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Editorial Views.

Coil Losses.

THE short notes by Mr. R. M. Wilmotte in E.W. & W.E. for May and June, and that by Mr. S. Butterworth in this issue, attract attention to one of the most important problems in wireless, which is also one of the most difficult: that of the losses in, or "effective resistance" of, a coil.

There has been great confusion for a long time as to the point of view from which to regard these losses, but it seems to be clearing up now, although the process has hardly yet spread far from the laboratory.

Roughly speaking these losses may be divided into three sections: Losses from the resistance of the wire to the main current passing through it; losses from the resistance of the wire to currents induced in neighbouring turns and other conducting objects by the main current (the "eddy current" losses); and losses due to the solid insulating matter necessary to support the coil (the "dielectric losses").

It appears to be fully established now that for coils of reasonably good design working at 200-1,000 meters, the most important losses are those due to eddy currents. At extremely long waves the actual resistance of the wire itself preponderates, while at extra-short waves the dielectric losses become important. We must confess that we ourselves have been inclined to over-estimate the importance of dielectric losses at medium frequencies (the broadcast band for example). This is because it is extremely difficult to separate eddy current losses from dielectric losses experimentally, while as a rule the special precautions taken to diminish the latter (careful spacing of wires, etc.) also diminish the former.

There is, however, one possible method, as shown by Mr. Butterworth in this issue: The eddy current losses in a given coil depend simply on the currents in near turns, while the dielectric losses depend on the voltage between near conductors. If we keep the same current in all turns, but vary the voltages between near turns by altering the order of the turns in the circuit, we get a change in the dielectric loss from which could be calculated approximately the total dielectric loss.

Perhaps the most important point for the general user to realise is that the choice of wire dimensions should be governed (as regards all but long-wave coils) almost entirely by eddy-current considerations. The D.C. resistance, or even the H.F. resistance of a similar length of wire straightened out, is not really relevant to the case.

It is unfortunate that the mathematical analysis involved in working out formulæ for these eddy-current losses is to the ordinary wireless enthusiast very advanced. Since, moreover, it still leaves the dielectric losses unknown, few of the "practical" men have as yet given to the eddy-current calculations the attention they deserve. This is undoubtedly a mistake. Apart from anything else, the comparison of calculated eddy-current losses with measured total losses for a wide range of coils should give

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sufficient information about the remaining dielectric losses to allow an empirical formula to be found for them, in which case the design in advance of the best coil for given conditions will become possible.

It happens opportunely that an investigator who has for years specialised in the subject, and is regarded as one of the great authorities on it, has now completed tables by which the design of coils of most types for low eddy-current losses becomes a matter of simple arithmetic. We have recently carried out a series of measurements on various well-known receiving coils, with the object of checking this method against experimental results. The comparison is not yet completed, but if all goes well we hope to publish at an early date the method by which even a beginner can design a coil to fulfil any given conditions with lower losses than anything at present obtainable on the market.

The Tuning of Multi-Stage Sets.

An interesting point came up to us for decision not long ago in connection with the design of a supersonic set. As most of our readers are aware, many such sets use an intermediate amplifier of which the intervalve couplings are practically untuned, or at any rate very flat, except for one at the beginning or the end which is of the nature of a very sharply tuned loose coupling.

The question then arose as to which was preferable: one very sharp and several untuned stages: or several "fairly sharp" stages, the overall selectivity being the same in each case. The only way to solve it seemed to be to calculate out the resonance curves in each case, and on doing so some quite interesting results were found. It is hardly necessary to give the calculation in a special article, since it is in no way out of the ordinary. The result shows that, for an equal ratio of tuned current to that at a frequency well "off-tune," the set with several equal stages gives a curve with a flatter top and steeper sides than that with one extra-sharp stage. It is therefore the superior for supersonic work on telephony, where one needs a flat-topped curve to include the side-bands. On the other hand, a concentration of selectivity in one or two super-efficient circuits is valuable for cases where we wish to amplify an unmodulated input of single frequency.

In American supersonic practice, it is common to refer to such a single sharply-tuned coupling as a "filter." It should be realised that on this side of the Atlantic the word "filter" is used especially for circuits giving a flat-topped resonance curve. It is therefore singularly inappropriate in this case, and should not be used in this country.

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Aerial Tuner Design. [R141

(CONCLUSION).

By W. B. Medlam, B.Sc., A.M.I.E.E., and U. A. Oschwald, B.A.

Case III.—Effect of parallel capacity in a crystal circuit.

The existence of optimum values of parallel capacity for low values of the inductance in the case of a crystal circuit is well shown by the curves in Figs. 16 and 17. In these diagrams crystal current is plotted against inductance for a number of different values of added parallel capacity. The results were obtained by setting a parallel condenser to a fixed value (shown by the figure, indicating μF, against each curve) and retuning on the series condenser as the value of L was altered by stripping turns off the A.T.I. The curves in Fig. 17 refer to a perikon crystal with one pair of 4 000 ohms phones in series with the crystal; those in Fig. 16 refer to the same crystal but with the phones shorted.

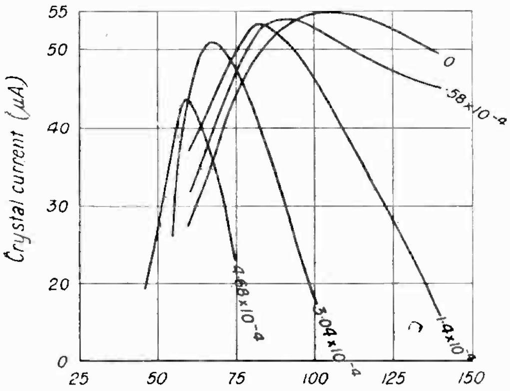

Fig. 16.

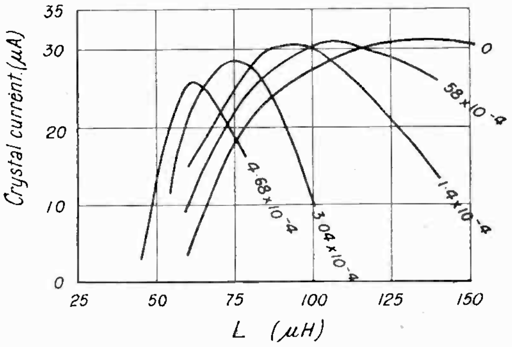

Fig. 17.

It will be noted that with low values of L, the crystal current is increased by parallel capacity so long as this capacity does not much exceed its optimum value. Also, as the inductance is increased, the amount of parallel capacity required to give the maximum current steadily decreases until, for a certain value of L, the best results of all are obtained with no parallel capacity. If L is still further increased the crystal current drops, as was shown in Figs. 8 and 9. The variation of optimum crystal current with parallel capacity is shown separately in Fig. 18.

Effect of Parallel Capacity in a Valve Circuit.

The family of curves in Fig. 19 illustrates the effect of parallel capacity in the case of a valve circuit. In this diagram values of the voltage across the A.T.I. are plotted against L. The figures against the graphs give the values of parallel capacity in microfarads. These curves exhibit the same general characteristics as those in Figs. 16 and 17; that is, they show that both the optimum voltage and optimum inductance increase as the value of parallel capacity is reduced. The variation of optimum voltage with parallel capacity is shown in Fig. 20. The scale values of parallel capacity are those obtained from the readings of a condenser connected across the A.T.I. Hence they do not include the unavoidable capacities of the valve and the A.T.I. itself. Thus, the real zero of the capacity scale is a little to the left of the marked zero.

Optimum values of L and K, taken from the curves in Figs. 16, 17 and 19, are plotted separately in Fig. 21.

It is interesting to see whether results such as those in Fig. 21 are calculable on purely theoretical grounds by application of the formulæ given above.

Taking Equation (IV.), and writing the coefficient of $\omega^2 L^2$ as a, we have

$$a\omega^2 L^2 + 2\omega K_3 . \omega L - 1 = 0$$

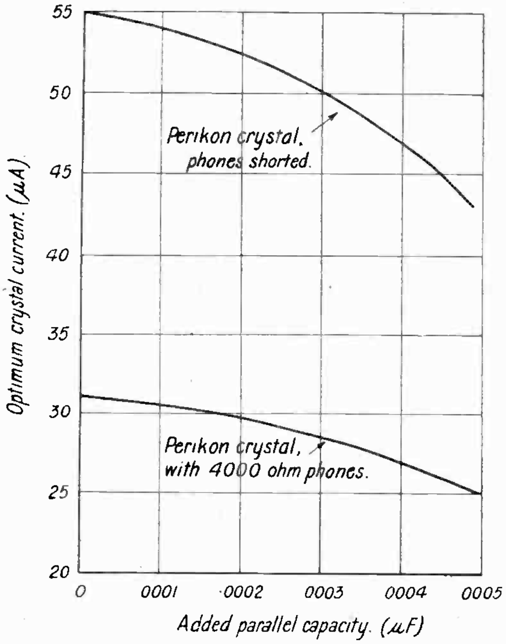

Fig. 18.

from which

$$L = \frac{-K_3 + \sqrt{K_3{}^2 + \frac{a}{\omega^2}}}{a}$$

where

$$a = \frac{1 - \omega^2 K_3{}^2 R r_1}{R(r + r_1)}$$

In the case of the valve, the grid-filament resistance, R, under the test conditions, was of the order of 7×10^4 ohms. On 360 metres $\omega = 5{\cdot}2 \times 10^6$, and $\omega^2 = 27{\cdot}4 \times 10^{12}$. Taking an aerial resistance of $r_2 = 40$ ohms, we have

$$a = \frac{1 - .767 \times 10^{20} K_3{}^2}{7 \times 10^4 (r + 40)}$$

We have to calculate L for a series of values of parallel capacity, K_3. Suppose we make $K_3 = {\cdot}000\,1\ \mu\text{F} = 10^{-10}\,\text{F}$. Then

$$a = \frac{{\cdot}233}{7 \times 10^4 (r + 40)}$$

We have now to choose a value of the coil resistance r. The high frequency resistance of the coils used in these tests was about ·2 ohm per microhenry over the range we are considering. As the value of L is not known we must first assume a reasonable value of r and calculate L. Then we have to correct r to agree with this value of L, finally recalculating L.

As a trial we will take 200 microhenries for the A.T.I. for which $r = {\cdot}2 \times 200 = 40$ ohms. Substituting this value of r we get

$$a = {\cdot}04 \times 10^{-6}$$

and $L = 177$ microhenries.

As L is lower than anticipated we must reduce the value of r. An inductance of 175 microhenries gives a corrected value of $r = 35$ ohms.

The corrected value of

$$a = 4{\cdot}44 \times 10^{-8}$$

and that of $L = 175$ microhenries. Thus, the change in r has produced no appreciable alteration to L.

Proceeding in this manner, giving various values to K_3, we obtain the results shown in Table II.

TABLE II.

$K_3(\mu\text{F})$	L
0	670
·000 01	515
·000 02	420
·000 1	175
·000 2	106
·000 25	87

These results are plotted in Fig. 22. The curve is in very close agreement with the corresponding experimental curve shown in Fig. 21, reproduced as the dotted line in Fig. 22, after allowing for 25 μμF stray capacity, considering that the values of the resistances taken in the calculations are only approximate.

We will next check a point on the lower crystal curve of Fig. 21, say for a parallel capacity of ·000 2 μF. The resistance of the perikon crystal used in these tests was between 15 000 and 25 000 ohms. Taking an average value of $R = 20\,000$ ohms, and a trial value of coil resistance of 9 ohms, the value of L works out to 68 microhenries. The experimental value from Fig. 21 is 75 microhenries, or 76 microhenries after allowing about 30 μμF for stray parallel capacities.

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Variation of Optimum Value of L with Wave-length.

We have not had an opportunity of carrying out any experiments to determine the best value of L for wave-lengths greater than 365 metres, so that the following conclusions are based only on theoretical grounds, and require experimental confirmation.

If we assume the parallel capacity to be low, Equation (VIII.) shows that ωL is constant, provided that the various resistances remain unchanged on altering L and ω.

Thus, if the wave-length (λ) is doubled, ω will be halved, and L will have to be doubled. The aerial capacity required to tune this value of L will also have to be doubled. We have roughly, then, that for maximum efficiency both L and the aerial capacity must be equally increased with λ.

In the case of a valve of low self-capacity, operated with plenty of negative grid bias to maintain a high value of R, and used in conjunction with a tuning coil of minimum self-capacity, the optimum value of L will be in the neighbourhood of 360 microhenries on 360 metres, which suggests the very simple relation

$$L \text{ (microhenries)} = \lambda \text{ (metres)}.$$

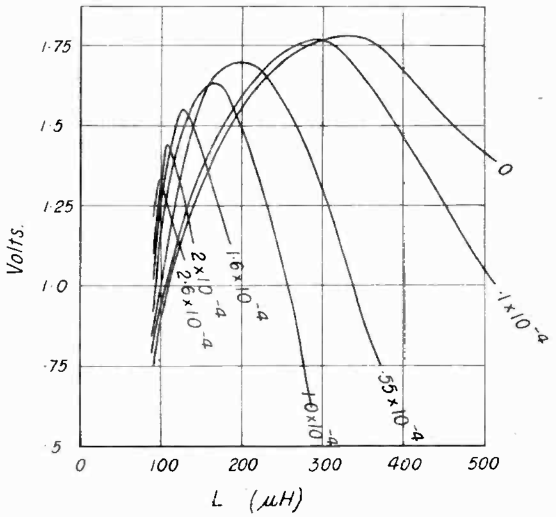

Fig. 19.

The aerial capacity (K) required to tune this value of L will be

$$K\ (\mu\text{F}) = \cdot 28 \times 10^{-6}\ \lambda \text{ (metres.)}$$

For a crystal circuit the corresponding relations are

$$L\ (\mu\text{H}) = \tfrac{1}{3}\ \lambda \text{ (metres)}.$$

and

$$K\ (\mu\text{F}) = \cdot 84 \times 10^{-6}\ \lambda \text{ (metres)}.$$

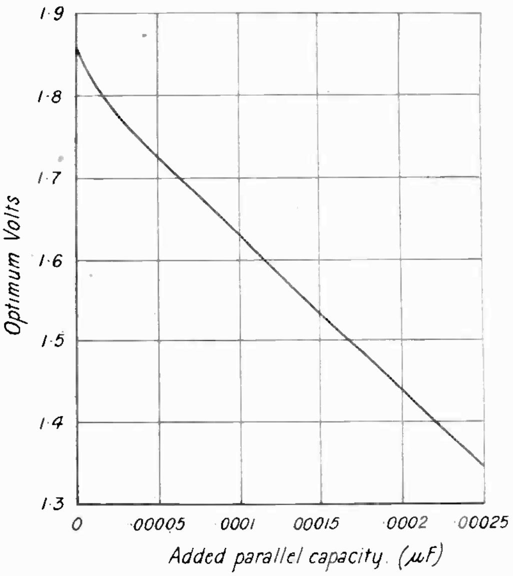

Fig. 20.

The above simple formulæ must be taken as giving only a rough idea as to the best value of L on long waves. To obtain an accurate estimate a number of corrections have to be applied.

(a) On long waves the inductance has to be more concentrated, giving greater self-capacity. This tends to lower the optimum value of L. On the other hand, the general formulæ shows that the effect of the self-capacity becomes smaller as λ increases. For example, in one numerical case, a parallel capacity of 25 cm. altered L by 26 per cent. on 360 metres (for a valve), but only by 3 per cent. on 3 000 metres.

(b) As the number of turns on the A.T.I. are greater, its resistance will be higher. The effect of increased coil resistance is to increase L.

(c) The aerial resistance will be higher, in general.

Correction (a) tends to reduce the optimum value of L and (b) and (c) tend to increase it. As the effect of (b) predominates we should expect to find that the simple formulæ given above lead to values of L which become more and more on the low side as λ is increased. If this is so it is a fortunate result, for then the aerial capacity required to give the best possible results will not increase so fast as is indicated above. For example, the simple formulæ indicate an aerial capacity of 3 000 metres of about ·000 8μF for a valve, and about ·002 5μF for a crystal set. In favourable situations, using a cage aerial, the former value may be obtainable, but a P.M.G. aerial having a capacity of ·002 5μF would be something of a curiosity.

Effect of Aerial Capacity.

On long waves, then, 100 per cent. results may not be obtainable on account of insufficient aerial capacity, and we have to decide whether it is better to tune on the inductance only, or to tune with a parallel condenser.

Some idea of the relative efficiencies of these two arrangements on long waves may be obtained by considering a numerical example. Suppose we have an aerial of capacity ·000 25μF (K_4), and we tune it to 3 000 metres ($\omega = \cdot628 \times 10^6$) using various values of inductance and parallel capacity. The resonant voltage rise across the A.T.I. is given by Equation (1). This equation may be put in a simpler form for the purpose of this calculation as the aerial capacity, K_4, is to be kept constant.

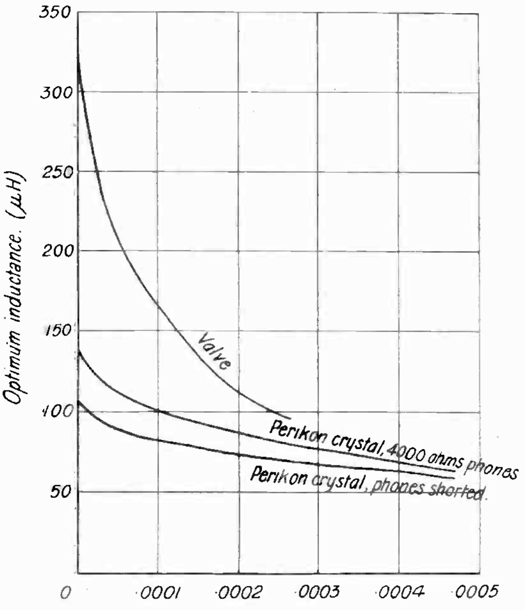

Fig. 21.

From the resonance condition,

$$\omega^2(K_3+K_4)L=1,$$

we have $1-\omega^2 K_3 L = \omega^2 K_4 L$

Hence we may write $\omega^2 K_4 L$ in place of q in Equation (i.), giving

$$\frac{E_1}{E_2}=\frac{\omega K_4}{\omega^2 K_4^2 r_1 + \frac{1}{R} + \frac{r}{\omega^2 L^2}} \quad .. (26)$$

showing that for a fixed value of K_4, E_1 increases indefinitely as L is increased. Thus plain inductance tuning cannot be improved upon in such a case. To complete our numerical results we will take $r_1 = 15$ ohms, $r = 40$ ohms, and $R = 10^5$ ohms for a valve. Substituting these values, together with those of K_4 and ω, in Equation (26) gives

$$\frac{E_1}{E_2}=\frac{1.57}{.104+\frac{1\cdot014\times10^{-6}}{L^2}}$$

By giving L a series of values we obtain the values of E_1/E_2 shown in Table III.

