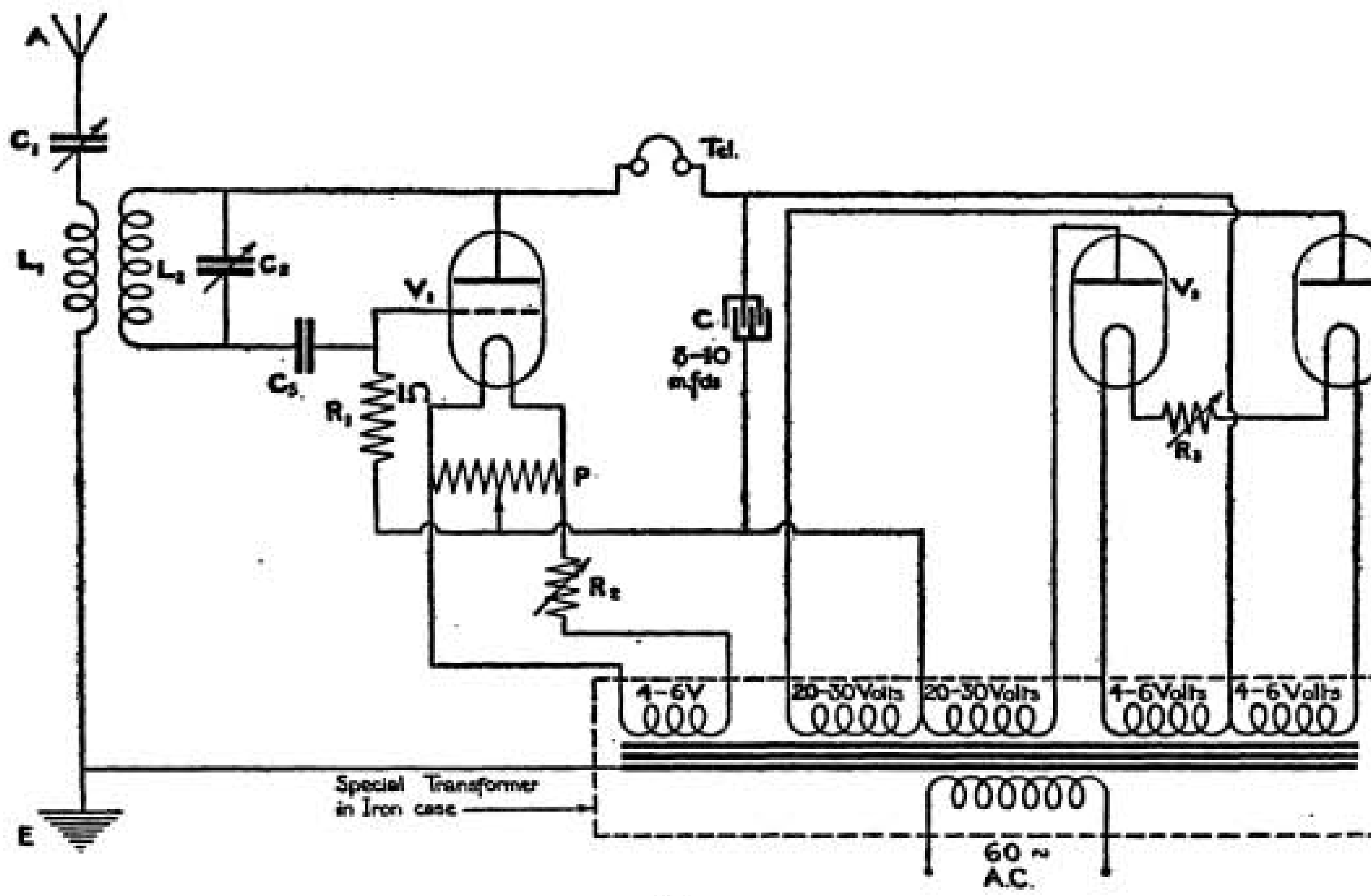

FIG. 11.

308. ON THE MEASUREMENT OF THE FREQUENCY OF ACOUSTIC AND ELECTRIC OSCILLATIONS BY A BEAT METHOD. R. Weller. (*Jahrbuch der Drahtlosen Telegraphie*, 14, pp. 599—608, November, 1919.)