TABLE III.

$L\mu$H.	$K_3(\mu$F)	E_1/E_2.
10 100	0	13·8
5 600	·000 2	11·5
3 730	·000 42	8·88
1 000	·002 3	1·43

The above results show that parallel capacity leads to loss of efficiency, a ·000 5μF parallel capacity reducing the grid-filament volts by about 50 per cent. For the case of a crystal circuit we will take R=5 000 ohms, leaving other values unaltered. This gives

$$\frac{E_1}{E_2}=\frac{1.57}{2+\frac{1.014\times10^{-6}}{L^2}}$$

The maximum value of E_1/E_2 approximates to ·78 as L is increased and K_3 is reduced, but the loss of voltage due to a given parallel capacity is very much less than in the case of a valve. The damping may be so great with a low resistance crystal that there may be no resonant voltage rise across the A.T.I.

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We have shown that on 3 000 metres, with the given values of resistance, the best we can do with the ·000 25μF aerial is represented by $E_1/E_2=13{\cdot}8$ for the valve, and $E_1/E_2={\cdot}78$ for the crystal. As we increase the aerial capacity the value of E_1/E_2 (for a given parallel capacity) increases until the optimum capacity is reached.

The absolute optimum value of L, given by Equation (VIII.) for zero parallel capacity, works out to 3 730 microhenries for the valve, and 835 microhenries for the crystal, necessitating aerial capacities of ·000 67μF and ·003μF respectively. The corresponding voltages from Equation (IX.) are $E_1/E_2=21{\cdot}3$ for the valve, and 4·76 for the crystal. Thus the optimum aerial increases the grid-filament voltage about 50 per cent. and the voltage across the crystal about sixfold.

Effect of Coil and Aerial Resistances.

In measuring the effect on the grid-filament volts of the size of wire on the A.T.I. many experimenters make their measurements using a fixed value of inductance. The results obtained in this way may give quite a wrong impression as to the real effect of the resistance, and, numerically, the results are of little value as they depend on the particular values which ω, L and R may have during the test. This is clearly shown from Equation (VII.). For example, if the inductance is considerably overwound—as might happen if the experiment is carried out on a small aerial—so that ω^2L^2/R is large compared with $(r+r_1)$, the voltage across the A.T.I. will be largely independent of the gauge of wire, and the experimenter will come to the conclusion that the gauge of wire does not matter much. Another experimenter, choosing a low value of L for his tests, will find that the gauge of wire is of considerable importance, for when ω^2L^2/R is made small compared with $(r+r_1)$, the volts vary inversely as $(r+r_1)$.

To obtain consistent results it is necessary to take an inductance-voltage curve for each gauge of wire, so as to enable the optimum values to be located in each case.

Assuming the parallel capacity to be small, Equation (IX) shows that, with the optimum value of L, $E_1 \propto 1/\sqrt{r+r_1}$. On long waves the coil resistance r will be large compared with the aerial resistance r_1, and E_1 will be inversely proportional to $\sqrt{r}$, thus, wire of the lowest possible resistance is indicated. On very short waves, where r_1 is likely to be several times greater than r, the latter becomes of less importance.

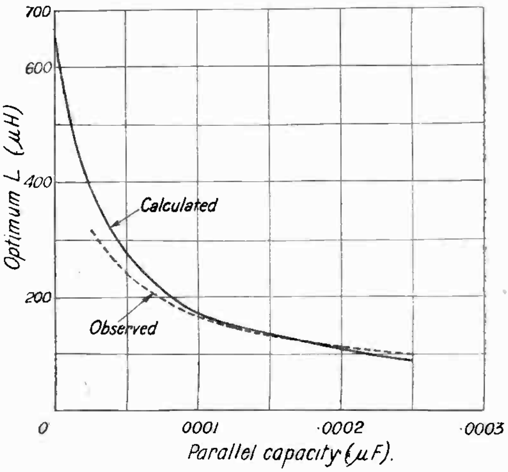

Fig. 22.

In fact, on 100 metres, if the coiled resistance of the A.T.I. is made as high as 1 ohm per microhenry, the voltage will be in the region of 70 per cent. of that which would be given with an A.T.I. of zero resistance. The extra resistance, without doing much harm, adds to the stability of the circuits.

In conclusion, we may perhaps point out that there is a snag in crystal testing similar to that dealt with above in connection with resistance tests. In an aerial test two crystals gave currents of 260 and 150 microamps respectively, with their optimum values of inductance on 2LO—that is current ratios of nearly 2 to 1. On testing, with the same crystal adjustments, on an overwound inductance the currents were 22·5 and 23 microamps respectively. In this case any current ratio between 2 to 1 and unity could be obtained by a suitable choice of inductance.

APPENDIX A.

Relation between the E.M.F. induced in an aerial and the power absorbed. In this paper it is assumed that the E.M.F. induced in an aerial is practically independent of the power absorbed, over the range covered by various resonant circuit conditions, and we present the following experimental results in support of our assumption.

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Method 1.—By connecting our aerial directly to earth through a Duddell thermo-galvanometer, as shown in Fig. 1*a*, we have been able to measure the current, *I*, due to the E.M.F., *E*, induced by 2LO's transmission. If the aerial constants are *K*, *L*, and *r*, and the resistance of the instrument is r_1 we have

$$E = I\sqrt{(r+r_1)^2 + \left(\frac{1}{\omega K} - \omega L\right)^2}$$

and the power $W = I^2(r+r_1)$.
The power was varied over a range of about 70 to 1 by altering the value of r_1 from 4 to 400 ohms. For the calculation of *E* it is necessary to know accurately the *K*, *L* and *r* of the aerial. We are certain of our measured values of *K* and *L*, but the measurements of *r* by different methods give results which are not at all in agreement. However, the desired relation between *E* and *W* may be obtained without it being necessary to know the aerial *r* or *L* by the following modification of the method.

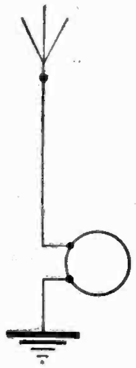

Fig. 1*a*.

Method 2.—Retaining the galvanometer in the earth lead, an inductance and variable condenser of low losses were connected in the aerial circuit as shown in Fig. 2*a*. The galvanometer deflection was read for a series of values of the series capacity K_1, above and below and passing through the tuning point. Let the aerial constants be *K*, *L* and *r*, the instrument resistance r_1, the self-capacity of the A.T.I. *k*, and its inductance L_1. For the whole circuit, the capacity will be $\frac{KK_1}{K+K_1}+k$; the inductance $L+L_1$ and the resistance $r+r_1$.

The total reactance

$$X = \frac{1}{\omega\left[\frac{KK_1}{K+K_1}+k\right]} - \omega(L+L_1)$$

Let the series capacity at resonance be K_0, then

$$\omega(L+L_1) = \frac{1}{\omega\left[\frac{KK_0}{K+K_0}+k\right]}$$

Hence, the total reactance may be written as

$$X = \frac{1}{\omega\left[\frac{KK_1}{K+K_1}+k\right]} - \frac{1}{\omega\left[\frac{KK_0}{K+K_0}+k\right]}$$

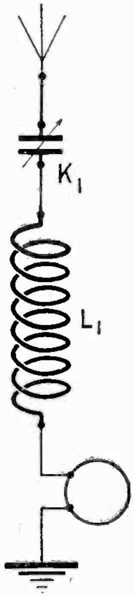

Fig. 2*a*.

Denoting the total circuit resistance by *R* $(=r+r_1)$, and the induced voltage by *E*, then the current *I* is given by

$$I = \frac{E}{\sqrt{X^2+R^2}}$$

The deflection *d* of the galvanometer used in this test is proportional to I^2, thus

$$I = a\sqrt{d}$$

where *a* is a constant determined from a D.C. calibration.

Combining the last two equations and squaring both sides gives

$$a^2 d = \frac{E^2}{X^2+R^2}$$

whence

$$\frac{E^2}{a^2}\left(\frac{1}{d}\right) = X^2 + R^2$$

Now, on plotting $1/d$ against X^2 a curve will be obtained if *E* varies with *d* (and thus with the power absorbed), but a straight line will result if *E* be constant. So long as numerical values of *E* are not wanted, values of *d* and *X* only need be known, and *X* involves the measurement of two capacities (*K* and *k*) only, and the use of an accurately calibrated condenser for K_1 and K_0.

Numerical results of one test using this method are given in Table I*a*. For this test the circuit constants were: $K = 3{\cdot}9 \times 10^{-10}$F, $k = 10\mu\mu$F, $r_1 = 4{\cdot}25$ ohms, $L = 17\mu$H, $L_1 = 200\mu$H (approx.). For the galvanometer $I = {\cdot}163\sqrt{d}$ milliamps.

The relation between X^2 and $1/d$ is shown graphically in Fig. 3*a*. The scales marked on the diagram refer to the points indicated by *X*'s, the point corresponding to the observation $d = 4.7$ being omitted. To bring in this observation the points are re-plotted to one-fifth of the marked scales.

These latter points are shown by dots. Thus the dot and the X marked A represent the same values, *i.e.*, $1/d = \cdot 05$, $X^2 = 21\,304$. Within the limits of experimental error the points lie on a straight line on either scale.

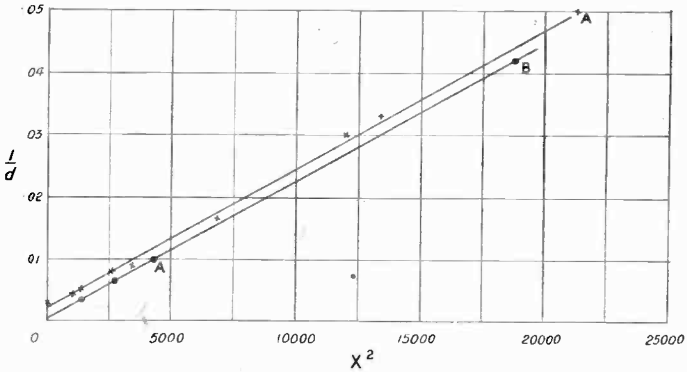

Fig. 3*a*.

As the slope of the two lines is the same it is evident that the point for which $1/d = \cdot 21$ and $X^2 = 93\,150$ (shown at B on the lower line) lies on the upper line produced to about four times the length shown. If there were an increase in the induced E.M.F. when the power absorbed by the aerial were reduced, the points in Fig. 3*a* would lead to a curve which was concave to the X^2 scale. There is no evidence in these results of such a curvature, and if it exists it is to such a slight degree that it would not affect any of our results based on the constancy of the induced E.M.F.—especially as we require the E.M.F. to be constant only for comparatively small changes of power. The extreme observations in Fig. 3*a* cover a power ratio of about 3 000 to 1. From this set of results we calculate that $R = 37$ ohms and $E = \cdot 12$ volt. Observed values of d and K_1 are plotted in Fig. 4*a*.

TABLE IA.

K_1 $\mu\mu F$	$\dfrac{KK_1}{K+K_1}$ $\mu\mu F$	$\dfrac{1}{\omega\left\{\dfrac{KK_1}{K+K_1}+k\right\}}$ Ohms.	X Ohms.	X^2	d mm.	$\dfrac{1}{d}$
190	1 277	1 406·5	—208·7	42 600	10	·10
170	1 186	1 505·7	—109·2	11 924	33	·03
166	1 165	1 530·6	— 84·3	7 100	65*	·015 3
162	1 144	1 556·5	— 58·4	3 411	113	·008 85
158	1 123	1 583·2	— 31·7	1 005	230	·004 35
153	1 099	1 614·9	0	0	400	·002 5
148	1 072	1 651·9	+ 37	1 369	200	·005
146	1 062	1 666·4	+ 51·5	2 652	125	·008
142	1 041	1 697·6	+ 82·7	6 840	60	·016 7
138	1 019	1 730·6	+115·7	13 390	30	·033
130	975	1 801·2	+146·3	21 304	20	·05
110	858	2 020·1	+305·2	93 150	4·76	·21

* Off curve.

In a test using Method 1 the galvanometer current was 319 microamps with a heater resistance of 197 ohms. Taking the aerial resistance as 27 ohms gives a circuit resistance of 224 ohms. The circuit inductance was about 27 microhenries, made up of 17 microhenries for the aerial and an estimated 10 microhenries for the wiring of the circuit. Thus the inductive reactance on 365 metres = 139 ohms. Capacity reactance of the aerial = 496 ohms. The impedance of the circuit

$$= \sqrt{(224)^2 + (496 - 139)^2} = 421 \text{ ohms.}$$

Hence $E = 319 \times 10^{-6} \times 421 = \cdot 134$ volt.

This result is somewhat higher than that given by the other method, but in the calculation we are not sure of the figures given for the aerial resistance and the stray inductance. While an error of 2 or 3 ohms in the aerial resistance makes but little difference to the result in this case, the

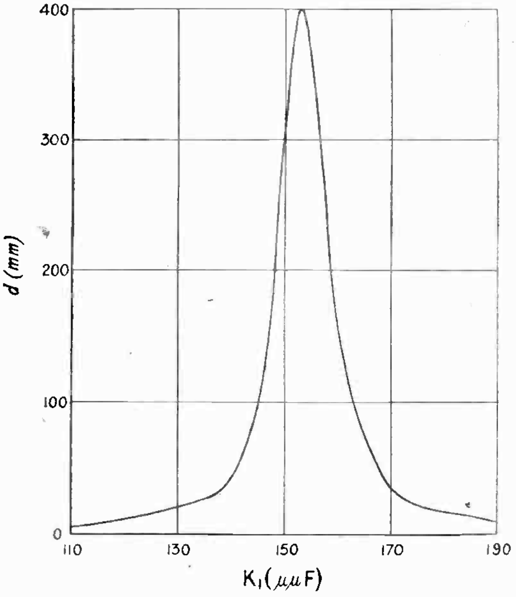

Fig. 4*a*.

inductance of the wires to the galvanometer (which had to be set up some 12 ft. from the lead-in and earth wires) was important. The figure of 10 microhenries for this inductance was calculated from the area of the loop; and the effects of an iron motor frame within a few inches of the loop had to be ignored. Had the stray inductance been 20 microhenries the value of E would come out to ·115 volt.

APPENDIX B.

Equivalent Load Resistance of Receiving Circuit.

(1) *Input resistance of valve circuit.*—The magnitude of R is fairly easily obtained experimentally for a given valve working under given conditions; but it is quite another matter to give quantitative data applicable to all cases, owing to the large variation of R with the circuit conditions. Its value at a given frequency depends upon the H.T. voltage and filament current, the grid-current, the inter-electrode capacities of the valve, and the nature of the anode circuit.* It also depends on the type of valve holder, the layout of the wiring, and the dielectric loss of the material on which the input terminals are mounted. In addition there is a shunt loss resistance associated with the self-capacity of the A.T.I., although with properly designed coils this resistance may be made much higher than that of a valve under working conditions.

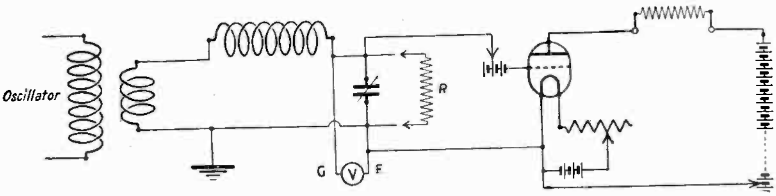

Fig. 1*b*.

The method used for measuring the input resistance is shown in Fig. 1*b*. The valve under test is connected across the condenser of a resonant circuit loosely coupled to an oscillator. The voltage across the condenser (indicated by a thermionic voltmeter V) varies according to the load produced by the valve. For calibration a series of high resistances R were substituted in place of the valve under test, and the resistance required to bring down the reading of the voltmeter to the value obtained with the valve in circuit is taken to be the equivalent input resistance. Each of the resistances used in this calibration consisted of a single straight line of platinum deposited on mica. These resistances were suspended from two stout bare wires mounted on the condenser terminals, so that no extra dielectric loss resistance was added to the circuit with the resistance R. This precaution was found to be necessary with the higher values of R. The results of tests on an R-type valve are given in Figs. 2*b* to 4*b*, and Table IB. The peak value of the voltage across the condenser, when unloaded except for the voltmeter, was kept constant in all these tests at 2·2 volts. $\lambda = 365$ metres.

The curves in Fig. 2*b* show the general effect of H.T. and negative bias on the input resistance. Observations for the marked curves were taken with a constant anode load of 35 000 ohms (the resistances used here were those used in the calibration test. They are non-inductive and have a self-capacity not greater than $1 \mu\mu$F). Filament current ·65 amp. A load of 35 000 ohms was chosen as it was approximately that load giving the maximum loss and minimum value of R. The input resistance at the working H.T. voltage for amplifying is seen to be below 15 000 ohms with no bias, and about 20 000 ohms with —3 volts bias. Although the input resistance increases with the bias for a given H.T. voltage, there is no advantage to be gained by increasing the bias much beyond the peak value of the input voltage, owing to the reduction in R due to the necessary increase in H.T. counterbalancing the increase due to the extra bias. With anode loads under 1 000 ohms the input resistance with the correct grid bias and H.T. voltage for amplifying was found to be of the order of 300 000 ohms. The unmarked line in Fig. 2*b* shows the variation of R with H.T. for the valve used as a grid-leak rectifier, with a constant anode load of 8 000 ohms (self-capacity $1 \mu\mu$F). The input resistance is seen to be about 75 000 ohms with 70 volts

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* J. M. Miller, *Bulletin Bureau of Standards*, No. 5351.

H.T. With a suitable condenser across the anode load of the detector valve the input resistance would be considerably higher

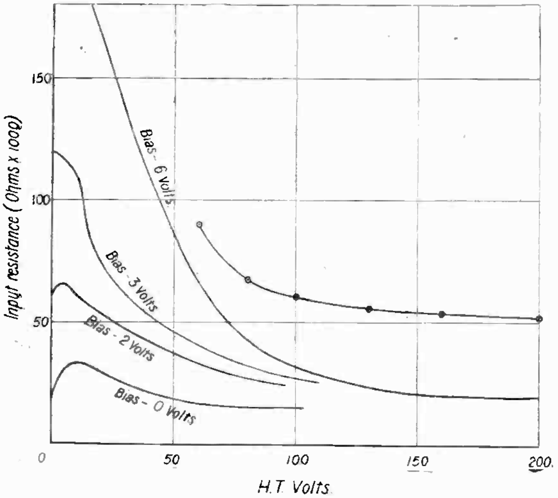

Fig. 2*b*.

than this figure. Results obtained by varying the anode resistance are given in Table I. (col. 2) and in Fig. 3*b*. The curves show clearly the existence of a "worst" anode resistance from the point of view of input load. If the capacity reactance between plate and filament is large, the resultant resistance due to this worst anode load and the internal resistance of the valve in parallel with it is equal to the reactance of the plate to grid capacity. This point is further illustrated in Fig. 4*b*, which shows the general effect of filament current on *R*. The observations were taken with a plate load of 35 000 ohms and 90 volts H.T. The minimum input load resistance occurs near the working filament current of ·65 amp in this case, because the worst plate load of approximately 35 000 ohms was previously determined with this particular current, and this same load was used in the filament current test.

(2) *Equivalent resistance of crystal circuit.*—Before giving the results of high frequency resistance tests on crystal circuits it may be helpful to outline the action of the various parts of a crystal circuit supplied with a modulated H.F. voltage. The circuit is shown in Fig. 5*b*. It contains four elements likely to affect the equivalent resistance, namely, the forward effective crystal resistance r_1, a resistance r and inductance L representing the phones, and a shunt capacity K. First, if K be omitted, and the phones have no self-capacity, the reception of telephony would be impossible, and only a minute rectified H.F. current could flow through the circuit if L had its normal value. Thus some parallel capacity, which may be wholly or partly provided by the

TABLE IB.

Grid bias —6 volts. Fil. ·65 amp.

Anode Resistance (Ohms × 10^3).	Input Resistance (Ohms × 10^3)	
	H.T. 90 volts.	H.T. 200 volts.
0	425	
2		180
3	190	130
5		58
6	95	
8	65	
10	54	35
25	37	21
56·4	40	21
75	45	22·5
131	56·5	25
530	120	

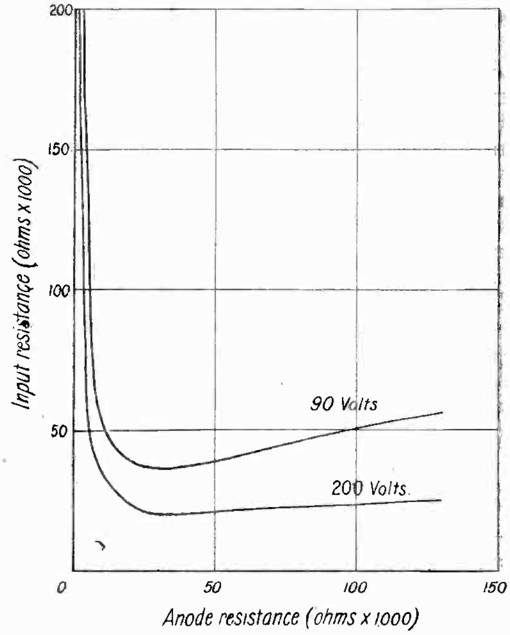

Fig. 3*b*.

phones themselves, is necessary. From considerations given later it would appear that the necessary capacity in μF should exceed T/r, where T is the time in μ-secs. of one cycle of the H.F., and r is the phone resistance in ohms. Thus, for 2 000 ohm phones on 300 metres ($T = 10^{-6}$ secs.), K should exceed $1/2\,000 = \cdot 000\,5\,\mu$F, and on 3 000 metres, the minimum value of $K = 10/2\,000 = \cdot 005\,\mu$F. To be on the safe side the capacity should be made equal to twice the value calculated as above. If a microammeter A, Fig. 5b, is included in the phone circuit it will be found that its reading increases rapidly as K is increased to the value T/r, and then increases more and more slowly as K is further increased beyond this value. In an actual test we have found that an increase in K from ·001 to 20μF (with 2 000 ohm phones on 365 metres) made no measurable difference to the reading of A, and also had no noticeable effect on the load produced by the crystal circuit. But the large value of K killed the L.F. current through the phones. Turning now our attention to L, we have found that the magnitude of the pure inductance —from zero to 100 henries—has no noticeable effect either on the reading of A or on the load resistance of the circuit. The L.F. current, however, decreases continuously as L is increased. Thus, the equivalent resistance R depends only on r and r_1, and curiously, it is often less than either the D.C. or the A.C. resistance of the crystal circuit, and may be less than the phone resistance alone. In explanation of these results, we may suppose the crystal to pass no reverse current, so that, during the forward half-waves of the applied voltage, current starts to flow through the crystal at the instant the applied voltage exceeds the voltage of the condenser, and stops at the instant the applied voltage falls to the same value as that of the condenser. As the average condenser voltage is usually an appreciable fraction of the supply volts, the active period of the crystal is less, in general, than half the H.F. period. Thus, current gets through the crystal in gushes lasting only, say $\frac{1}{3}$ or $\frac{1}{4}$ of a period. The current through r, on the other hand, is continuous throughout the cycle. As the same quantity of electricity, per cycle, flows into the condenser through the crystal as flows out of it through r, it follows that the average crystal current during the active portion of the cycle must be 3 or 4 times the steady current through r, and the actual crystal resistance will be correspondingly lower than its value when carrying the same current as the phones. As regards the phone resistance r, this does not really enter into the circuit as a resistance: it merely controls the mean voltage of K, which in turn regulates the flow of current through the crystal. For example, if r is increased, the rate of leakage from K is reduced, and the voltage of K will be higher than before at the end of the cycle. Thus, crystal current can flow only during a smaller fraction of a cycle; it starts later and ends earlier in the cycle. It may be noted that, if the crystal is an imperfect rectifier, the imperfection will have more harmful results than is apparent from a D.C. test, for reverse current flows during

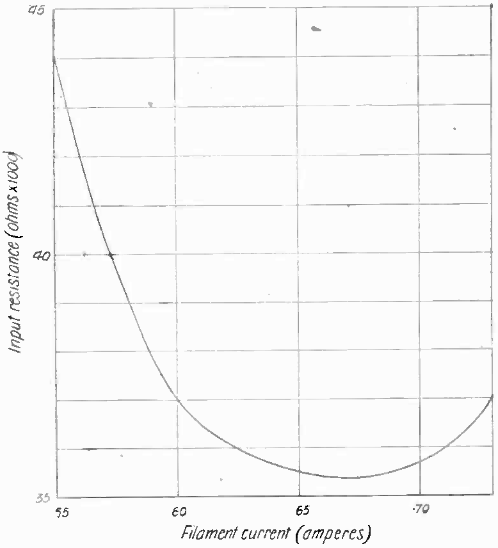

Fig. 4b.

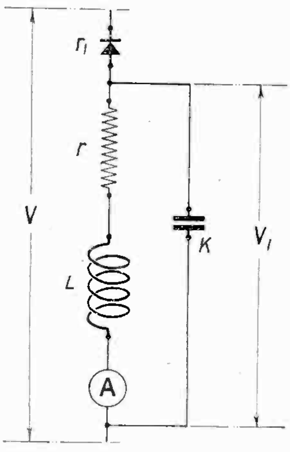

Fig. 5b.

the whole of the reverse half-cycle and also during the commencement and end of the forward half-cycle while the condenser volts exceed the instantaneous value of the supply voltage. That is, reverse current flows for, say, $\frac{2}{3}$ to $\frac{3}{4}$ of a cycle. In addition, the maximum value of the reverse voltage is the sum of the condenser voltage and the maximum value of the supply volts, instead of the difference between these two voltages as in the case of the forward current. The maximum reverse voltage may easily be three times the maximum forward voltage.

Summing up, we find that the load resistance of a crystal circuit does not depend—at least to any appreciable extent—on K and L; that while it depends indirectly on r, the ohmic value of r is not a part of the load resistance; and that the actual crystal resistance r_1 during its active period must be taken as the value corresponding to a current several times greater than the steady phone current.

Experimental results obtained with a galena crystal are given in Table IIB. The A.C. test was made on 365 metres, the equivalent load resistance R being determined by the method of substitution described above. Measurements of R, the A.C. voltage, V, supplied to the crystal circuit, and the steady current, I, through r, were made with five different values of r. These measurements were repeated for four different input voltages. Also, at the same time, a D.C. test was made on the crystal circuit. The D.C. voltages, E, required to send the same current, I, through the circuit are shown in the fourth column. The input, phone and crystal powers are shown in columns (9), (10) and (11), respectively. In all cases the capacity across r was ·001μF.

TABLE IIB.

(1) V Volts.	(2) I μ Amps.	(3) r Ohms.	(4) E Volts.	(5) R Ohms.	(6) D.C. Resist. $=\frac{E}{I}\times 10^6$	(7) V_1 Volts.	(8) δV_1 Volts.	(9) $P_1=\frac{V^2}{R}$ μ Watts.	(10) $P=rI^2$ μ Watts.	(11) $P_c=P_1-P$ μ Watts.	(12) α °	(13) I_c μ Amps.
·375	200	30	·21	1 500	1 050	·006	·244	93·7	1·2	92·5		
·76	189	2 030	·593	3 400	3 140	·38	·23	170	72	98·1		
1·03	170	4 030	·90	4 650	5 300	·68	·207	228·5	116·5	112		
1·48	154	8 030	1·46	6 750	9 460	1·24	·188	325	190	135		
1·67	146	10 100	1·68	7 640	11 500	1·47	·178	366	213	153	102°	515
·26	100	60	·147	2 200	1 470	·006	·122	30·7	0·6	30·1		
·375	85	2 060	·317	3 600	3 730	·175	·104	39	14·8	24·2		
·485	78·5	4 060	·467	4 900	5 950	·319	·096	48	25	23		
·67	71	8 060	·733	7 000	10 300	·572	·087	64·2	40·6	23·6		
·77	68	10 130	·843	8 000	12 400	·689	·083	74	46·2	27·8	102°	240
·185	50	60	·117	2 850	2 340	·003	·061	12	0·15	11·8		
·26	44	2 060	·193	3 850	4 400	·09	·054	17·5	4	13·5		
·32	41	4 060	·267	5 000	6 500	·166	·05	20·5	6·77	13·73		
·405	37	8 060	·417	7 250	11 300	·298	·045	22·6	10·9	11·7		
·458	35·9	10 130	·477	8 400	13 300	·364	·044	25	12·9	12·1	112°	115
.125	20	60	·077	2 200	3 850	·0012	·024	7·1	0·024	7·1		
·16	18	2 060	·113	3 600	6 300	·037	·022	7·1	0·65	6·45		
·18	16·8	4 060	·143	4 000	8 500	·068	·021	8·1	1·13	7·0		
·23	15	8 060	·190	5 900	12 700	·121	.018	9·0	1·8	7·2		
·26	14·2	10 130	·217	7 900	15 300	·144	·017	8.6	2·02	6·6	134°	38

Comparing columns (3) and (5) it will be seen that the equivalent resistance of the whole circuit is about equal to the phone resistance, r, when the latter is 4 000 ohms. The value of R is less than r when this exceeds 4 000 ohms, and is greater than r when this is less than 4 000 ohms.

Regarding the necessary value of K, the average voltage, V_1, across K is evidently given by the expression

$$V_1 = rI \times 10^{-6}$$

The quantity of electricity in coulombs drawn from the condenser in one cycle (neglecting reverse crystal current), $\delta Q = I.T \times 10^{-12}$, where T = period of the H.F. supply in μ secs. The average change in condenser volts, δV_1, due to this quantity Q, is given by

$$\delta V_1 = \frac{\delta Q}{K \times 10^{-6}} = \frac{IT \times 10^{-6}}{K}$$

where K is in μF.

In order that the condenser may not run dry before the end of the cycle, and thus starve the phones of D.C., we should make $V_1 > \delta V_1$*

$$i.e. \quad rI \times 10^{-6} > \frac{IT \times 10^{-6}}{K}$$

$$i.e. \quad K > \frac{T}{r}$$

In the present test $K = \cdot 001\mu\text{F}$, $T = 1\cdot 22$ μ secs. Thus, we do not get the best results unless $r > 1\cdot 22 / \cdot 001$ *i.e.*, $> 1\,220$ ohms. This condition holds except for the cases in which the instrument alone, of resistance 30 or 60 ohms, was in circuit. In these cases the inductance of the instrument probably reduced the current below the value it would have attained had the correct value of K been used. Values of V_1 and δV_1 are tabulated in columns (7) and (8) of Table IIB. It will be noted that δV_1 is only about 12 per cent. of V_1 when $r = 10\,000$ ohms; and apparently exceeds V_1 only in the particular cases mentioned above in which the instrument alone was across K. In these cases δV_1 does not really exceed V_1. As K is insufficient to store the full quantity of electricity passing through the crystal the excess flows directly through the impedance of the instrument.

The time interval during which the crystal is active and the average crystal current during this interval may be approximately estimated in a number of ways. Probably the most direct method is to determine the instants at which the supply voltage rises above, and falls below, the condenser voltage. Assuming a sine wave of supply voltage,† the maximum input voltage is $1\cdot 41 \times$ R.M.S. voltage V, and the instantaneous voltage

$$e = 1\cdot 41 V \sin \omega t$$

Assuming the fluctuation of condenser voltage, δV_1, to be small compared with V_1, the crystal current starts and finishes when $V_1 = e$, *i.e.*, at instants given by

$$\omega t = \arcsin \frac{V_1}{1\cdot 41 V},$$

and the angle, $\alpha°$, during which the crystal is active, will be

$$\alpha = 180 - 2 \arcsin \frac{V_1}{1\cdot 41 V},$$

if we take the smallest value of $\arcsin \frac{V_1}{1\cdot 41 V}$ in degrees. In the present test this formula is applicable, with any degree of certainty, only to the cases in which $r = 10\,000$ ohms. With smaller values of r the magnitude of δV_1 was too large compared with V_1 (owing to the low value of K). When δV_1 is large the crystal current starts and also finishes earlier in the cycle, and the active arc may be somewhat different from that given by considering the average value of V_1.

Knowing the active period t of the crystal the average crystal current, I_c, is calculable from the equation

$$I_c = \frac{IT}{t}$$

Values of $\alpha°$ and I_c are given in the last two columns of Table IIB. The peak values of crystal current work out to somewhat over four times the steady phone current I, and the average values are, roughly, three times I.

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* δV_1 is the average and not the maximum voltage change. Thus, to be on the safe side, K should be made equal to twice the calculated minimum value.

† A discontinuous load, such as that provided by a crystal circuit, might be expected to cause distortion of the applied voltage wave. We have some experimental evidence that such is not the case. The crystal load appears to diminish the amplitude of the applied voltage wave without affecting its wave form. The amplitude is reduced to the same value in both halves of the wave. The evidence on which these statements are based cannot be given here.

An Acknowledgment.

In our last issue we published two photographs of the new wireless installation at Basle (Switzerland) Aerodrome, but omitted to mention that both the transmitting and receiving plant were by Marconi's Wireless Telegraph Co., Ltd. The photographs also were supplied by Messrs. Marconi.

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The High-Frequency Copper Losses in Inductance Coils.

By S. Butterworth, M.Sc.

[R382·1

IN the issue of E.W. & W.E. for May, various writers have made suggestions as to what is the correct basis upon which to design inductance coils suitable for reception throughout the broadcasting range of wave-lengths, and the general impression gathered seems to be that the main losses in these coils are due to the imperfections of the dielectric surrounding and supporting the wires, spacing being resorted to in order to reduce these losses.

Now, although adequate spacing will no doubt reduce these losses, yet it will be shown that with a reasonably good dielectric these losses contribute only a small amount to the total resistance even when the turns are fairly close together. The reason why a proper spacing brings about a considerable reduction in resistance is made clear by a short consideration of the *copper* losses in the coil.

If first we consider an inductance coil through which a *low* frequency alternating current is passing, the main loss in the coil is that due to the direct current resistance of the wire, and everything is to be gained by making the section of the wire as large as possible, that is, by winding the coil closely with thick wire.

But in addition to this loss there is another copper loss. Each turn is situated in the magnetic field due to all the remaining turns, and since this field is alternating, eddy currents are induced in the turn in question in exactly the same way as the eddy currents induced in neighbouring metal objects. The losses due to these eddy currents differ from those due to the main current in that they increase with the diameter of the wire, while the ordinary D.C. resistance diminishes as the diameter of the wire is increased.

Now, if the frequency is increased the eddy current losses grow more rapidly than those due to the main current flowing in the wire, and a stage is reached when they become the predominating factor in the alternating current losses. It then becomes profitable to diminish the section of the wire (keeping the same total winding space and number of turns, so as to hold the inductance constant) as a considerable reduction of eddy current loss may then be obtained, which more than counterbalances the resulting increase in the main current loss. The minimum copper loss is obtained when the diameter of the wire is such that the two losses are about equal. This diameter will of course depend upon the frequency for which the coil is to be designed.

It is possible to obtain formulæ for the two types of copper losses. Thus, four years ago, the writer published formulæ for calculating the copper portion of the resistance of single layer solenoids and disc coils which are applicable for all wave-lengths exceeding about three times the natural wave-length of the coil and for any solenoid having a length not greater than its diameter.

More recently, Professor Fortescue has given corresponding formulæ suitable for deeply wound inductance coils, which are applicable over a wide range of frequency. Unfortunately these formulæ only hold for coils having a winding length which is greater than the overall radius, so that the usual type of commercial wireless receiving coil is not included. The writer however has, for his own use, calculated the necessary factors for these shorter coils, and has generalised Professor Fortescue's formulæ so as to be applicable over the same range of frequency as the single layer coil formulæ referred to above. He hopes to be able to publish this generalisation when sufficient confirmatory or contradictory experimental evidence has accumulated.

It may be stated, however, that the formulæ have been tested by comparison with the measured values in the case of a well-known series of commercial inductance coils for which the inductances ranged from 80 to 2 000 microhenries, and it was found that the calculated copper losses lay between 82 and 92 per cent. of the measured losses at wave-lengths for which the coils are normally used.

As regards single layer coils, considerable experimental evidence is available, and in the great majority of cases the ratio of copper loss to total loss in a resonating circuit containing a good quality air condenser is between 0.7 and 0.9. A few comparisons have also been made in which the measured resistance did not include any condenser loss, and these gave agreement with observation within the probable order of accuracy of measurement.

The evidence therefore is all in favour of design which aims at making the total copper loss a minimum. Since there is a correct diameter of wire to make the copper loss a minimum, it is useless to suggest an alteration in this diameter in order to bring about a reduction in the already small dielectric loss.

In the issue of E.W. & W.E. referred to above, Mr. R. M. Wilmotte contributed an excellent article on the Parasitic Losses in Inductance Coils, and gave a short table of measured resistances for a single layer coil at a wave-length of 300 metres. Although these measurements were primarily intended to illustrate the effect of reducing the quality of the dielectric, yet they supply sufficient evidence to emphasise the real proportion of copper to other losses when the dielectric is in a normal condition. We append here the data necessary for the present analysis.

Coil.—Single layer wound on square frame of 7.5 cm. side.
Turns.—30.
Winding pitch.—1.5 mm.
Wire diameter.—0.711 mm. No. 22 S.W.G.
D.C. resistance.—0.405 ohm.
Inductance.—Not stated, but found by known formulæ to be about 77 microhenries.
Self capacity.—Not stated.