Beats are obtained between the oscillation to be measured and the oscillation of a vacuum tube source. If an alteration dC in the capacity C of the oscillatory circuit of the tube generator produces a difference dn in the frequency as measured by the beats n, the frequency is given numerically by $2C\frac{dn}{dC}$. Many examples are given.

309. ON THE ORIGIN OF THE NOTE SPECTRUM PRODUCED BY BEAT RECEPTION. M. Wien. (*Jahrbuch der Drahtlosen Telegraphie*, 14, pp. 608—619, November, 1919.)

The secondary note spectrum obtained with beat reception cannot be explained as due to the harmonics of sending and receiving stations. It is due to combination tones arising from "double forcing" in a circuit not obeying Ohm's law. These combination tones have been separated from the ordinary harmonics by resonance methods both in laboratory experiments and in radio reception tests. The question of interference by harmonics and combination tones is discussed.

310. IMPROVEMENTS IN RECEIVING CIRCUITS FOR WIRELESS TELEGRAPHY. H. J. J. M. de R. de Bellescize. (*British Patents* 132434, June, 1917; 132435, April, 1918. Patents accepted September 18th, 1919.)

Means are described for eliminating disturbing effects due to earth capacity of the valves and receiving telephones, particularly in the case of D.F. receivers. Inaccuracies in the indicated direction may arise through the receiving loop acting as an imaginary open circuit and thus setting up a second series of oscillations which are superimposed upon the main oscillations. The disturbance is removed by making the circuit as symmetrical as possible with respect to the earth. One arrangement is indicated in Fig. 12, where the capacities shown serve to render the complete arrangement more symmetrical as regards earth capacity. The condenser C_1 and auxiliary telephones T_1 balance the condenser C_3 and the main telephones T; the condenser C_2 joined to the frame of the auxiliary telephones represents the capacity of the main telephones T to the operator; the condenser C_4 and resistance R_2 represent the operator; the condenser C_5 balances the effect of the capacity between the grid and filament of the valve. The receiving arrangement may also be electrostatically screened and, if necessary, one point of the receiving loop may be connected to the screen.