MEASURED A.C. RESISTANCE AT 300 METRES.

Condition of Insulation.	Type of Insulation.			
	Bare.	D.S.C.	Enamel.	D.C.C.
Dry	1.58	1.58	1.61	1.64
Wet	1.68	2.09	1.71	4.09

This coil has a remarkably low resistance for its inductance and the length of wire employed.

Except for the fact that the coil is square, the specification conforms almost exactly to the coil I recommended in my paper on single layer coils, viz.: that the coil should have a winding length something less than its radius and a winding pitch twice the diameter of the wire. No one, apparently, has hitherto troubled to test this out. It is seen that the winding pitch of Mr. Wilmotte's coil is nearly the correct one, while, since the equivalent circular coil has a radius of 4.26 cm. and the winding length (30 × 0.15) is 4.5 cm., the coil length is somewhat greater than its radius. However, since the variations of resistance are very slow in the neighbourhood of the minimum conditions an *exact* fulfilment of the conditions is unimportant.

We can estimate the magnitude of the copper loss in the coil by calculating the loss in the equivalent circular coil. The writer's formula for the A.C. (copper) resistance of single layer short solenoids with the wires *well spaced* is

$$R' = R\left\{1 + F + \left(3{\cdot}29 + \frac{b}{2}\right) - \frac{d^2}{D^2}G\right\}$$

where R' is the A.C. resistance,
R is the D.C. resistance,
d is the diameter of the wire,
D is the winding pitch,
b is the coil length,
a is the coil radius,
f is the frequency,

and F and G are tabulated functions of $d\sqrt{f}$.

For the stated frequency and diameter of wire

$$1+F=3.08, \quad G=1.27.$$

The equivalent circular coil (that is, the circular coil having the same winding length, turns, and inductance) has

$$a=4.26, \quad b=4.5,$$

while

$$d=0.711, \quad D=1.5.$$

Inserting these values in the formula we find that the total A.C. copper resistance is 4.32 times the D.C. resistance.

Now the equivalent circular coil requires a shorter length of wire than the square coil and its calculated D.C. resistance is 0.343 ohm. Hence the A.C. copper resistance is 1.48 ohms.

This estimate is admittedly approximate, but when we remember that the A.C. resistance of the wire of the square coil when straightened out would be 1.18 ohm, the above value cannot be much too great. There is therefore only about 0.1 ohm left to account for when the coil is dry.

It is unfortunate that Mr. Wilmotte did not state the self capacity so that an estimate could be made of the power factor and self capacity corrections given in his formula.

Mr. Wilmotte's method of illustrating the effect of the dielectric on the losses by applying moisture is interesting, but a much more powerful method may be applied which has the advantage that the dielectric may be studied in its normal dry condition. The method consists in winding the coil in a number of separate sections, of which the ends are brought out and connected in various ways so that in all cases the current circulates in the same direction round the coil, but the potential difference between contiguous sections may be varied. By this means the self capacity, and therefore the dielectric losses, may be subjected to large variations while the inductance and copper losses remain practically constant.

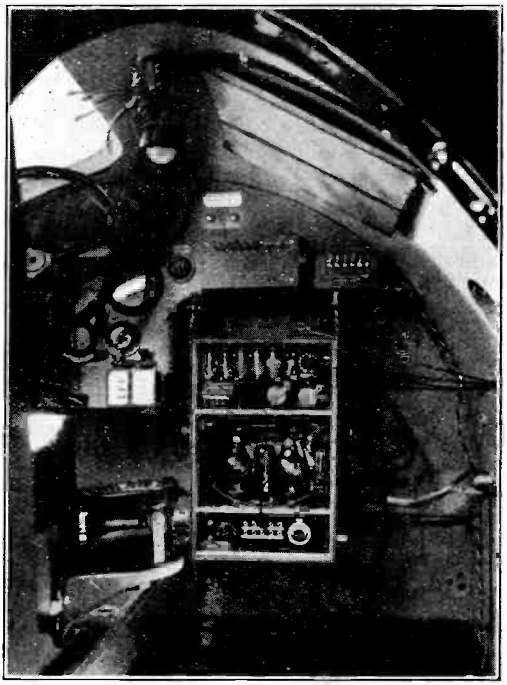
The writer constructed a single layer coil of this type some years ago and the following experimental results may be of interest. The coil was wound on a waxed wood former of 17.5 cm. diameter to a total length of 6.7 cm. with (in the following tests) No. 24 S.W.G. D.C.C wire. The total number of turns was 102, and the coil was broken at the centre into two sections having 48 and 54 turns respectively. The free ends were brought out to two extra terminals. Calling the normal terminals of the coil *A B* and the central terminals *C D*, it was found that when the terminals *C D* were shorted and the terminals *A B* used as the current terminals so that the coil was working in its normal manner, the inductance was 2070μH, the self capacity $11\mu\mu$F, and the resistance at a wave-length of 1 730 metres was 11.7 ohms.

When, however, the terminals *A B* were shorted and the terminals *C D* used as the current terminals, so that the full potential drop in the coil was thrown across contiguous turns, the inductance was still 2070μH, but the self capacity rose to $93\mu\mu$F and the effective resistance to 36 ohms.

In this case, the proper formula to apply in order to correct for self capacity and dielectric loss is

$$\text{Effective resistance} = \frac{R' + \omega^3 L^2 CP}{(1 - \omega^2 LC)^2}$$

where ω is 2π times the frequency, L is the inductance, C the self capacity, P the power factor of the dielectric and R' the A.C. copper resistance. Now the theoretical formula makes the copper resistance equal to 8 ohms. This may be a slight underestimate as the coil is rather closely wound, but as we are concerned with the difference between the two cases this does not matter. Multiplying the measured effective resistances by the value of $(1-\omega^2 LC)^2$ appropriate in each case and then subtracting 8 ohms, the portion of the resistance unaccounted for is 3 ohms in the normal and 13 ohms in the abnormal case. The difference, 10 ohms, is due to the power factor of the added self capacity, and is accounted for by a value of P equal to 0.023, which appears quite normal for this type of dielectric. As regards the coil when used in the normal manner, if we assume that the whole of the normal self capacity is due to distributed condensers having the above power factor, the dielectric loss cannot contribute more than 1.3 ohms to the measured resistance at this frequency.



A Marconi A.D.6 telegraph and telephone transmitter and receiver as installed on an Imperial Airways' Machine.

It will be noted that if we assume the power factor of the dielectric to be invariable with frequency, the dielectric loss introduces into the resistance a term varying as the cube of the frequency. Now the writer, although he has met with experimental formulæ involving square roots, first powers, and squares of frequency, has never met an experimental analysis which requires a power of the frequency as high as the cube. We are therefore forced to assume either that the power factor diminishes with frequency or that the dielectric losses are unimportant. The former assumption seems to be ruled out in view of the experimental evidence on dielectric losses quoted by Mr. Wilmotte.

The case is different if the coils are used at frequencies getting near to the resonance frequency of the coil, as then a considerable fraction of the total current will pass along the capacity paths, but a receiving coil is very seldom required to be used at such frequencies.

Practically the whole of the criticism launched against the utility of the copper loss formulæ turns out on examination of the experimental evidence offered to apply only to the case of large transmitting coils, where by reason of the greater volume of copper employed the copper losses are reduced to a negligible figure. The evidence given in this paper should be sufficient to show that for receiving coils of the sizes usually employed the copper losses are the predominant factor unless the insulation is rankly bad or the current is led through the coil turns in an obviously unsound order. Advice on the choice of the dielectric and on the order in which the current shall pass through the turns is very desirable, but "design" is only beginning and not complete when these points have been settled. The formulæ referred to above enable a complete scheme of design to be worked out and a very close estimate to be made of the resistance for an inductance coil of the type used in reception.

References.

A short list of the more recent papers dealing with the theory and measurement of copper losses is appended for those readers who wish to pursue the matter further.

HOWE.—"The High Frequency Resistance of Wires and Coils."—*Journ. I.E.E.*, Vol. 58, p. 152, 1920.

FORTESCUE.—"The Design of Inductances for High Frequency Circuits."—*Journ. I.E.E.*, Vol. 61, p. 933, 1923.

HICKMAN.—"The Alternating Current Resistance and Inductance of Single-layer Coils."—*Bulletin Bureau of Standards*, Vol. 19, p. 74, 1923.

BUTTERWORTH.—"On Eddy Current Losses in Cylindrical Conductors and Short Coils."—*Phil. Trans. A*, Vol. 222, p. 57, 1922.

BUTTERWORTH.—"Note on the Alternating Current Resistance of Single-layer Coils."—*Phys. Rev.*, June, 1924.

BUTTERWORTH.—"On the Alternating Current Resistance of Solenoidal Coils."—*Proc. Roy. Soc. A*, Vol. 107, p. 693, 1925.

BREIT.—"The Self Capacity of Short Coils."—*Phys. Rev.*, Vol. 17, p. 649, 1921.

BREIT.—The High Frequency Resistance of Inductance Coils."—*Scientific Paper, Bureau of Standards*, No. 430, 1922.

The first two papers treat the subject in a fairly elementary manner and certain approximations are necessarily made. The remaining papers are more mathematical, but the more elaborate formulæ developed therein are necessary not only to justify the simplifying assumptions made in the elementary treatments, but also to fill in gaps where the elementary treatment fails. Breit's two papers are noteworthy as they form the first serious attempts to deal with the distributed self and earth capacities of short coils. They are difficult to read, but the writer believes that the conclusions are reasonably sound.

Low-Power Experiments at 6QB.

By L. H. Thomas. **[R401·22**

A record of some rather remarkable results achieved.

THIS article has been written with the object of encouraging those readers who despair of getting satisfactory results from a transmitter because they have no A.C. available and cannot run a generator. It is also intended to show that some really useful work may be done although conditions seem almost hopeless.

The writer cannot possibly obtain an A.C. supply, on account of a contract held by the gas company, and as the "den" is at the top of the house, a generator, or even a T.V.T. -unit would be very inconvenient. The first experiments were therefore conducted with an input of .15 watts from 60 volts in pocket-lamp batteries. With an

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aerial 70 ft. by 28ft., very badly screened, and an ordinary "water-main" earth, reports on the C.W. were received from a distance of 20 miles, although the aerial current could not be read with a 0.5 amp. H.W. meter.

This was encouraging, so the H.T. was increased to about 150 volts (36 pocket-lamp batteries in all). With this, using the reversed feed-back circuit with extremely inefficient inductances, an aerial current of .14 amp was obtained, the valve used being a French "R" with its filament slightly overrun. A report was immediately received from Paris reporting C.W. signals R3 on one valve.

At this the writer determined to see how efficiency could be increased, for if Paris could be reached with an input of 1.2 watts and everything as inefficient as it was humanly possible to make it, better things might obviously be hoped for!

First, a counterpoise was erected. It was seven feet high, and a diagram is shown (Fig. 1). The situation is not exactly ideal. The aerial current was increased and the transmitter rendered much more stable by this arrangement, although the capacity of the aerial system was increased.

The next step was to dispose of the old inductances, which were wound on 8 in. cardboard formers with 7/22 copper. Two helices were therefore wound with $\frac{1}{32}$ in. copper strip on ebonite crossbars, and put into service. An enormous increase resulted from this reduction of the tuner losses, and the space occupied by the transmitter was reduced by about 70 per cent.! Up to this point the circuit in use was still the reversed feed-back; but the Hartley was now tried, and it seemed to be better suited to the radiating system. The circuit was now as shown in Fig. 2.

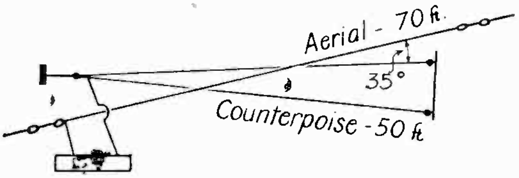

Fig. 1.

The R.F. choke was an ancient duolateral coil of relatively high self-capacity, and yet it gave better results than any of the numerous single-layer coils specially wound for the purpose. The grid-leak was the secondary of a power transformer.

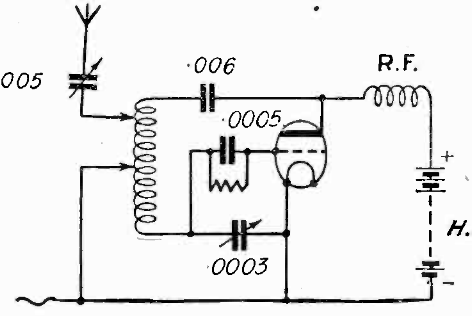

Fig. 2.

The next event of interest was the burning-out of the French "R," which obviously disliked 6 volts. As there was a test arranged for that night, a feverish search was made, which resulted in the use of a D.E.R., with a filament voltage of 2.5. This gave an aerial current of .26 amp on 1.3 watts input, and is still in use. The writer has not yet succeeded in finding its saturation point, and its emission is still perfect although it has had 600 volts (from a spark coil) on its plate.

Reports on C.W. transmissions were now received from Luxembourg, Italy, Denmark and Sweden, and many N. British amateurs worked. The H.T. was then increased once more to 250 volts, and with this voltage, and a plate current of 15mA (making an input of 3.75 watts) and the *same* D.E.R., a report was received from Brooklyn, N.Y. This has been fully confirmed, and the signals are stated to have been received at R4 on a superheterodyne. The time was 22.30 GMT, and the wave-length 150 metres. Finnish 2NCA also reported signals from 6QB as R8 on the same night.

In conclusion, the writer is always glad of reports from any distance, as the power used here has never yet exceeded 4 watts—and is never likely to!

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The Perfect Set.

Part X: More about Reflex Circuits.

[R342·4

A detailed examination of a typical reflex circuit which embodies the results of experiments over a long period.

IN our last part we made some general remarks about reflex circuits. This month it is proposed to deal in detail with one typical circuit: that shown last month, and illustrated again, in slightly fuller detail, in Fig. 1 herewith.

We will deal with it bit by bit, giving, as far as possible, reasons for any definite values assigned to the components. This circuit is shown, as an example, for two valves, but may obviously be extended to more, and altered in various ways without change in principle.

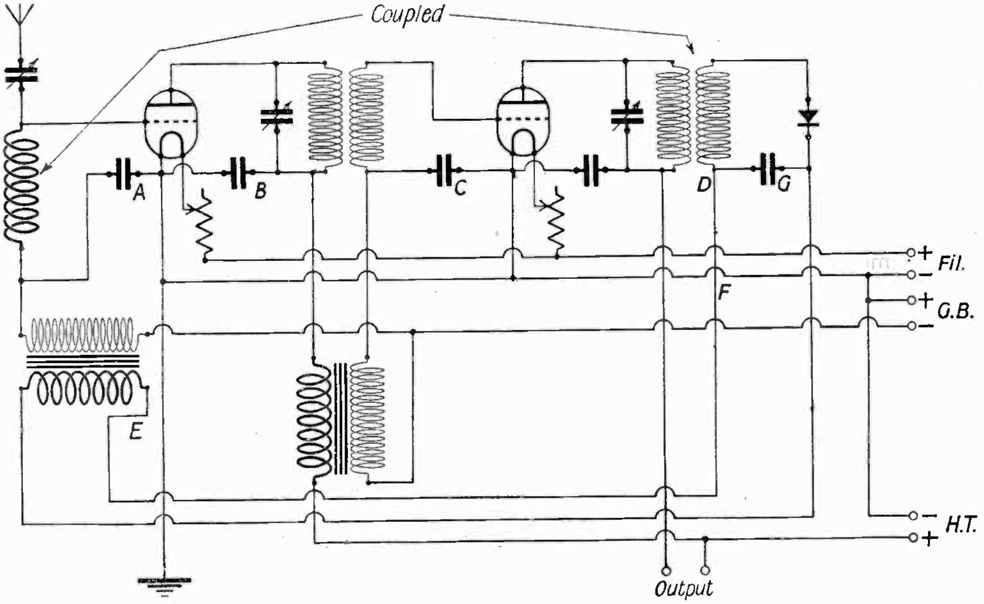

Fig. 1.

Taking the filament circuit first, there are only two noteworthy points. Firstly, the filament rheostats are in the positive lead—in our opinion the only place for them. It is a favourite device of the semi-skilled to try and avoid a grid battery by putting the rheostat in the negative lead, but it has two grave disadvantages: the bias obtained is often insufficient; and every change of filament heat also alters the bias, whether this is desired or not. It is much better practice to do as we have done here.

Secondly, though it is not really a matter of the filament circuit itself, the H.T. is connected to filament negative, not positive, the negative side of the filament being a regular "omnibus" lead taking all returns. This is a great practical convenience, and also makes it simpler to work from the characteristic curve of the valves used. It has the minor disadvantage of needing two or three volts extra of H.T. battery, but we regard this as by far the lesser of two evils.

In the aerial circuit the first point for consideration is the value of the condenser *A*. It will be seen that the connection of the earth to filament negative (a great help to

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stability) puts this condenser into the aerial circuit. As stated in the last instalment, it should be kept small in sets for telephony to avoid unduly lowering the tone by interfering with the action of the L.F. transformer. For all wave-lengths from 200 to 600, it will be found that .000 1μF is a suitable value. This allows of tuning with an inductance of convenient size, and at the same time produces only a quite unnoticeable lowering of tone. A useful rule for longer wave-lengths is to divide the proposed wave-length by 500, take its square root, and put three o's in front of it. Thus for 1 600 metres we have 1 600 ÷ 500 = 3.2 ; the square root is 1.8 approximately, so the condenser *A* should be .000 18—say .000 2.

The actual tuning of the aerial circuit can be done in any way desired. The writer prefers a series condenser, as shown, but usually has a series-parallel switch for use if required. If it is not desired to react on to the aerial, a variometer can be used, together with wave-traps, rejectors, loose-coupled circuits, or whatever the user may prefer. Note, however, that if a loose-coupled circuit is used, it is an advantage to link the earth terminal across to the filament negative. The L.F. part of the circuit will be dealt with later.

The Intervalve Coupling.

The main item here, of course, is the transformer. We have already, in the part of this series dealing with H.F. amplification, described our favourite type, and little further remark is necessary. It might be noted that with a close-coupled transformer the tuning condenser may be across primary or secondary. We have often seemed to get better signals with it across the secondary, but this has not yet been confirmed by measurement. When, as is usual, a step-up transformer is being used (1 to $1\frac{1}{2}$ or 1 to 2 is best), there is a slight disadvantage in having the condenser across the secondary, as its stray capacity—when set at zero—has a much larger effect (four times with a 1 to 2 transformer) in shortening the range of wave-length, than when across the primary.