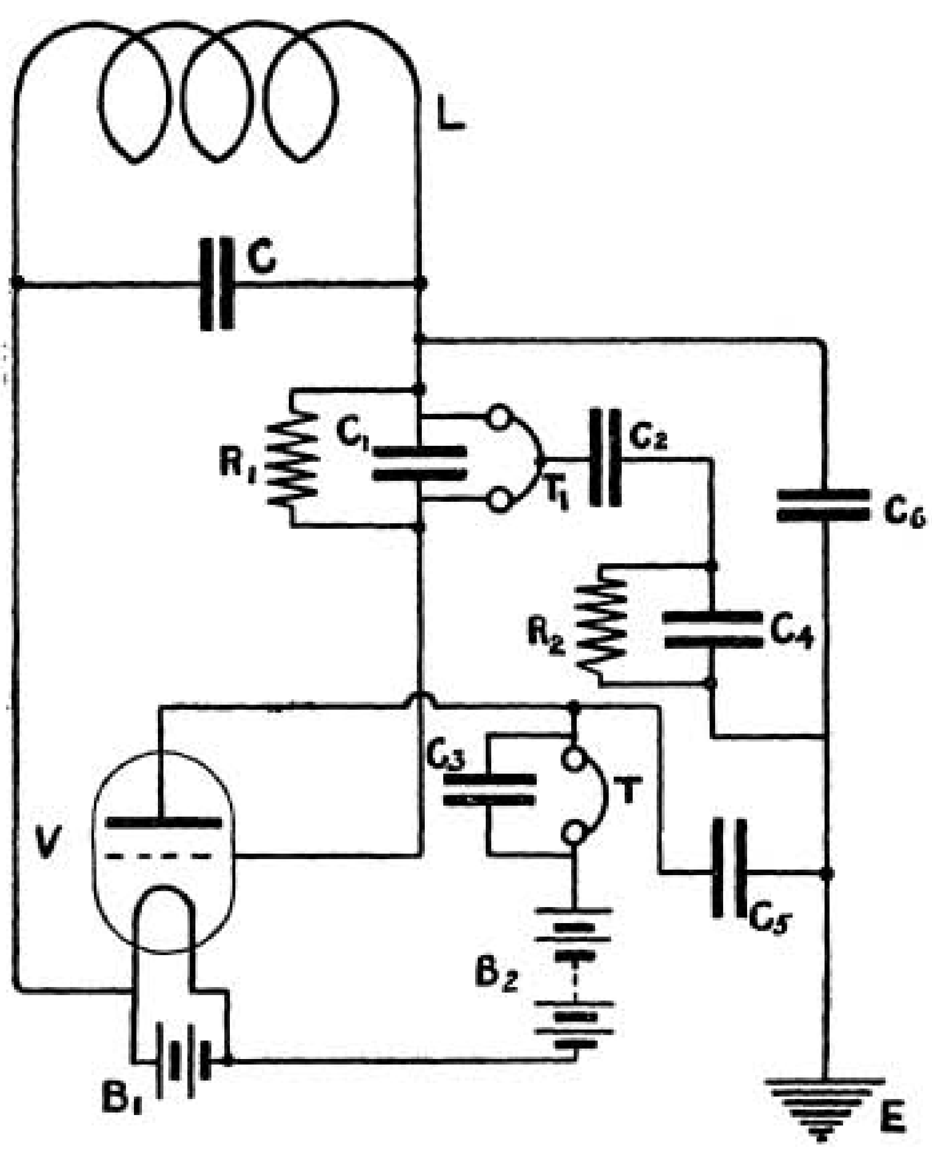

FIG. 12.

311. VALVE DETECTORS. V. J. Brochard. (*French Patent* 496562, June 20th, 1918. Published November 11th, 1919.)

The invention relates to improvements in galena wireless detectors, the improvements consisting in so constructing them that it is impossible for them to be put out of order. The construction is also such that the immediate replacement of a damaged detector is rendered possible without interfering with the remainder of the apparatus.

312. IMPROVEMENTS IN APPARATUS FOR RECEIVING RADIO SIGNALS. R. A. Weagant. (*British Patent No.* 132548, July, 1917. Patent accepted, September 25th, 1919.)

A receiving system for reducing or eliminating the effects of atmospheric and the like disturbances is described. It operates upon the principle described in the first part of RADIO REVIEW Abstract No. 18.

313. LONG WAVE RECEPTION AND THE ELIMINATION OF STRAYS ON GROUND WIRES (SUBTERRANEAN AND SUBMARINE). A. H. Taylor. (*Proceedings of the Institute of Radio Engineers*, 7, pp. 559—583, December, 1919.)

A further account of the author's work on the properties of ground wires * with special reference to long wave reception and the elimination of strays. It is found that a best wire length is only obtained in the case of lead-covered cable lying on the face of the ground, but that this optimum length is much less sharply defined than in the previous experiment on short waves. Multiplex reception is possible as with short waves on the same ground wire so long as the local heterodyne oscillations do not interfere audibly. The ratio of signal audibility to stray audibility with ground antenna has been compared with other systems. For long waves the difference between this ratio in the case of ground antenna and rectangular aerial is not large. The best ratio of signal to stray is obtained with wires laid in salt water.

Methods of reducing the effects of strays are described, the one which

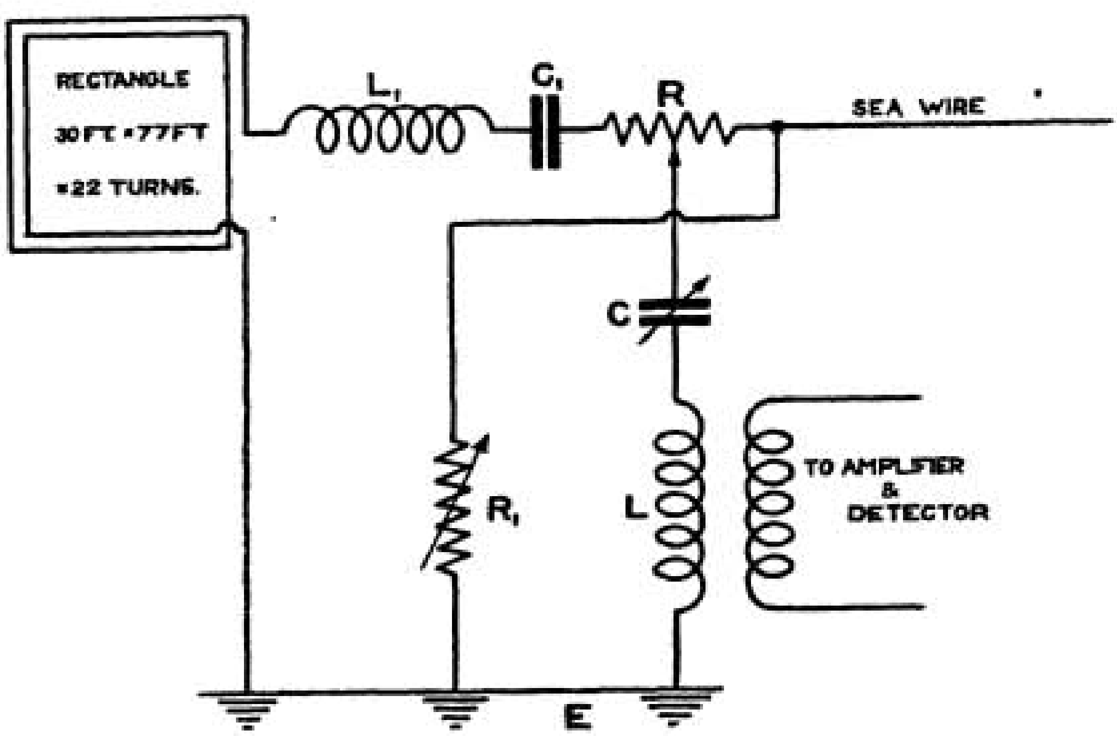

FIG. 13.

* See RADIO REVIEW Abstract No. 149.

produced the most successful being that in which the dissimilar properties of land and sea wires were utilised. The essential part of this circuit is illustrated in Fig. 13, in which L_1 C_1 R represent an adjustable phase differential coupling.

The presence of the variable resistance R_1 seems to be necessary although its exact functioning is not understood. The ratio of improvement in readability of signals through strays with this arrangement is conservatively estimated as 8·6 to 1.

314. RECEIVING APPARATUS. Y. de Saint-Melluc. (*French Patent* 496551, May 10th, 1918. Published November 11th, 1919.)

The invention consists in means for preventing "tapping" of wireless telegraphy communications, and consists in employing two antennæ of unequal radiating power. Unequal radiation can be obtained in many ways, but particularly, the inventor proposes to do this by employing antennæ placed at different heights, or by arranging antennæ at the same height and employing different inductances connected thereto.

315. RECEIVING APPARATUS. Société Française Radio-Électrique. (*French Patent* 495915, November 3rd, 1916. Published October 22nd, 1919.)

The invention relates to wireless telegraphy and telephony receiving apparatus in which the usual antennæ are not employed. The frames employed as antennæ are formed with groups of turns which can be connected in parallel or in series with or without capacities in circuit therewith.

316. CONCENTRATED OR LOOP AERIALS. L. M. Knoll. (*Electrical Experimenter*, 7, p. 328, August, 1919.)

In this article the author appears to claim joint inventorship with T. Appleby of the use of the small loop aerial for reception, and states that Appleby discovered the directional properties of the device. Simple diagrams showing the method of connecting the loop to the detector are given.

317. TALKING THROUGH THE TREES. G. O. Squier. (*Electrical Experimenter*, 7, p. 204, July, 1919. *Electrician*, 84, pp. 111—112; 147—149, January 30th and February 6th, 1920, Abstract.)

Describes the author's researches into the use of living trees as antennæ, as carried out at the U.S. Signal Corps Laboratory near Washington.

318. WIRELESS IN CHINA. (*The Times of India—Indian Engineering Supplement*, No. 20, p. 4, September 26th, 1919.)

An illustrated article dealing with the apparatus to be used by the Chinese National Wireless Telegraph Co., and with the natural obstacles to be overcome in erecting the stations.

319. A METHOD FOR TRANSMITTING SECRET VISUAL SIGNALS. L. R. Matout. (*British Patent* 132858, June, 1918. Patent accepted, September 23rd, 1919.)

This relates to the use of polarised light for telegraphic transmission. The light may be circularly or elliptically polarised at the transmitter and analysed at the receiver, with a view to secrecy in transmission.

320. IMPROVEMENTS RELATING TO RADIANT ENERGY SIGNALLING SYSTEMS. T. W. Case. (*British Patent* 132341, September, 1918. Patent accepted, September 10th, 1919.)