The values of the by-pass condensers *B* and *C* also need a little thought. Their design is based, as was that of *A*, on a compromise between the H.F. and L.F. requirements. In this case, however, we have the fact that *B* and *C* do not, like *A*, form part of a tuned circuit. A little difficulty is that in order that *B* and *C* may each have the same effect on its own circuit, *B* should be s^2 times *C*, where *s* is the step-up ratio: but of which transformer? Theoretically, of both ; but this is obviously impossible, for the H.F. transformer should not as a rule be more than 1 to 2, while the L.F. will probably be 1 to 4. Actually, it is our usual practice to take about the average, and for broadcast wave-lengths or less to make *B* ten times *C*, using .001 and .000 1 for them. Actually it seems to matter little whether *B* is as low as .000 2, or as high as .002 ; but above this latter value it sometimes begins to lower the tone if music is being received.

The question of stabilising may be considered now. As far as our experience goes, any method may be used if required, and reference should be made to the earlier articles (already mentioned) on H.F. amplification. We have not, however, tried any except neutrodyne condensers—which did not seem very effective—and shunt or series resistances either across or in series with the tuning condensers.

The Detector Circuits.

Bearing in mind that the input resistance of a detector is of the order of 5 000 to 10 000 ohms for galena, or less when the applied voltage is fairly large ; while the output resistance of a valve will be at least 20 000 ohms, as a rule we see that efficiency calls for a step-*down* transformer between valve and crystal, about $1\frac{1}{2}$ or 2 to 1 being correct. Actually, however, we often use a 1 to 1 ratio, which has the advantage of causing the crystal to damp the oscillating circuit rather heavily, and so assist stability. In this case, one need not use two separate windings at all, simply tapping the crystal circuit across a single " tuned anode " coil, which replaces primary and secondary of the transformer. If, however, the set is to be used for long waves, the inductance is likely to be so large that a transformer of the proper ratio will be preferable.

It will be noticed that when the transformer is used, the system consisting of transformer secondary, crystal and condenser, and L.F. transformer primary, is completely isolated. It steadies the set if this is avoided, which can be done in various ways. Some part of the lead *DE* should be connected to part of the set which is approximately at earth potential for H.F. currents: the primary and secondary of either the H.F. or the L.F. transformer may be linked at their low potential ends, or some point on *DE* may be connected to the common L.T. lead, which can be done by making a join instead of a cross-over at the point *F*.

When a tuned-anode coil, and not an H.F. transformer, is used before the crystal, remember that the steady anode current flows through it and sets up a D.C. voltage across it. For long waves, where this coil is large and has a fairly high D.C. resistance, this may be large enough to affect the crystal, and in such cases it is useful to insert a reversing switch as in Fig. 2, so that the crystal can be used either way round.

Next, as to the value of the condenser *G*. This, of course, is simply the condenser which ought to be found in every crystal set, but is often omitted in the hope that the phone leads will have sufficient capacity. In this case also it *may* be omitted if the primary of the first L.F. transformer has sufficient self-capacity. But it is very bad practice to do so. Any H.F. voltage which may be applied to the primary will probably be transferred by capacity coupling to the secondary, thus appearing in the grid circuit of the first valve and upsetting things. Such H.F. voltages can be kept down by making condenser *G* so large that it offers only a low impedance to H.F., and for this reason we make it as large as we dare without risk of upsetting the L.F. performance of the transformer. If, as is usual (see below), this transformer is of high ratio, it will probably stand quite a large condenser across its primary, and we are using, at the moment, .001μF for *G*. If this gives a muffled tone with some other type of transformer, it can be reduced to .000 3: below this there are distinct reaction effects at broadcast wave-lengths. For other wave-lengths adopt the same principle as already described in connection with the other by-pass condenser.

Reaction, if required, is simply arranged for by placing the aerial coil and the crystal transformer or coil so that they can be coupled together. It will be found to work quite smoothly and sweetly until the set oscillates, when there will probably be a loud howl.

The L.F. Side.

From this point onwards we are dealing with audio frequencies. The first point arising is obviously the ratio of the "throw-back" transformer. The particular connections do not affect it: it is simply to be considered as a crystal-to-valve transformer, and its ratio is governed by the impedances in its input and output circuits. Reference to our earlier instalments on L.F. amplification will bring to light a simple approximate rule for the ratio when a valve-grid circuit is across the secondary: divide 250 000 by the impedance in the primary circuit, and take the square root.

Now F. M. Colebrook has shown in "The Rectifying Detector" (E.W. & W.E., May, 1925) that the galena crystal has a quite low output resistance—below 500 ohms. This would give, for the ratio, the square root of 500, or about 20 to 1. But in practice the self-capacity of the windings, and other difficulties, limit the ratio. We have found that 8 to 1 is considerably better than 6 to 1, but that 10 to 1 is little better when commercial transformers are being used. Perhaps an expert might design a suitable transformer of higher ratio, but we have not yet come across one. There is another reason why it is perhaps best not to push the ratio too high where telephony is concerned. This is, that with an 8 or 10 to 1 ratio the transformer has a much higher input impedance than the crystal resistance, which, as also shown by Colebrook, leads to freedom from distortion. So, taking all things into consideration, we can just use the highest-ratio transformer obtainable on the market in the make preferred by the user, 1 to 8 or 1 to 10 being best if obtainable. This is for galena. If perikon, with its higher resistance, is used, then probably 1 to 6 or 1 to 8 will be best.

One transformer secondary lead goes to the grid bias battery, and naturally raises the question of the bias required. This, however, has already been dealt with in an earlier article of this series ("L.F. Amplification"), and the only remark to be added here is that it is occasionally necessary to increase the bias to cover the H.F. components of grid voltage. In the particular set illustrated in Fig. 1, we could calculate as follows, calling the input voltage 1 unit: the H.F. input to second grid is $1 \times \mu$ of first valve × step-up of H.F. transformer; but a deduction must be made for the well-known losses in H.F. amplification. At broadcast waves, with a μ of 8 for the first valve, we may expect an over-all magnification of 10 to 12, so that we may put the input to second valve at 10. This is again multiplied by the μ of the second valve, but is then stepped down to the crystal. With a μ of 8, and step-down of 1½ to 1, we may expect to get 40 on the crystal. Of this we should get 20 to 30, say 15 on the transformer primary, giving, at 1 to 8 ratio, 200 on the first grid, for telegraphy (for telephony see below). If the second transformer has a 1 to 4 ratio, we have $200 \times 8 \times 4$ or 6 400 units on the second grid. So that in each case the L.F. grid input is so far above the H.F. on the corresponding grid that the latter can be neglected.

In telephony, we must remember that the L.F. is only a modulation on the H.F., so that the L.F. voltages will be smaller. If the modulation is 20 per cent., we can divide them by 5, still leaving the L.F. much larger than the H.F. This excess of L.F. over H.F. will increase with the number of valves used for H.F. If only one is in use, it will be found that the H.F. input may have to be considered in arranging the bias.

Apart from this point, the L.F. side should be dealt with just as an ordinary L.F. amplifier. If, however, as is usual, loud-speaker strength is being used, it will be necessary to have a power valve in the last stage. Now power valves as a rule are not suited for H.F. work, and it is a good rule to specify, for loud-speaker work, that the last shall be a pure L.F. power stage.

One additional point is that, owing to stray couplings, it will probably be found that the L.F. side works much better with the transformers connected in one particular way, so trials should be made with the windings reversed (not primary to secondary, but crossing and uncrossing first the primary and then the secondary leads).

General Notes on Sets of this Type.

As has been already stated, this type of set is not really suited to the self-heterodyne reception of C.W. We have used it mainly on telephony and ship work, and with a separate oscillator for long-wave C.W.

For broadcasting, it will be found that a two-valve set, with only the first valve reflexed, and the second a power valve, is perfection for the nearest B.B.C. station. Up to 40 miles or so it will give really good loud-speaker strength with moderate reaction, and up to 10 miles it works well on a small inside aerial. Increased by one reflex valve (*i.e.*, a 2-valve reflex plus one power stage) all the B.B.C. stations come in well on the loud-speaker. Long-wave stations up to, say, 3 000, come in equally well, but really need, for the highest efficiency, slightly larger by-pass condensers. This need shows more strongly on separate heterodyne long-wave work up to 20 000 metres, when larger condensers—say .001 in the grid circuits and .005 in the anode, become really necessary.

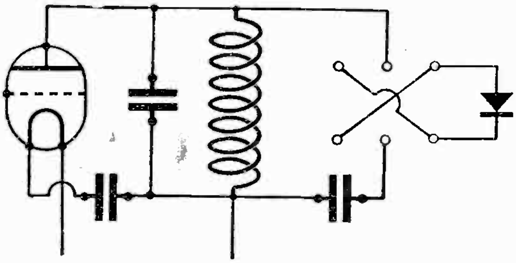

Fig. 2.

It will be found at first that the circuit has little tricks of its own when working at its utmost power, but these are soon learned, and it will then be found delightful to handle.

In our next instalment it is proposed to describe some of the alternative arrangements that have been suggested.

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The Propagation of Electric Waves through Liquids.

By *S. G. Matthews.* [R110

THE conduction of an electric current through a liquid, as in the case of a secondary cell, is a very different proposition from the conduction of a similar current in a metallic wire.

In the wire we have a number of free electrons which pass between the places occupied by the fixed atoms of the metal when a potential is applied. In a solution, such as the sulphuric acid of the secondary cell, there are no fixed atoms—which is the reason why the liquid flows—and it is also believed that there are no great number of free electrons. It does, however, contain a very great quantity of ions, *i.e.*, atoms or groups of atoms which have lost or gained an electron or electrons, thereby acquiring a charge of electricity.

Now, in the case of sulphuric acid, there are believed to be many millions of ions of two different kinds. The first of these is the hydrogen ion, which is a hydrogen atom that has gained an electron and become negatively charged; while the second is the sulphate ion, which is a group of four atoms, one of sulphur and three of oxygen, which has lost one electron and is therefore positively charged.

Now it is these ions which carry the current through the solution, the process being as follows: An electron enters the solution at one of the terminals and finds nearby a single hydrogen atom possessing, as usual, a single electron. The new electron joins up with the hydrogen atom, which then has two electrons and becomes a hydrogen ion. By virtue of its negative charge it is attracted to the positive plate of the cell and it passes across the solution to it, gives up its spare electron and becomes once again an ordinary hydrogen atom. This process is what occurs when a secondary cell is charged (with the exception of the chemical changes which take place on the surface of the lead plates), and is known as electrolytic conduction.

Now in the case of the passage of electric waves or of rapidly alternating electric currents through a solution, there has always been considerable doubt as to whether it was necessary for the ions to move right across the solution carrying the same electron to the other electrode or whether the electrons were exchanged during the passage. It could also be assumed that all the ions simply swing backward and forward under the impulse of the oscillating current and never move very far from their medial positions.

These problems reduce themselves, however, to the question: Do the ions move far or only a short distance as the waves of current pass through the solution? Until quite recently experiments indicated that the ions moved a relatively long distance. For example, it was found that the resistance of a solution was much higher at high frequencies than for D.C., or at frequencies of the order of 50 cycles per second, which indicated a relatively long path for the ions. It was thought that when the frequency was too high, it became impossible for the ions to complete their swing across the solution in one cycle of the wave.

Some experiments have been conducted recently in France however by M. Granier which have cast a doubt on this conclusion. M. Granier made every effort to remove sources of error, such as those due to capacity between conductors, electrodes, etc., with the result that the conclusion of a lower conductivity for very high frequency currents is wrong. When the disturbing effects of internal capacities in the apparatus have been removed or compensated, the conductivity of a given solution for high frequency current is practically the same as for low frequency current or, neglecting chemical effects, for direct current.

We can only conclude, therefore, that the conduction of electric waves in liquids is carried on by a process similar to that involved when a metallic conducting medium is employed: that is by the to and fro swing of charged particles, each ion, or electron if the solution contains free electrons, swings through only a small distance depending on the frequency of the current or wave that is passing through the solution.

In conclusion, therefore, we may say that no special electrolytic effects are to be expected due to the passage of wireless waves passing through or over the surface of the sea, which will behave exactly as does a metallic conductor having practically the same conductivity as sea water.

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The Paris Conference.

[R545·06

REPORT OF SUB-COMMITTEE ON THE ORGANISATION OF THE INTERNATIONAL AMATEUR RADIO UNION.

THE Sub-Committee No. 1 of the Amateur Congress, on the organisation of the International Amateur Radio Union, convened at the Faculté des Sciences in Paris at 5 p.m. on the 15th April, 1925.

The following nations were determined to be represented by the delegates appearing after their respective names :—

> ARGENTINA, AUSTRIA, BELGIUM' BRAZIL, CANADA, CZECHO-SLOVAKIA' DENMARK, ENGLAND, FRANCE, FINLAND' GERMANY, HUNGARY, ITALY, JAPAN' LUXEMBOURG, NETHERLANDS, NEWFOUNDLAND, POLAND, SPAIN, SWEDEN, SWITZERLAND, URUGUAY, UNITED STATES.

By acclamation Mr. H. P. Maxim was elected Chairman of the Sub-Committee, and Mr. J. G. Hezger, Secretary.

The meeting heard a general and open discussion by many delegates as to form that the proposed Union should take, what its aims should be, etc., and adjourned at 7 p.m. after agreeing that the delegates should give the matter careful thought over the night.

Reconvening at 10.30 a.m. on the 16th April in the same hall, the meeting continued its consideration of the general nature that the proposed Union should assume. It was unanimously agreed by the representatives of twenty-one countries (all listed above except Luxembourg, absent) that there was a need for such a Union, that it should be an organisation by individual membership, that it should have for its chief purposes the co-ordination and fostering of international amateur two-way communication, and that the headquarters of such a Union should temporarily be located in America.

The A.R.R.L. delegate from the United States was requested to prepare a proposed Constitution along the lines agreed upon, for the consideration of the Sub-Committee. The meeting adjourned at 11.30 a.m. to reassemble at 9.30 p.m.

The Sub-Committee met again in the same hall at 10 p.m., 16th April, to consider the proposed Constitution, but, because sufficient copies thereof were not available, adjourned until 17th April.

The Sub-Committee met again in the same hall at 10 a.m., 17th April, each delegate being supplied with copies of the Constitution under consideration. The roll was called and it was found that delegates were present from the following countries : Argentina, Austria, Belgium, Brazil, Canada, Denmark, England, France, Finland, Germany, Italy, Japan, Netherlands, Newfoundland, Poland, Switzerland, Spain, Uruguay, and the United States, a total of nineteen countries.

The proposed Constitution was considered section by section, and each section adopted unanimously after mature debate. It was then voted upon as a whole, and was unanimously approved and adopted by the delegates of the nineteen countries represented.

A copy of the Constitution is attached hereto as a part of this report.

The Committee adjourned at 1 p.m.

(Signed) HIRAM PERCY MAXIM, *Chairman.*
HEZGER, *Secretary.*

Constitution of the International Amateur Radio Union.

(*Adopted 17th April,* 1925.)

ARTICLE I.—NAME AND OBJECTS.

1. The name of this organisation is the International Amateur Radio Union, hereinafter called the Union.

2. Its objects shall be the promotion and co-ordination of two-way radio communication between the amateurs of the various countries of the world ; the advancement of the radio art ; the representation of two-way amateur communication interests in international communication conferences ; the encouragement of international fraternalism ; and the promotion of such additional activities as may be allied thereto.

ARTICLE II.—MEMBERSHIP.

1. Any person interested in the objects of the Union shall be eligible to membership. Applications for membership shall be submitted to the Executive Committee of the Union and a majority vote of the said Executive Committee shall elect to membership. The said Committee may refuse to elect to membership any person who, in their opinion, would be an undesirable member ; *provided* that any person who is refused membership may have his case reviewed by the Board of Directors of the Union upon the recommendation of two or more members of the Executive Committee, and the Board of

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Directors may, in its discretion, reverse the action of the Executive Committee.

2. Members shall comply with the requirements of the Constitution and of such regulations of the Union as may be adopted from time to time.

3. A member may voluntarily terminate his membership by written communication to the International Secretary. If all his dues and other indebtedness to the Union have been paid, the resignation shall be accepted.

4. Upon the written request of twenty-five or more members that, for cause therein stated, a member of the Union be expelled, the Executive Committee shall consider the matter, and if there appears to be sufficient reason, shall advise the accused of the charges against him. The accused shall then have the right to present a written defence, or to secure a hearing before a meeting of the Executive Committee, or authorised representatives of the Executive Committee, of which meeting he shall receive notice at least sixty days in advance. Not later than sixty days thereafter, the Executive Committee shall finally consider the case, and if in opinion of two-thirds of the members of the Committee a satisfactory proof of the undesirability of the accused as a member has been established, and he has not in the meantime tendered his resignation, he shall be expelled from membership.

ARTICLE III.—SECTIONS.

1. In each country represented in the Union, from which there are twenty-five or more members of the Union, there shall be formed a Section of the Union, which shall be known as " .... Section, International Amateur Radio Union."

2. The members in any country not possessing a total membership in the Union of at least twenty-five, shall temporarily be attached for administrative purposes to a neighbouring country which shall be specified by the Executive Committee. Whenever the total membership from such a country attains a total of twenty-five or more, a Section shall be created in that country as provided in Paragraph 1 of this article.

3. In each Section of the Union there shall be a National President, elected by popular vote of the members in that country. Nominations for this office shall be solicited by the International Secretary through the columns of the official organ of the Union, under regulations as to eligibility, dates, etc., to be determined by the Executive Committee. The election shall be by means of ballots mailed from the headquarters of the Union.

4. The National Presidents shall hold office for a term of two years, or until their respective successors have been duly elected.

5. Whenever a vacancy occurs in the office of National President, an election for his successor shall be held as quickly as possible, under the same general regulations as apply for regular elections.

ARTICLE IV.—OFFICERS.

1. The officers of the Union shall be an International President, an International Vice-President, and an International Secretary-Treasurer.

2. The first officers of the Union shall be elected by the amateur delegates present at the International Amateur Congress held in Paris, 1925, one vote to be assigned to each country represented. They shall assume office immediately upon election and shall hold office for two years or until their successors are duly elected.

3. Except for this first election of officers, the officers shall be nominated and elected by the Board of Directors for two-year terms, under regulations as to eligibility, dates, etc., that shall be determined by the Board.

ARTICLE V.—MANAGEMENT.

1. The affairs of the Union shall be managed under this Constitution by an Executive Committee, consisting of the officers of the Union and two Councillors-at-large.

2. The first Councillors-at-large shall be elected by the amateur delegates present at the International Amateur Congress held in Paris in April, 1925, one vote to be assigned to each country represented. They shall assume office immediately upon election, and shall hold office for a term of two years or until their successors are duly elected. Their successors shall be nominated and elected for two-year terms by the Board of Directors, under regulations as to eligibility, dates, etc., that shall be determined by the Board.

3. Whenever there is any vacancy in any office in the Executive Committee, it shall be filled by special election by the Board of Directors, under such regulations as they may determine.