In signalling systems employing light radiation the receiving apparatus comprises a light sensitive element connected in the grid circuit of the three-electrode valve which is also arranged to generate oscillations of audible frequency. The incidence of the signalling rays on the receiver causes a variation in the frequency of the note heard in the telephone which is connected in the plate circuit of the valve. Infra-red or other invisible light rays may be used if necessary. For infra-red rays the receiver is preferably a compound of thallium and sulphur, which is particularly sensitive to these rays. For work with ultra-violet rays the receiver may be a compound of thallium and iodine. It is mentioned that the arrangement may be used for harbour defence purposes as well as for ordinary signalling.

321. TELEGRAPHY AND AVIATION. M. Delgieu. (*Annales des Postes, Télégraphes et Téléphones*, 8, pp. 382—397, September, 1919.)

Reviews the methods of radiocommunication with aircraft.

322. HIGH-FREQUENCY MULTIPLEX TELEPHONY AND TELEGRAPHY ALONG CONDUCTORS. H. Fassbender and E. Habann. (*Jahrbuch der Drahtlosen Telegraphie*, 14, pp. 451—478, October, 1919.)

A triode system designed before the armistice for military purposes. It can be used in conjunction with the Hughes or Siemens high-speed telegraph apparatus.

323. SOME ASPECTS OF RECENT PROGRESS IN RADIOTELEGRAPHY. G. Montefinale. (*Le vie del Mare e dell' Aria*, 3, pp. 256—265, 1919.)

A popular account of duplexing, direction finding, and high frequency amplifiers.

324. THE CONSTITUTION OF TUNGSTEN. H. Baerwald. (*Verhandlungen der Deutschen Physikalischen Gesellschaft*, 21, pp. 474—478, July, 1919.)

Deals with electronic emission from tungsten filaments.

2. Books.

Telephony without Wires. Philip R. Coursey, B.Sc., A.M.I.E.E. (London: *The Wireless Press, Ltd.* 1919. Pp. xix. + 414. Price 15*s.* net.)

This book is a valuable addition to the literature of the subject. It contains a very complete collection of information on the various schemes, proposed and tried, relative to the electrical transmission of the sound of the voice through space without wires.

Chapter I. is introductory, and gives a classification of methods which have been used, under three heads, viz.:—(1) Conduction and Induction Methods, (2) Photophone and Thermophone Methods, and (3) Hertzian Wave Methods.

Chapters II. and III. deal with methods (1) and (2), describing Morse's and Preece's arrangements for communicating across water, the Bell photophone and the selenium cell receiver. It is interesting to note that, as the author remarks in the preface, the photophone method was resuscitated and improved for use under war conditions.

Chapter IV. describes the early attempts by Dolbear and others to transmit speech by wavelengths corresponding to voice frequencies. An immense stride was made when it was realised that, to cover any distance, Hertzian waves, modulated in amplitude by the voice, must be employed, and the first attempts, using low spark frequencies are described in this chapter. One rather wishes that the author had pointed out either in Chapter IV. (at the dividing line between the attempts to transmit at voice frequency, and those employing Hertzian frequency) or in Chapter XVI. on "modulation," that the operation of modulation is equivalent to the addition to the "carrier" wave of other waves having the same order of length, so that the energy is carried entirely by waves of Hertzian length, and not by those of the immense lengths corresponding to voice frequencies.

Chapter V. deals with the necessary conditions to be fulfilled for successful speech transmission, and the next chapter with a general consideration of "spark" generators. The different forms of "quenched" gap are then described including that due to Chaffee using copper-aluminium electrodes.

Chapter VIII. deals with the production of continuous oscillations by means of spark gaps, describing and illustrating in detail the Marconi multi-disc discharger, although the author does not state that this discharger has been successfully employed in telephony.

Chapter IX. deals with multiphase spark apparatus as used to increase the spark frequency. One would hardly think, however, that the ring phase transformer in Fig. 73 would make a very satisfactory arrangement for transforming from three phases to a larger number. It would certainly be a very poor form of transformer for ordinary power purposes, and for the purpose in question one would expect that a winding similar to that of an induction motor would give far better results.

In the next two chapters the interesting and important arc generator is dealt with, and an excellent description of the action given, both static and dynamic characteristics being considered. A chapter is given to a description of the various practical forms of arc oscillation generator commencing with the Poulsen arc and including the Vreeland mercury vapour oscillator. The chapter concludes with descriptions and diagrams showing various ways of coupling an arc oscillation circuit to an aerial.