4. The Executive Committee shall direct the investment and care of the funds of the Union, shall make appropriations for specific purposes, shall act upon all questions of admittance or expulsion of members, and in general shall direct the business of the Union, either itself or through its officers and Committees. It shall arrange the place, time and programme for the biannual Congress and shall handle all affairs relating thereto, either itself or through appointees.

5. It shall be the particular purpose and duty of the Executive Committee to devise ways and means for the encouragement of international two-way amateur radio communication : by the promulgation of rules and regulations to co-ordinate international amateur operation, by the management of tests and relays, by encouraging and assisting the development of amateur radio in countries where assistance is desirable, by arranging for adequate representation of two-way amateur communication interests at international communication conferences, by endeavouring to secure a removal of legal restrictions prohibiting amateur operation in certain countries, and by kindred methods.

6. The Executive Committee shall meet in person at the call of the International President when possible and desirable. At such meetings three members of the Committee, present in person or by proxy, shall constitute a quorum, and action shall be determined by the concurring vote of a majority of the members present. In general, however, the determinations of the Executive Committee shall be made by post, through the Agency of the International Secretary-Treasurer and under the direction of the International President, and action shall be determined by the concurring vote of a majority of the whole membership of the Committee. The International Secretary-Treasurer shall acquaint the entire membership of the Board of Directors with the actions taken by the Executive Committee, and such actions shall then become binding upon the Union ; *provided* that if three or more National

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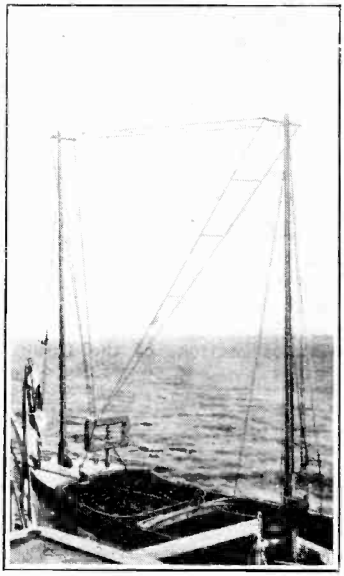
Presidents within sixty days after such announcement of action by the Executive Committee formally protest the same, the Executive Committee shall cause the International Secretary-Treasurer to submit the question in point to the entire Board of Directors by post, and unless it is within one hundred and twenty days thereafter ratified by a majority of the Board of Directors, the action of the Executive Committee shall be deemed reversed.

7. The International President shall have general supervision of the affairs of the Union, under the direction of the Executive Committee. He shall preside at meetings of the Executive Committee and at the Congresses, and shall direct the work of the International Secretary-Treasurer in the determination of Executive Committee affairs by post. He shall be, *ex-officio*, a member of all committees. The International Vice-President shall be responsible for such matters of general supervision as may be delegated to him by the International President. In the absence or disability of the International President the International Vice-President shall act in his stead.

8. The International Secretary-Treasurer shall be the general manager of the affairs of the Union, under the direction of the International President and the Executive Committee. He shall attend all meetings of the Executive Committee and all Congresses and record the proceedings thereof. He shall collect all moneys due the Union and deposit them in the name of the Union in a depository satisfactory to the Executive Committee. He shall certify the accuracy of bills or vouchers on which money is to be paid, and shall draw and sign all cheques. He shall invest such funds as may be ordered by the Executive Committee. He shall have charge of the books and accounts of the Union and shall furnish to the Executive Committee from time to time such statements and reports as may be required. He shall conduct the general correspondence of the Union, and shall keep full records. Under the direction of the International President he shall canvass the Executive Committee by post to determine the action of the Union on current matters. He shall be in responsible charge, under the International President and the Executive Committee, of all property of the Union. He shall, with the approval of the Executive Committee, employ such clerical force as may be necessary and shall be responsible for the work of all employees of the Union. Under the direction of the Executive Committee, he shall be the general manager of any publications owned by the Union. He shall prepare and submit at each Congress of the Union a comprehensive report on the progress and status of the affairs of the Union. He shall perform such other duties as may be assigned to him by the Executive Committee. He shall furnish a bond satisfactory to the Committee, the expense of same to be borne by the Union.

9. The National Presidents shall have general supervision of the activities of the Union in their respective countries. They shall be responsible for carrying out in their respective countries the plans and policies of the Union. They shall represent their respective countries on the Board of Directors, and to this end shall keep themselves informed on the needs and desires of their members, in order that they may faithfully and intelligently represent them. They shall have the right to appoint such assistants as they deem desirable, to handle such portions of their duties as they desire. So far as possible, they shall attend all Congresses of the Union, but shall be authorised to send an alternate of their own selection to act in their stead at the Congresses.

10. No person commercially identified with the radio industry shall be eligible to serve as a member of the Executive Committee or as a National President. All members of the Executive Committee and all National Presidents must be members of the Union.



Showing the aerial system of the Marconi transmitter now being fitted to lifeboats. Note the D.F. frame aerial.

ARTICLE VI.—BOARD OF DIRECTORS.

1. The officers of the Union, the Councillors-at-large, and the National Presidents of Sections of the Union together shall constitute the Board of Directors.

2. The Board of Directors shall meet in biannual Congress in April of each odd-numbered year, at the call of the Executive Committee. The Executive Committee shall select the exact dates and the place, shall plan and announce the programme, examine and authenticate credentials, and in general administrate the Congress.

3. At the Congress, the Board of Directors shall receive the reports of the officers, elect and instruct the new officers and Councillors-at-large; act upon such matters as may come before it; and in general delineate the policy of the Union for the ensuing two years. The rules of order of the Congresses shall be so arranged as to permit free and open discussion of international amateur radio matters.

4. Members of the Board of Directors present in person or by alternate or by proxy to a number

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representing one-third of the membership of the Board, shall constitute a quorum at any Congress. The actions of the Congress shall be determined by the concurring majority of those present, but if less than a majority of the whole membership of the Board is present the actions taken shall not become binding upon the Union until they have subsequently been ratified by a majority of the whole membership of the Board.

5. If the finances of the Union, in the opinion of the Executive Committee, permit it, the travelling expenses of the International President and the International Secretary-Treasurer to attend the Congresses shall be paid by the Union.

Article VII.—A.R.R.L.

1. Until otherwise determined by the Board of Directors by the amendment of this Constitution, the headquarters of the Union shall be located at the headquarters of the American Radio Relay League in the United States of America. Until otherwise determined by the Board of Directors by the amendment of this Constitution, the magazine of the American Radio Relay League, *Q.S.T.*, shall be the official organ of the Union.

2. The provisions of this Constitution relating to the formation of Sections of the Union and the election of National Presidents shall not apply in the United States and Canada. The United States portion of the A.R.R.L. shall constitute the United States Section of the Union and its President shall be deemed the National President of the Section within the meaning of this Constitution. The Canadian Section of the A.R.R.L. shall constitute the Canadian Section of the Union and the A.R.R.L. Canadian General Manager shall be deemed the National President of the Section within the meaning of this Constitution.

Article VIII.—Dues.

1. The dues for membership in the Union shall be one dollar ($1.00) per annum.

2. Members in arrears shall be carried on the records of the International Secretary-Treasurer for ninety days. If by the end of that time they have not renewed their membership, they shall be dropped from the rolls.

Article IX.—Amendment.

1. This Constitution may be amended by a two-thirds vote of the Board of Directors, at any Congress. At the initiative of the Executive Committee it may be amended at any time by post by a two-thirds vote of the Board of Directors.

Accumulators for High Tension Supply.

[R621·354·009

Messrs. C. A. Vandervell & Co., Ltd., Acton, London, W.3, have for some time been manufacturing small accumulator cells, a number of which are connected up in series for the plate supply of a valve set.

For any but the smallest sets, high tension accumulators of this type are almost a necessity. As everyone knows, the usual small-capacity, dry cell batteries, used with multi-valve or power amplification sets, are of very little use. The disadvantage of the accumulator cells, however, is heavy initial cost.

The C.A.V. H.T. accumulators are supplied fully charged, and are in two forms—with "jelly" electrolyte or dry charged. The first type is stated to be a vast improvement. The electrolyte is run into the cells in liquid form, and it sets in perfect contact with the plates. It is claimed that it may be left standing for 12 months, keeping the plates inert throughout this period. Another advantage is that the electrolyte is unspillable.

The other type (dry charged) is supplied with plates which have been subjected to a long process of forming. To prepare the cells for use it is only necessary to fill with acid of a specified density, when 75 to 90 per cent. of the full capacity will be obtained.

One of the most popular types of accumulator unit put up by Messrs. Vandervell is the "H.T.3." This consists of 30 cells, each of one ampere-hour capacity, connected in series to give 60 volts. Each cell contains two plates, which rest on celluloid prisms, with ribbed separation. The mouth of the cell is permanently sealed, and contains a special vent plug. The cells are connected by bending over the plate extension lugs and burning them together.

Means for making tappings are provided at every sixth cell.

The whole assembly is enclosed in a strong wooden case with a lid, and plugs and sockets for making connections are provided. The prices of this model are £3 dry charged and £3 10s. dry charged with jelly electrolyte.

We have had a set of these in use delivering 6 mA during broadcast hours for three months on one charge, and they have been very satisfactory.

Other model cells are made, having larger capacities, such as the H.T.2, and the H.T.1 with capacities of 2 and 3 actual ampere-hours respectively.

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Apparatus Tested. [R009

TWO R.I. COMPONENTS.

A NUMBER of components manufactured by Messrs. Radio Instruments, Ltd., of 12, Hyde Street, Oxford Street, W.C.1, have recently passed through our test room, and a description of the results obtained with two of them are given herewith.

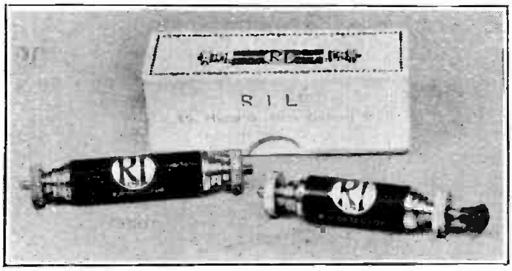
The "Permanent Mineral" Detector. [R374·009

The makers claim that this is a really permanent detector, not needing adjustment, and one pattern is therefore supplied in a "fixed" form. Realising, however, that most experimenters prefer facilities for improving the adjustment, another type is supplied, in which a spring plunger is provided, thus enabling correct adjustment to be made.

The detector is of the double crystal type, one of the crystals being apparently bornite and the other a special compound of zinc (not the usual zincite).

For our tests the adjustable type was used. The method of testing has been described before in these pages, and it will be remembered that we measure the H.F. input power and the D.C. output power, and express the latter as a percentage of the former, which gives us the "efficiency."

Five points were taken at random and tested at 0.5 volt, at which voltage the efficiency varied from 5.8 to 40 per cent., the H.F. resistance varying greatly also. Incidentally, in this case, the test of five consecutive points is hardly fair, since the double crystal type of detector is not expected to be sensitive all over, as are some of the treated galena crystals.

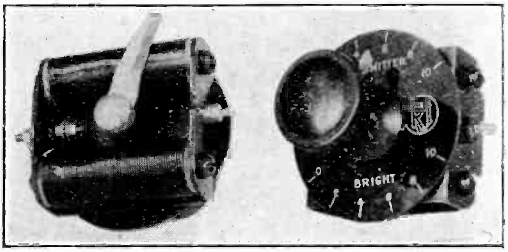


A really good setting was then obtained, and tests were performed at various voltages. It was found that for high voltages, corresponding to strong signals, the efficiency was 52 per cent., which is roughly that of a first-class galena. For lower voltages the efficiency dropped, which is usual with this type of detector.

One of the chief claims of the makers, however, is for stability, and this was tested by jolting the test apparatus and applying sudden high voltages to represent atmospherics. Nothing we could do (within reason) made the slightest difference to the results obtained, and therefore the detector can be accurately described as permanent; and as instability is often cited as a reason for not using a crystal as detector in a valve set, it is suggested that the R.I. detector may remove this difficulty—with a consequent improvement in the tone of reproduction. The price of either type of detector complete with mounting brackets is 6s. retail.

The "Duostat." [R383·3·009

This is a double rheostat, having two separate windings, with resistances of 4 and 25 ohms respectively, and is suitable for controlling the filament heat of both bright and dull-emitter valves. The resistances are of wire, wound on two cylinders mounted parallel to each other, and the contact is arranged so that a complete revolution of the knob gives a range of 0-4 ohms and 0-25 ohms. A definite "off" position is provided. The dial is engraved for the "dull-emitter" and "bright" ranges.



The rheostat is both mechanically and electrically sound, the movement of the slider being very sweet, and the variation of resistance quite regular. The price is 7s. 6d.

THE "DARCO" GRID-LEAK. [R383·1·009

We have recently had the opportunity of testing some Darco grid-leaks, which are being made by Messrs. Darco, Ltd., 77-79, High Street, Watford, and sold at 2s. each. The process of manufacture is novel, but we are not at liberty to disclose details at present. It is sufficient to say that there is every prospect that the leaks will prove constant in use.

The makers are able to claim an accuracy of 15 per cent. for these accessories, which is, of course, very good: on test, however, we found they were even better. Of the six tested, only one approached an error of 15 per cent., the average of the batch being 7 per cent.

The component is tubular in form and of the usual size. It can be connected up by the nuts and screws provided, by soldered connections to the tags, or by the usual grid-leak clips.

The Rectification of Small Radio Frequency Potential Differences. [R149

A paper read by Mr. F. M. COLEBROOK, B.Sc., D.I.C., A.C.G.I., before the Radio Society at the Institute of Electrical Engineers, on 27th May, 1925.

An Ordinary Meeting was held at the Institute of Electrical Engineers, Victoria Embankment, London, on Wednesday, 27th May, Admiral Sir Henry Jackson in the Chair.

The minutes of the previous meeting were taken as read and confirmed.

The following paper was then read: "The Rectification of Small Radio Frequency Potential Differences," by Mr. F. M. Colebrook.

Mr. Colebrook said: About a year or so ago it became necessary in connection with some work at the National Physical Laboratory to have some quantitative information with regard to the phenomena of rectification. On going through the literature of the subject at that date, I found that very little work of a really useful practical kind had been done, and that if I wanted to find out anything about the subject I should have to find it out for myself, starting practically from scratch. I did so, and I have not in any way regretted the necessity that was laid upon me at that time, because it proved to be an exceedingly useful and interesting subject. I hope I shall be able to-night to make it at least as interesting for you as it was for myself. I have got the results of nearly a year's work to cover in a very short time, and I shall probably make considerable demands upon your attention.

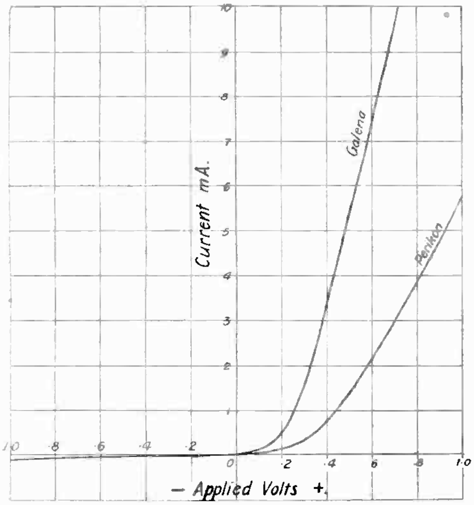


Fig. 1.

With regard to the scope of the present talk, it is going to be concerned with the general principles of rectification, with special reference to crystal detectors. I have continued the work with valves, and a paper on that subject will probably be published some time in the future in Experimental Wireless & The Wireless Engineer, but I am afraid I shall not have time to go into the valve side of the question to-night. Further, I am going to deal with the subject from the electrical and not from the physical or molecular-physical point of view. I am not going to consider at all the internal molecular mechanism of rectification, but shall consider a rectifier as a conductor of electricity having certain special useful properties.

I am going to approach the subject by very easy stages. Of course, the most common application of the crystal detector at the present day is to the reception of telephony or broadcasting, but when you have a crystal detector connected across a coil and in series with an inductive load you have a mass of complexity which it would be very difficult to resolve into simple terms. Therefore, in order to get an understanding of what happens in the practical application, it is necessary to approach the subject from the very beginning on the simplest possible lines.

I do not think I need go very deeply into the essential and fundamental principles of rectification, but it will be well to have some understanding of what we mean by it, and for the purposes of this lecture I propose to define it on these lines; we will consider a rectifier to be a conductor of electricity whose current-voltage relationship can be expressed in the perfectly general form: $i=f(e)$.

That looks very mathematical, but it only means that i depends upon e; but it depends upon e in some way which is different from the ordinary Ohm's Law relationship which applies to the ordinary conductor of electricity.

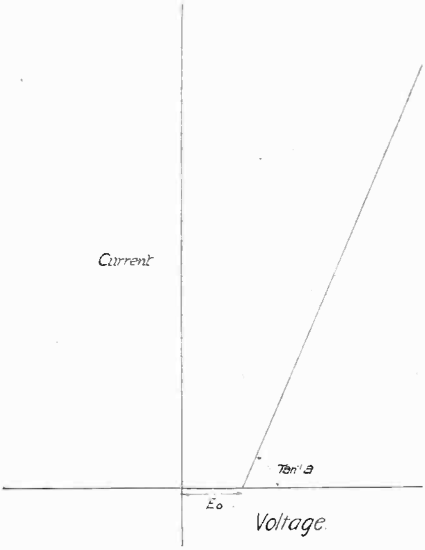


Fig. 2.

Rectification is used for the purpose of obtaining continuous current, or a continuous voltage, from an alternating electromotive force. If, therefore, the e in this case is an alternating E.M.F., the characteristic of a detector will turn that sine wave alternating E.M.F. into a current whose shape is not a sine wave, but some irregular form such that its mean value is finite. If $e = E \sin \omega t$ is the alternating E.M.F., the mean value of the current during one period is given by the formula :—

$$I_c = \frac{1}{T}\int_0^T f(e)\,dt.$$

The most common form of conductor which has this characteristic is the ordinary crystal detector. The current-voltage characteristic of the crystal detector is, in most cases, a curve of the type shown in Fig. 1.

When I started work on this subject, I thought it would simplify matters very much if I could find some simple expression for that characteristic, and I spent several months trying all possible kinds of functions to represent it in symbols in such a way that the necessary calculations of efficiencies, etc., could be carried out. I had to give it up, but I was able to establish quite a satisfactory compromise. For large amplitudes, this characteristic is very much like Fig. 2; *i.e.*, for amplitudes greater than .4 or .5 volt we can consider the crystal detector behaves as if its current-voltage characteristic were of this comparatively simple form, which is a form on which calculations can be based. That, of course, applies only to comparatively large signal amplitudes, greater than .4 volt. For amplitudes smaller than that, say up to .1 volt, a suitable enlargement of Fig. 1 will give a curve something like Fig. 3.