Chapter XIII. deals with vacuum oscillation generators. Nearly all the matter in this chapter, however, refers to the "soft" type of tube, *i.e.*, the type in which gaseous action plays a considerable part. The "pliotron" of Langmuir is mentioned, but on the whole this chapter rather gives the impression that for generating oscillations the "soft" type is more generally used, whereas actually the tendency is all towards the "hard" or highly exhausted type. One is perhaps treading on delicate ground to suggest it, but should not the fact that an enormous stride was made by De Forest when he first added the "grid" to the simple two-electrode valve of Fleming be brought out more clearly? This addition increased the potentialities of the vacuum bulb to an unlimited extent. It turned the simple rectifier of Fleming into a repeater having enormous possibilities as to ratio of energy amplification.

It is a pity that the excellent work done by the French during the war was not available when this chapter was written, for it was the French type of valve which was used to a great extent during the war, being manufactured, with improvements, by British firms in hundreds of thousands, both for transmitting and receiving.

Chapters XIV. and XV. deal with "Alternators and Frequency Raisers," describing the Alexanderson machine (of which type one has been running for two or three years at the station at New Brunswick, on the other side of the Atlantic), the Goldschmidt machine, and the various arrangements of stationary transformers which exploit the vagaries of the magnetisation curve of iron, and turn them to useful account in frequency raising. We note that in describing the Spinelli arrangement on p. 226 the author states that one of the secondary coils is "reversed as compared with the normal 'delta' connections." If this were the case, it would result in a large E.M.F. of primary frequency. The writer has looked up the reference and finds that the connection shown is a "star" primary connection, and "delta" secondary connection, but with one corner of the delta open. This eliminates the fundamental frequency and delivers the triple frequency E.M.F. to the load. The working of this arrangement, however, was not first shown by Spinelli, but by the present writer in an article entitled "Wave Shapes in Three-phase Transformers" published in *The Electrician* on November 10th, 1905.

Chapter XVI. deals with the important subject of modulation. One is at first sight, perhaps, a little disappointed that the author does not say a little more on the general subject than is given on pp. 238 and 239. A diagram or two showing the superposition of audible upon radio frequency waves would be a considerable help to the student, as also would a brief explanation of the analysis of a modulated wave into its high frequency components. The chapter is devoted to consideration of the various ways in which a microphone may be applied to the high frequency circuit, while the next chapter describes the different types of microphone which have been used, including the Alexanderson magnetic amplifier.

Chapter XVIII. describes in detail several schemes of microphonic control which are particularly adaptable to certain types of oscillation generator. Chief amongst these are the schemes used to control oscillating valves. The author points out the necessity for "exhaustive quantitative testing of different microphone constructions and of different methods of control" if further real progress in microphonic control is to be made.

Chapter XIX. deals with the efficiency of transmitters, average figures being given for quenched gaps, valves, high frequency alternators, static frequency raisers, and arc generators. The concluding paragraphs describe sources of current available for radiotelephone work, both A.C. and D.C., including the combination of a transformer with rectifying valves.

A short chapter is devoted to the Braun cathode-ray tube, showing its possibilities for high frequency work, and giving curves of oscillatory currents.

Chapter XXI. is devoted to receiving apparatus. After reference to the magnetic detector, several pages are devoted to crystals, characteristic curves being given. Vacuum receivers are then discussed commencing with the Fleming valve, and passing on to the three-electrode receiver. On p. 320 an account of the action of the grid electrode is given which hardly accords with the facts, however. The author states that "a positive charge upon the grid will attract the electrons, and so prevent them from reaching the anode, if a suitable path is provided for them by which they can flow away from the grid, and if the grid has sufficient area to adequately collect them." This would mean that the grid diverts or intercepts the electron stream to the anode. Now, although it is true that at very high grid potentials the anode current may begin to fall, this effect is not used in a detecting or amplifying valve, in both of which cases the very opposite is the truth. The positive charge on the grid tends to neutralise the "space charge" and *more* electrons not less, are drawn to the plate. The deduction given in the last three lines of this page is incorrect unless it is assumed that a series condenser is placed in the grid circuit. In this latter case, owing to the curvature of the grid current characteristic, the condenser and grid are charged negatively by a train of oscillations, and the plate current falls. An application of an oscillatory potential direct to the grid, however, results in an *increase* of the average plate current if we are working at the lower bend in the plate current characteristic, and in no change of average current, if working on the straight portion. Fig. 228 illustrates the arrangement when working on the bend of the plate current curve. The addition of a few characteristic curves of valves would be a great help in this chapter. The only curve given in the book for a three-electrode valve is one on p. 184 applying to the "pliotron" or hard valve. In justice to the author, however, it must be stated that the part of the book referred to was written before the present forms of high vacuum triode were in existence, and the ideas expressed were intended to refer to the lower vacuum type in which there was a large number of positive ions present, and also a grid of larger surface area. Chapter XXI. concludes with a description of that interesting device, the thermal telephone.