This second type of curve is a perfectly smooth continuous curve, and can in general be represented by a fourth power equation. That, again, is perfectly amenable to mathematical treatment. As far as the galena detector is concerned—which is the most commonly used crystal detector at the present time — Fig. 2 can be represented by the equation :—

$$i = a\,(e - e_0).$$

where e_0 is the small potential difference, so marked in Fig. 2, and a is the slope of the line. e_0 is generally about .25 volt, whereas the co-efficient a is usually of the order of about 3×10^{-2}, or 3/100. These two forms of

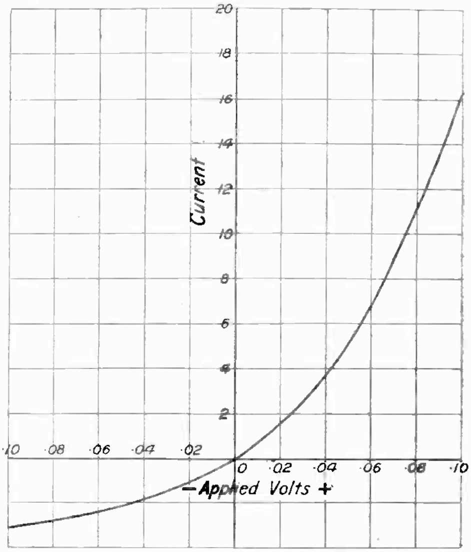


Fig. 3.

characteristic, from which calculations can be made comparatively simply, are exceedingly useful for any investigation of the behaviour of detectors.

Now I come down to the more practical view of the situation. In most applications of the crystal detector there is some form of load in series with the rectifier, because the rectifier is used in order to make readable certain radio-frequency signals. When a load is included in series with the rectifier, the whole of the conditions of operation are fundamentally altered, and any discussion as to efficiency or values of resistance, etc., must be based on a consideration of a loaded rectifier circuit. The first kind of circuit I am going to talk about can be represented in general form, as in Fig. 4.

That, I think, is the simplest form of circuit in which we have a crystal detector supplying a continuous current to a load. The load, for the sake of simplicity, I have shown in the form of a non-inductive resistance. The E.M.F. will be taken to be a pure sine wave alternating E.M.F., and it is to be considered as a *maintained* E.M.F. Whatever the load imposed upon that source of E.M.F., the E.M.F. is maintained: that is an important difference between this ideal simple application of the crystal detector and the reception of wireless telegraph signals, but we have to take the simple case first and see what we may expect when we come to the more complicated case.

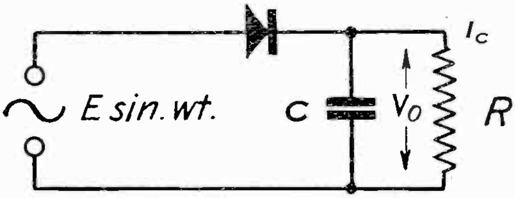


Fig. 4.

The load is short-circuited by a condenser. That, of course, is very general practice, and I have found that it is a fundamentally sound practice. That condenser is to be considered as of sufficient magnitude to prevent any appreciable fall of high-frequency voltage in the load due to the passage of the high frequency components of the current flowing in the detector circuit. In virtue of the characteristic of a detector, there will flow in this circuit a certain small rectified continuous current, for which I will use the symbol I_c. Here we can fall back on Ohm's Law. We have a current flowing and a resistance in the circuit. It therefore follows that somewhere in the circuit there is a continuous E.M.F. It is also common knowledge that if that resistance is removed, the continuous current flowing in this circuit will not rise to any phenomenally large value. That means that even if there is no external resistance in the circuit there is still a resistance somewhere in the circuit which limits the current. We have, therefore, in a rectifier circuit a continuous E.M.F. associated with some form of permanent resistance which we may consider as an internal resistance. We must therefore necessarily have, as an expression for the current in the load, an equation of the simple form :—

$$I_c = \frac{E_c}{R_c + R}.$$

I have used E_c to represent the effective rectified E.M.F., and R_c to represent the internal resistance. Both of these quantities must be associated with the crystal, since there is no other place they can be associated with. Both of these are clearly the important quantities that we want to know something about in relation to the crystal detector. Of course, they are not constants but will vary considerably, not only with the amplitude of the high frequency signal E.M.F., but also with the magnitude of the load R. I should like to make it clear that these two quantities, E_c and R_c are not merely mathematical fictions and convenient expressions, but that they do actually correspond to physical realities in this process, and I shall have to presume on your good nature while I write the details down in mathematical form. It is not a very abstruse form of presentation, but it will need a lot of talking unless I do it in this way :—

If $i = f(e)$, $e = E \sin \omega t$, and if there is no load in the circuit, the expression for the rectified current is :—

$$I_c = \frac{1}{T}\int_0^T f(e).dt = F(E).$$

If there is a load in the circuit, then the voltage operating on the detector instead of being e will take this form : $e - v_0$ where v_0 is the back E.M.F. due to the passage of the continuous component of the

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current through the resistance load. The continuous component in this case will be the mean value of $i = f(e - v_0)$ over a period,

$$I_c = \int_0^T f(e - v_0)\,dt.$$

It can be expressed in the form of an infinite series of terms involving successive powers of this continuous back E.M.F. :

$$I_c = F(E) - v_0 F_1(E) + \frac{{v_0}^2}{2} F_2(E) \quad ..$$

It can be shown that

$$E_c = \frac{F(E) + \frac{{v_0}^2}{2\,!} F_2(E) + \quad ..}{F_1(E) + \frac{{v_0}^2}{3\,!} F_2(E) + \quad ..}$$

$$\frac{1}{R_c} = F_1(E) + \frac{{v_0}^3}{3\,!} F_3(E) + \quad ..$$

These functions of the amplitude are comparatively simple functions derivable from the known form of the static characteristic of the detector. It is clear from the form of these functions that if there is no load in the circuit there is still an effective internal resistance. We can show the effect of having no load in the circuit by removing that part of the expression involving v_0. We are left with the simple expression $1/R_c = F_1(E)$. That function is the mean value of the first differential of the static characteristic, *i.e.*, it is not a thing which can be estimated by simply looking at the characteristic. It is a mean value function. The E.M.F. at no load can be obtained in the same manner. It is $\frac{F(E)}{F_1(E)}$. Dividing E_c by R_c at no load we are left with our original expression for the continuous component in the rectified current. That shows that these quantities, the effective rectified E.M.F. and the effective internal resistance, are actual physical realities and are important characteristics of a detector. I will give you some illustration of their importance by means of Fig. 5.

Suppose we have this simple rectifying circuit which I have been speaking about, and we apply a certain measured E.M.F., then we can plot the rectified current against the amplitude of the applied alternating E.M.F. and we shall get a curve like that marked "galena, no load." The same curve plotted for a perikon detector would come very much lower down the diagram. This would lead you to imagine that perikon is a very much less sensitive detector than galena, but now see what happens when you put a load of about 1 000 ohms in series with each of them. Although the galena detector is still somewhat more sensitive than the perikon it is not quite twice as sensitive, whereas judging from the first, or no load curves, you would think that galena was at least five or six times as sensitive as the perikon detector. The reason for this is perfectly clear in terms of the rectified E.M.F. and the effective internal resistance. It means that in these two cases the rectified E.M.F. is, perhaps, slightly greater in the case of galena than in the case of perikon, but the effective internal resistance is very much higher with perikon than it is for galena, and the result is that at no load a much greater rectified current flows in the galena circuit. When, however, the detector is called upon to do some work, the apparent superiority is greatly reduced, because the real merit of the detector depends chiefly upon the magnitude of its rectified

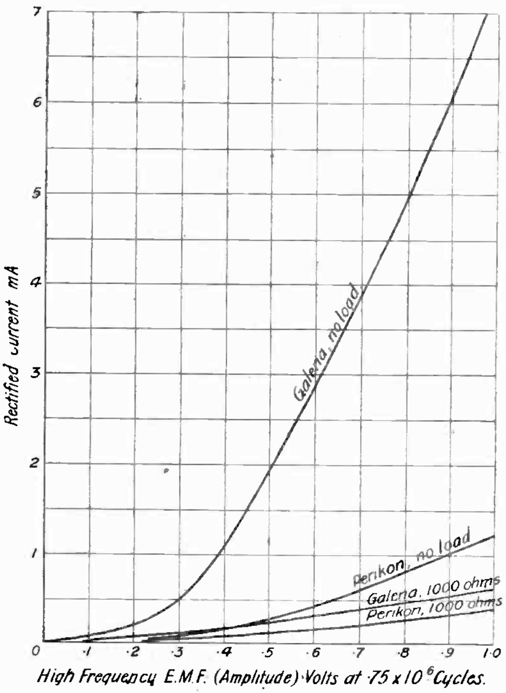

Fig. 5.

E.M.F.; and although it is slightly greater in the case of galena than in the case of perikon, the superiority is not nearly so great as the no load characteristics would lead you to imagine. It may be of interest to show one or two curves indicating the values of these important quantities in the case of the typical detectors. (Fig. 6.)

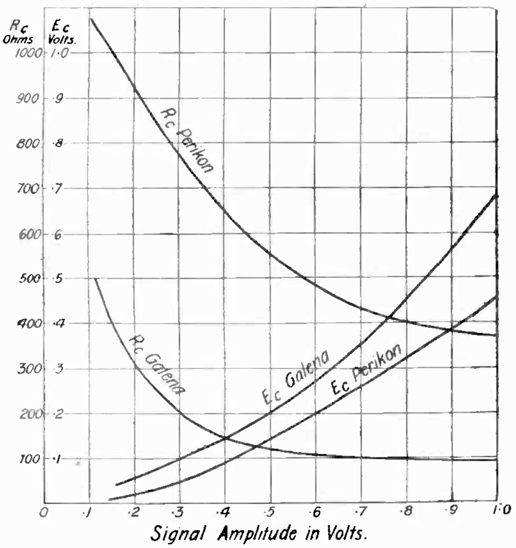

Fig. 6.

These curves show the values of the rectified E.M.F. and the effective internal resistance at no load, *i.e.*, the limiting values assumed by these quantities when R is zero. You will see that when the rectified E.M.F. is, for large amplitudes, something like half the signal amplitude, the effective internal resistance varies enormously with the signal amplitude. For comparatively large amplitudes it is relatively small. When the signal amplitude is about one volt, the effective internal resistance is only about 100 ohms for galena, but when you come down to .05 volt, the effective internal resistance goes up to 5 000 ohms, and that is characteristic of both the more general types of detector, the galena and the perikon.

One interesting deduction from the equations above is that there will be a rectified E.M.F. operating in the output circuit even if the load is made infinite, so that there is no continuous current flowing at all. You can see how that arises in this way. The back E.M.F. across the load is given by this expression: $v_o = Ri_c = \frac{RE_c}{R_c+R}$. Now, the limiting value of this fraction, $R/(R_c+R)$, when R is made infinite, is clearly 1, so that we have the limit of v_0 when R is infinite, as E_c. In other words, if there is no path for the continuous current to flow in at all, there will still be a rectified E.M.F. The form of the functional expression for this rectified E.M.F. indicates that it will increase with the load resistance in series with the detector. The last slide showed you that the magnitude of the no-load rectified E.M.F. for a galena detector was about half the signal amplitude. If we increase the load to infinity and then measure the rectified E.M.F., we should find that it is considerably greater than half the signal amplitude. I measured the effective rectified E.M.F., corresponding to infinite loading, for various specimens of both types of detector, the method being as shown in Fig. 7.

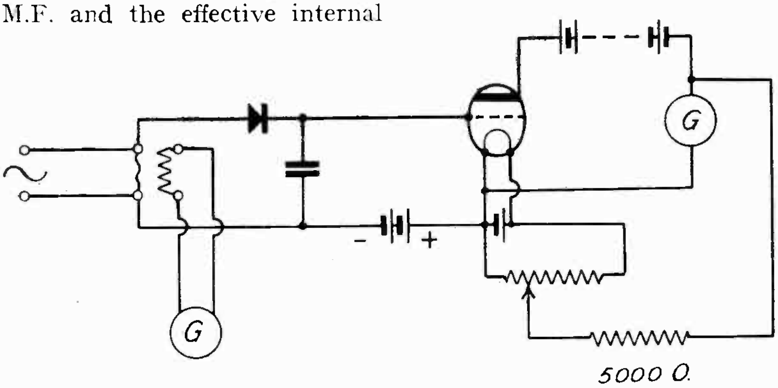

Fig. 7.

A detector in series with a source of high frequency E.M.F. was connected directly to the grid of a valve, and a sufficient negative potential was applied to the grid through the crystal to ensure that there would be no grid current flowing in the grid filament circuit. This, therefore, apart from the secondary effects of any inter-electrode capacities, can be considered as a path of infinite resistance, and there will be no continuous current flowing in the rectifier circuit. In the anode circuit of the valve is a sensitive reflecting galvanometer. If there is a change of potential on this condenser—in other words, if the rectified E.M.F., E_c, actually exists under the conditions of infinite load, there will be a change of potential which will be indicated by a change in the current flowing in the anode circuit, and this can be read on the galvanometer. Its magnitude in terms of change of grid potential can be determined by an ordinary D.C. calibration. I measured the change of E_c corresponding to infinite load for the two principal types of crystal detectors, and the results are shown in Fig 8.

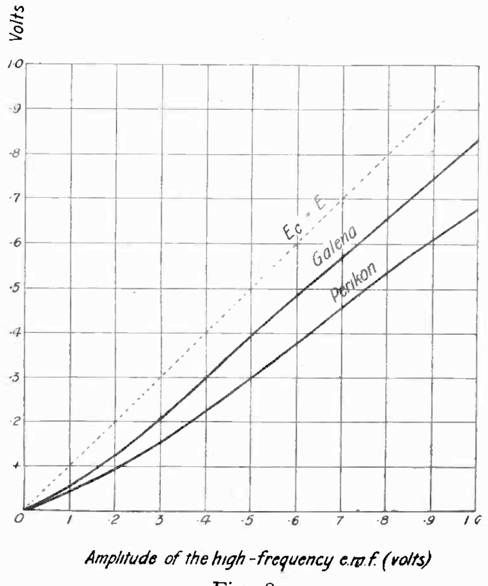

Fig. 8.

You will see that, as I said just now, the rectified E.M.F., corresponding to infinite load, is considerably greater than the rectified E.M.F. corresponding to no load, and the extraordinary thing about the curves is the apparently very high efficiency of crystal detectors as rectifiers of potential purely and simply. In the case of the galena detector particularly, the change of potential across the detector reaches something like 70 or 80 per cent. of the signal amplitude, *i.e.*, the change of grid potential is greater than the root mean square signal voltage and is nearly equal to the actual signal amplitude. In the case of the perikon detector the E_c is not quite so large, but even so the detector appears to be very efficient as a rectifier of potential. If the simple form of characteristic indicated in Fig. 2 applies, the open circuit rectified E.M.F. should be of magnitude E, the signal amplitude, minus e_0. For the galena detector recorded in this Figure, e_0 is between .15 and .2 volt. We should expect therefore that if this characteristic represented the behaviour of that galena detector, the open circuit rectified E.M.F. would be about .8 volt when the signal amplitude was 1 volt, and you see from the curve that it does approximate to that figure. That indicates that this type of characteristic will approximately represent the behaviour of these detectors at large amplitudes.

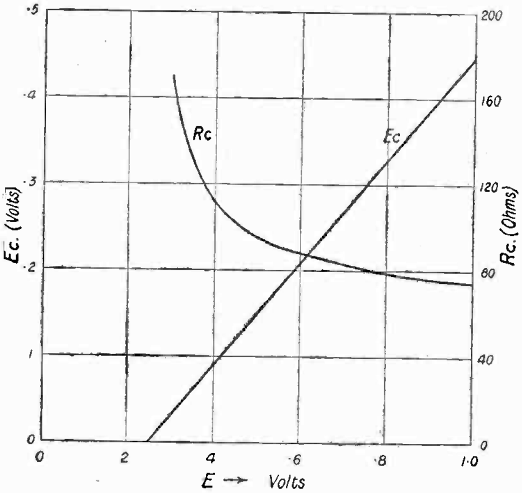

Fig. 9.

Fig. 9 indicates the calculated variation of E_c and R_c with signal amplitude with the ideal straight-line characteristic. Of course, if the signal amplitude does not exceed the small E.M.F. e_0, there will be no rectification taking place at all, and therefore the curve showing the variation of E_c and E will cut the axis at a point corresponding

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to a potential equal to e_0. These curves are calculated for a value of .25 for e_0, and correspond roughly with an ordinary galena detector, and you see the curve cuts the axis for a signal amplitude of .25. The R_c values show the same kind of variation as the other curves, *i.e.*, the R_c comes down fairly low for large signal amplitudes but at small signal amplitudes it begins to rise to a very high value. It cannot rise so high in this ideal case as in the experimental one, because the function becomes discontinuous when the signal amplitude becomes less than e_0, but there is the tendency for the internal resistance to rise to a very high value for small signal amplitudes.

Fig. 10 shows how the quantities E_c and R_c vary with the load. This is not for the ideal straight-line characteristic, but for the characteristic which corresponds to the operation of the detector at small amplitudes, *i.e.*, the fourth power characteristic. In the case of E_c, which increases slightly with the load, the values of the resistance of the load are marked on the top scale. The bottom scale shows back E.M.F. You see that with a load of 110 000 ohms, E_c is increased by 30 per cent. R_c decreases slightly with load, but it is characteristic of both these types of detectors that the quantities E_c and R_c are much more constant under small amplitude conditions than under large amplitude conditions. Also, that E_c is a very much smaller fraction of the signal amplitude when the signal amplitude is small, whilst the internal resistance is very considerably greater when the signal amplitude is small.

Now I come to what is a very important feature of the effect of this back E.M.F. on the operation of a detector. This has an important bearing on the use of a detector for the reception of radio-telegraphic signals.

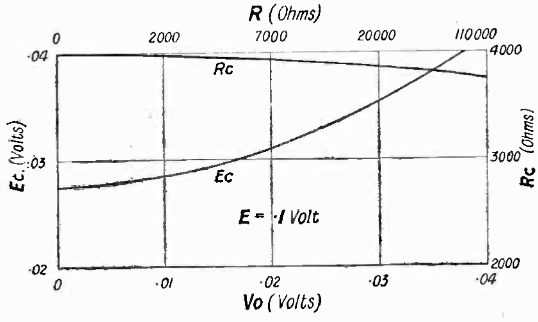

Fig. 10.