Chapter XXII. deals with receiving amplifiers, commencing with the Brown relay and passing on to the three-electrode amplifier with "cascade" combinations.

A short chapter is then given to interference prevention, and a final one on "Fields for Wireless Telephony."

There is a brief historical *résumé* of results achieved in wireless telephony since 1885, and a most excellent list of references to papers and articles. These number no less than 695, and form a most complete bibliography of the whole subject.

For any one making a special study of wireless telephony this list of references will prove an invaluable addition to the treatise.

The book is well and profusely illustrated.

R. C. CLINKER.

SELENIUM CELLS: The Construction, Care and Use of Selenium Cells with special reference to the Fritts Cell. By Thos. W. Benson. (New York: *Spon and Chamberlain;* London: *E. & F. N. Spon, Ltd.*, 1920. Pp. 63. Price 7*s*. 6*d*. net.)

It is probable—although it is not specifically so stated—that this little book is intended for the use of amateur experimenters. There are many such enthusiasts in almost every branch of science, who, while having little exact knowledge, love to dabble in what seems weird and wonderful. Much is to be found in Mr. Benson's book to tempt them to experiment with selenium and its fascinating properties. The details of manufacture and treatment, particularly of the Fritts type used by the author himself, are given with great precision. In some cases the instructions appear to be unnecessarily detailed. For example, a recipe is given for making a weight for the selenium press, while in the next sentence it is admitted that "any other weight of eight pounds can be used." The amateur reader will, no doubt, find useful the diagrams and text illustrating the electrical connections in the various experiments described.

Regarded from a purely scientific point of view the book leaves much to be desired. Dr. Fournier d'Albe's type of selenium cell is not mentioned at all, nor is his work on the "optophone," although Professor F. C. Brown's experiments in this connection find a place. It is somewhat surprising, also, to find no mention of other substances having properties similar to those of selenium. But the chief defect from the scientific aspect is loose description of experiments. As an example may be taken the statement that a Fritts cell (a type, it may be noted, in which the current flows in the same direction as the incident light) has been made whose resistance in *the light* was only $\frac{8}{10}$ per cent. of that in the dark. As no indication is given as to the intensity of the light in question, the information is worthless. Most of the well-known properties of selenium cells are mentioned with more or less detail. Two other supposed new properties are described so briefly that it is impossible to be sure what the author means. One of them, indeed, seems to be a palpable absurdity, viz. that the sensitivity to light of a selenium cell depends on the *kind of battery employed with it.* Thus Leclanché cells are said to be superior to bichromate cells, and Mr. Benson seems to think it possible that different cells give different *kinds* of electric current, or, as he puts it, "Is there some unrecognised force in one current that is not found in the other?"

The style of the book is distinctly American, although simplified spelling only appears in the word "thru" and its horrible progeny "thruout." "Galvonometer" occurs frequently and invariably, and on several occasions the word "staple" is used by the author when he is apparently referring to the *stability* of selenium cells. The grammar, also, is sometimes shaky, as the following sentence shows: "The supplies required are chemically pure selenium, specify electrolytic selenium for electrical purposes when ordering and the proper material will be supplied." One cannot help feeling that, had Mr. Benson's book been prepared with more care both in its scientific and literary features, its value would have been much enhanced.

A. O. RANKINE.

Books Received.

SELECTED STUDIES IN ELEMENTARY PHYSICS: a Handbook for the Wireless Student and Amateur. By E. Blake, A.M.I.E.E. (London: *The Wireless Press, Ltd.* 1920. Pp. viii. + 176. Price 5*s.* net.)

TREATMENT OF HARMONICS IN ALTERNATING CURRENT THEORY BY MEANS OF A HARMONIC ALGEBRA. By A. Press. (Berkeley, U.S.A.: *The University of California Press.* 1919. Pp. 66. Price $1.00.)

COURS ELÉMENTAIRE DE TÉLÉGRAPHIE SANS FIL. By G. Viard. (Paris: *Librairie de l'Enseignement Technique.* 1919. Pp. 303. Price 12 fr.)

MESURES PRATIQUES EN RADIOACTIVITÉ. By W. Makower and H. Geiger. (Paris: *Gauthier Villars et Cie.* 1919. Pp. viii. + 182. Price 12 fr.)

WIRELESS TELEGRAPHY. By W. H. Marchant. (London: *Sir Isaac Pitman and Sons, Ltd.* 1920. Pp. ix. + 305. Price 7*s.* 6*d.* net.)

LA THÉORIE ET LA PRATIQUE DES RADIOCOMMUNICATIONS. Vol. I., INTRODUCTION. By L. Bouthillon. (Paris: *Librairie Delagrave.* 1919. Pp. xiv. + 193. Price 20 fr.)

RADIO EQUIPMENT. By Wireless Speciality Apparatus Co. (Boston, Mass., U.S.A.: *Published by the Company.* 1919. Pp. 83.)
Contains excellently illustrated descriptions of the Company's products together with a collection of useful formulæ and curves relative to radio measurements.

Correspondence.

"THE THERMIONIC VALVE AND ITS DEVELOPMENT IN RADIOTELEGRAPHY AND RADIOTELEPHONY."

TO THE EDITOR OF THE "RADIO REVIEW."

SIR,—Referring to the reply of Professor Fleming on the above subject, I beg to thank Professor Fleming for his willingness to refer to my paper of 1916 on the three-electrode valve in the next edition of his book.

The theory of the three-electrode valve expounded in my paper has already been referred to by different authors in the following manner :—

Professor Hazeltine writes in the *Proceedings of the Institute of Radio Engineers* for April, 1919, page 167 : " Equations of this form ($i_p = e_p\, g_p + e_g\, g_m + c$) seem to have been first employed by Latour in the *Electrician*, December 1st, 1916, in discussing amplification."

Mr. John Miller of the Bureau of Standards, Washington, in his last paper on " Dependence of the Input Impedance of a Three-electrode Vacuum Tube upon the Load in the Plate Circuit," discussing the case when there is a measurable grid current, says : " All these facts are implicitly contained in the equations (5) derived by M. Latour in his paper on the " Theoretical Discussion of the Audion,' *Electrician*, 78, p. 280, 1916."

The correctness of these equations (5) of mine is shown again by the last paper of Professor Press which appeared in the issue of the *Electrician* of January 9th, 1920 (see page 35). In this paper Professor Press, discussing the work of Captain L. B. Turner, derives for *potential magnification* and *current amplification* equations corresponding to equations (5) of my paper of 1916.

MARIUS LATOUR.

Paris,
February 10th, 1920.

TRIODE NOMENCLATURE AND SYMBOLS.

To the Editor of the " Radio Review."

SIR,—I am afraid Mr. Turner's memory has played him false. In a conversation with him in December, 1918, I suggested terms for each of the *four* conductances of a triode clearly distinguishing between $\partial i_a/\partial v_g$ and $\partial i_g/\partial v_a$. Hazeltine in his paper on " Oscillating Audion Circuits " * used the term " mutual conductance " (a term obviously ambiguous) and feeling the need of names for all four conductances I suggested to Mr. Turner and to many other workers on triodes, the following terms :—

$\partial i_a/\partial v_g$ Mutual anode-grid conductance.
$\partial i_a/\partial v_a$ Anode conductance.
$\partial i_g/\partial v_g$ Grid conductance.
$\partial i_g/\partial v_a$ Mutual grid-anode conductance.

If we omit the word " mutual " (as one possibly would do in conversation) in the first and last cases, it will be seen that these terms are identical with those of Mr. Turner's " Colloquial Abbreviation " column. With the symbols suggested for these terms I find myself in complete agreement. In a full scheme of nomenclature and symbols it might however be useful to indicate the two methods of deriving the voltage amplification factor $\boldsymbol{\nu}$, *i.e.* a_g/a_a and $-\partial v_a/\partial v_g$.

E. V. APPLETON.

Cambridge,
March 6th, 1920.

* *Proceedings of the Institute of Radio Engineers*, April, 1918.