If we represent the static characteristic of a detector by a curve of the type of Fig. 11, then the effect of applying a continuous wave signal to the terminal of that detector can be represented as a variation of the potential in a simple harmonic manner on either side of the zero of the origin of the diagram. That is what happens when there is no load in series with the rectifier, and obviously the wave shape of the current will be a curve of the character shown, the mean value of that curve being, of course, the magnitude of the rectified current. But what happens when you put a load in series with the rectifier, that load being short-circuited by a condenser? There will be a back E.M.F. of the magnitude v_0 (Fig. 12), which is equal to the resistance multiplied by the magnitude of the continuous current. That back E.M.F. acts on the detector just as the alternating signal does, so that our new state of affairs is not a simple harmonic variation of potential about the point of origin. There is a shift back, so to speak, of the centre of the potential oscillation by an amount v_0, and our potential oscillation will now take place about the line A B, instead of the real origin of the diagram, and we shall have an oscillation of potential on either side of this new point of origin. The wave shape of the current will now be rather different, as there will be a much longer period of the alternation during which only a very small reverse current is flowing. It is obvious that the fundamental component of the wave form — which is, of course, the high frequency current of the same frequency as the supplying E.M.F.— will be very different in the second case from what it was in the first. The effect of that is that the same E.M.F. acting on the detector will produce a much smaller high frequency current in the second case than it did in the first. In other words, the apparent high frequency resistance of the detector is increased as the result of putting a continuous current load in series with the detector. It should be perfectly clear that the high frequency current does not flow through that load at all; nevertheless the effect of putting that resistance load in the rectifier circuit is very greatly to increase the high frequency resistance of the detector.

It is often said that if a detector has a characteristic of this kind, it is a good thing to apply a small polarising potential in order that the centre of oscillation shall occur at

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the point where the curvature is most marked. It may or may not be an advantage, it depends a great deal on the circuit conditions, but one thing is certain, and that is that in estimating by the appearance of the static characteristic the effect of applying a potential difference across the detector, you do not want to imagine that when you have applied that potential difference the oscillation will be taking place about the same point. Actually, it will be taking place about some point a long way farther back on the characteristic on account of this continuous fall of potential across the D.C. load which you have in series, and this back E.M.F. may reach considerable magnitude.

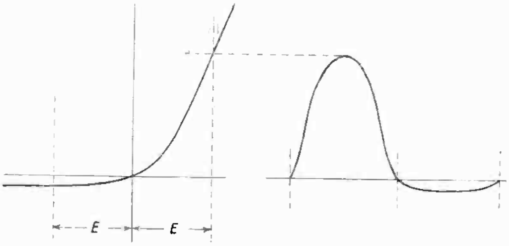

Fig. 11.

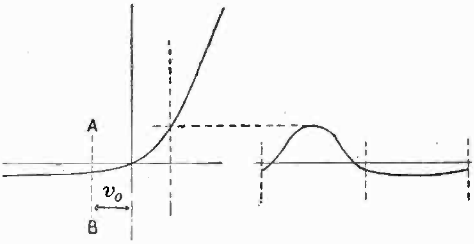

Fig. 12.

If you make R big enough, then you will get a back E.M.F. corresponding to the full rectified E.M.F. in the rectifier circuit, and this back E.M.F. may carry the centre of oscillation right back to very nearly the full amplitude of the signal. You saw that in the case I described where there was an infinite load in series with the detector. That back E.M.F., v_e, was equal to .8 of the signal amplitude, so that this shift of potential very considerably and profoundly modifies the behaviour of the rectifier. It may be that this is a considerable disadvantage; but it is not necessarily so, because the effect of this backward shift of the centre of oscillation is actually to increase very considerably the efficiency of the crystal as a transformer of alternating current energy into continuous current energy.

That is the side I must consider now, because that is, after all, the function of a crystal detector; it is to turn a radio frequency E.M.F. into continuous or low frequency current energy available for the operation of recording or detecting apparatus.

The fundamental equation describing the behaviour of a rectifier in series with a continuous current load is the one which we have had already, *i.e.*,

$$I_c = \frac{E_c}{R_c + R}.$$

In other words, it is as if we had a source of continual potential with a certain internal resistance. It is well known that you will get maximum D.C. power from a combination of that kind when your external load is equal to the internal resistance. Actually E_c depends on the load and increases with the load, while Rc decreases with the load, so that if you were to measure E_c and R_c on no load and then insert a resistance equal to R_c, you would not be developing your maximum continuous current energy. But the value of the resistance which, in fact, gives maximum continuous current energy, is not very different from the value of R_c determined on no load. In the case of the ideal straight-line characteristic, with a signal amplitude of 1 volt, the resistance corresponding to maximum output would be about 98 ohms, whereas the internal resistance on no load is about 70 ohms; but you will see that the resistances are of comparable magnitude. For galena the optimum load would be about 100 ohms, whilst the figure for perikon would be from 400 to 600 ohms for a signal value of 1 volt. This, of course, is running right in the face of current practice, because no one would dream of putting a resistance so low as that in series with a crystal detector and expect to get maximum D.C. output. It must be remembered that these conditions correspond to a maintained E.M.F., but actually the E.M.F. is not maintained. It would be truer to say that the input condition is one of constant energy than one of constant input E.M.F., because there is a limit to the amount of energy which can be received by an aerial in cases of ordinary direct crystal reception.

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What is required, therefore, is not a condition which will give you the maximum value of the continuous current power; we want a condition which will give the highest efficiency of transformation of A.C. energy into D.C. energy. We want the load which will give us the best value of P_c/P_1, P_c being the continuous current power and P_1 the radio frequency power.

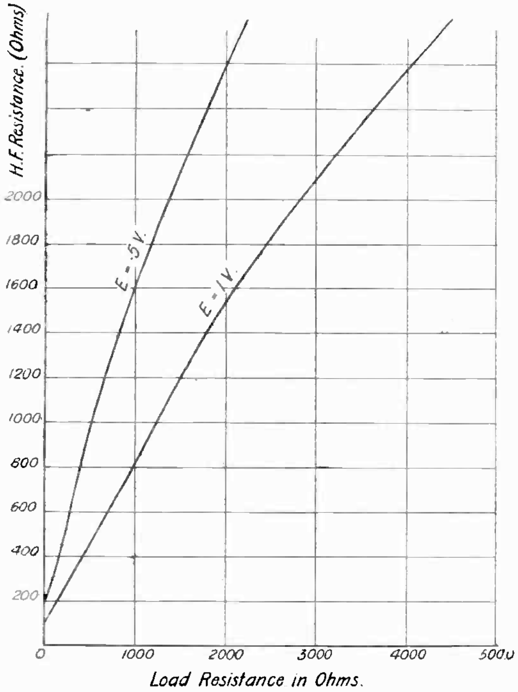

Fig. 13.

The maximum continuous current power is obtained when the external load is made equal to the internal resistance. The P_c reaches a very sharp maximum with a load of about 103 ohms, but P_c/P_1, which represents the efficiency of the transformation of energy, increases continuously with the magnitude of the resistance. This is calculated for the ideal straight-line case. Actually the measurements I have made on a galena detector show that a diagram of this nature will also illustrate the behaviour of a galena detector in the same respects. In other words, although the maximum continuous current energy appears to be associated with a comparatively low resistance; yet if the input energy is limited then it is probable that a much higher output of continuous current energy will be obtained with a considerably higher resistance load, because the efficiency of transformation of the A.C. energy into D.C. energy increases with the load. You will observe that the efficiency of transformation reaches a very high value. It is nearly 80 per cent. for a load of 5 000 ohms. When I first came to that conclusion I felt there must be something wrong, because one is not accustomed to regard a crystal detector as a very efficient transformer of energy. But after I had come to this conclusion, the input and output energies were actually measured by Mr. P. K. Turner by a very excellent method which he produced for the determination of performance of typical crystal detectors, and I was agreeably surprised to find that he had actually obtained higher efficiencies than those I have predicted. Therefore we are forced to the conclusion that a crystal detector, regarded simply as a transformer of A.C. power into D.C. power, is an exceedingly efficient piece of apparatus at large amplitudes and under suitable conditions of load. Efficiencies of 80 per cent. and as high as 90 per cent. can be obtained with a crystal rectifier in this transformation.

I have said that the high frequency resistance of the detector depends upon the magnitude of the continuous current load which is used in series with it. Fig 13 shows typical results for the galena detector obtained by the actual graphical analysis of the calculated form of the effective or dynamic characteristic. You will see that for small signal amplitudes, the effective high frequency resistance is higher than for large signal amplitudes. In other words, the high frequency resistance at constant load increases as the signal amplitude decreases, and for constant E.M.F. the high frequency resistance increases very rapidly as the continuous current load resistance is increased. In other words, the crystal behaves very much like an ordinary A.C. transformer. That is the most useful way to regard a crystal detector; not as a detector which allows current to flow in one direction and not the other, but as an actual transformer of A.C. into D.C. power, and it has the actual characteristics of such a transformer inasmuch as the input resistance or power-consuming resistance depends on the load which you put in the output circuit side.

In Fig. 14 I show the calculated effective high frequency resistance for the ideal straight-line detector, which I said could be regarded as an idealisation of the ordinary crystal detector. You will see that I have been able to do this in more detail, because it did not involve troublesome experimental work, and you will see that the essential character of the result is the same, which confirms that the straight-line characteristic can be regarded as a suitable substitute, for the purpose of calculation, for actual crystal detectors. You will see that the high-frequency resistance with constant load increases rapidly as the signal amplitude increases and for constant signal E.M.F. it increases as the load resistance increases.

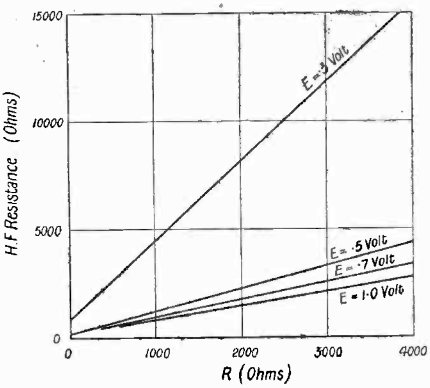

Fig. 14.

Fig. 15 shows the same thing calculated for a fourth power characteristic, *i.e.*, for a detector working on small amplitudes. In this case, the variation is considerably less. You will observe that with an amplitude of .1 volt, the high frequency resistance only varies from 7 000 ohms, with variation of load, to 4 000 ohms, and as the signal amplitude decreases, the effective high frequency resistance becomes more and more constant. That is a result one might expect, since for a very small signal amplitude the curvature of the characteristic is scarcely appreciable and it behaves practically like an ordinary Ohm's Law conductor.

This question of the measurement of the effective high frequency resistance of a detector is an important one for determining the relative merits of different types of detectors, but it is one of very considerable difficulty from the experimental point of view, and a matter upon which much more work still requires to be done. The only experimental method I know which is capable of practical application in a comparatively simple manner is one which has been developed by Mr. P. K. Turner, and perhaps he will say something about it in the discussion.

In the *Wireless World* a short time ago a description was given of a method of measuring the high frequency resistance of a detector based upon plotting resonance curves, the detector being connected across the resonance circuit. For reasons which by now will be quite clear, such a method will be practically useless, because the high frequency resistance depends on the signal amplitude and on the load, so that no method of measuring high frequency resistance will give very useful information if it does not take into account the variation of resistance with the conditions of operation.

I think I will trespass on your toleration for another five minutes just to outline the application of this analysis to the practical reception of radio-telephony signals. Consider, first, the case in which we have an unloaded rectifier circuit. If we plot the magnitude of the continuous current against the signal amplitude we shall obtain a curve of the character of Fig. 16, which becomes approximately a straight line when the signal amplitude exceeds .3 or .4 volt. The abscissæ are not D.C. E.M.F.s, but the amplitude of the applied alternating E.M.F.

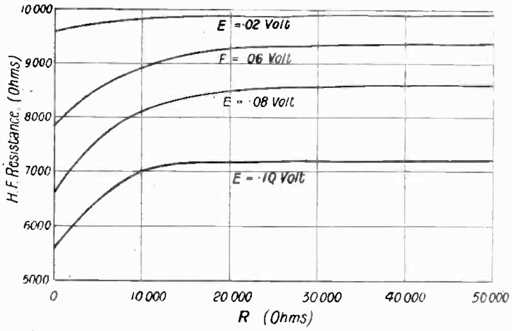

Fig. 15.

Suppose we fix a certain signal amplitude E, we shall have a corresponding continuous current, I_c. Suppose that amplitude is modulated by an audio-frequency, as is the case in wireless telephony. We cannot consider the general case of speech or music because that involves much too complex a wave form of modulation; but imagine we have modulation at a single frequency, and let us see what happens to the rectified current. The amplitude E is no longer constant, but varies at an audio frequency by an amount M, where M is the amplitude of the modulation. That will produce a corresponding variation of the rectified current flowing in that circuit, which can be represented by I_m.

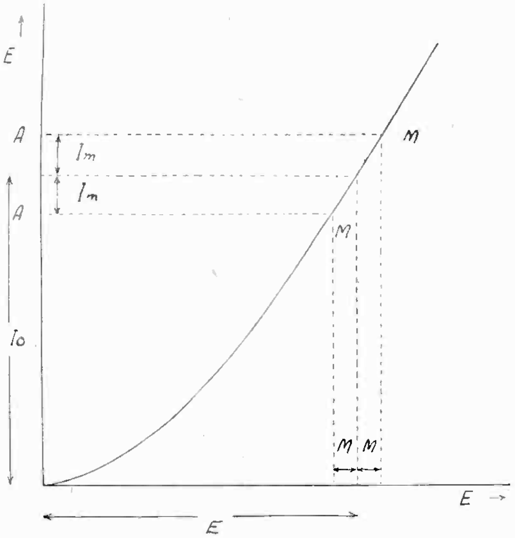

Fig. 16.

Now, if the input amplitude varies in a simple harmonic or sine wave manner by an amount M, there will be a corresponding variation of the continuous current by an amount which is obviously M multiplied by the slope of the curve. In other words, we shall have a modulation frequency component current given by the expression :—

$$I_m = M \frac{dI_c}{dE}$$

If the characteristic is a straight line, this variation of the continuous current, which is really a modulation frequency component of the current, will obviously be a faithful reproduction of M. In other words, if we want to get pure reproduction of the modulation, it is essential that the variation should take place over a part of the characteristic which is appreciably a straight line, and that is where a crystal detector has a very considerable advantage over the valve, because actually, if I_c is plotted against amplitude, for almost any ordinary crystal detector either of the galena or perikon type, it will be found that for signal amplitudes exceeding .4 volt, the rectification characteristic becomes practically a straight line, and that means that such a detector is capable of giving singularly pure and undistorted reproduction of modulation. That is a well-known characteristic of crystal reception of broadcast telephony or music.

I am afraid I have not time to go into the variations of these rather simple analyses when we come to an inductive load in series with the detector, but briefly the position is very much the same as that which I have already described in connection with the rectification of continuous wave signals, *i.e.*, it will be found that the expression for the current can be put in the form of modulation frequency E.M.F. divided by a certain internal resistance plus a load impedance; and the optimum condition, as before, will correspond to an equality of the load impedance and the internal resistance. This latter is slightly different from the corresponding figure in the case of a continuous wave. For galena it is still very low, of the order of 100 ohms, and for perikon it is from 400 to 500 ohms. Just in the same way as the efficiency of power transformation increases with load in the case of continuous wave reception, so also in the case of modulated wave reception the efficiency of transformation of the input power into modulation frequency power increases when the load is increased beyond the apparent optimum corresponding to a maintained input potential. The result is that actually the loudest signals will be obtained with a definite load which is apparently greatly in excess of the appropriate internal resistance of the detector. Actually in nine cases out of ten this is overdone I think, *i.e.*, it is taken for granted that a telephone resistance should be of the order of at least 4 000 ohms. You will find, however, that in most cases a considerable increase of signal strength is obtained with

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lower resistance telephones provided the input E.M.F. is stepped down to avoid excessive aerial damping. However, the detailed analysis of that side of the question would take me another hour, so that I am afraid I shall have to leave it out. I hope I have been able to convey something of the essential principles of the subject to you, and if there are any outstanding points upon which you would like more information I will do my best to give it you as briefly as I can in the reply to the discussion.

The Discussion.

The CHAIRMAN: I am sure you will agree that this has been an extremely interesting lecture, which has shown us not only how the crystal detector works, but has also given us the reason why it is not very much use on very weak signals. We shall now be pleased to have discussion of the lecture.

Mr. P. K. TURNER: I have listened with great interest to Mr. Colebrook's talk. Some of it has been more or less familiar to me, because I have had the painful job of reading a rather extended form of it word by word and letter by letter and correcting printers' errors in it, and in its fully expanded form the task of going through it has been one of labour and certainly not a labour of love! Mr. Colebrook emphasised the importance of the two characteristic quantities E_c and R_c, which may be called the output characteristic quantities of a crystal, but it was not until considerably later that he spoke of the importance of the corresponding input quantity—the apparent input resistance. That is very important, as he made clear later on, but I do not know that he laid quite sufficient stress, from my point of view, on the influence of that input resistance on tuning. One often hears complaints of flatness of tuning in a crystal circuit, which is simply due to the fact that it is being used under unsuitable conditions, so that this comparatively small input resistance is overloading the circuit to which it is connected and damping it so heavily as to flatten its tuning. That is got over in the way Mr. Colebrook suggests, by practically using a high frequency transformer in front of it.

The effect of a potentiometer may be very peculiar in this connection. I have been using crystals a lot for broadcast reception—incidentally those who have not tried crystals under proper conditions have no idea of how good broadcast reception can be with them—and at two miles from London I have been using a high frequency valve in front of a crystal, so that the high frequency E.M.F. applied to the crystal was thus the same as that mentioned by Mr. Colebrook, 1 to 2 volts. While using that circuit on more distant stations I thought, to increase the efficiency, that I would apply a potentiometer, because I had realised some time ago that there was the D.C. E.M.F. effect due to the load in the crystal circuit—a D.C. voltage coming on to the crystal itself. I realised it was in the wrong direction from the potentiometer point of view, so I used an applied E.M.F. on a galena crystal (which nominally requires no potentiometer), in the hope that it might be made to work better. In the particular case I put the detector across the "tuned anode" coil of a valve, and I got very much louder signals by putting the potentiometer farther still the wrong way! It took me some time to realise what Mr. Colebrook has brought out in his lecture to-night; namely, that I was diminishing the efficiency of my rectification as such, but was increasing the H.F. input to the crystal. In effect I was putting more reaction on to the set by increasing the H.F. input resistance of the crystal, and thus taking off damping from the valve. Nevertheless in such a case as that one can sometimes get better effects by using potentials on the crystal, but you must allow for the fact that you are thereby increasing the damping on the circuit. With regard to the actual measurement of crystals, I gave some account of that here not long ago. The method of measurement is, in essence, quite a simple one, but in practice it is perhaps not quite so simple. All high frequency resistance measurements are unpleasant. They require much more care than anybody usually has time to give them.

The highest efficiency I found was a ratio of output power to input power of 0.94, or 94 per cent. on one point of one crystal. On galena crystals, of which I have tested three or four dozen, I suppose the average efficiency is about 50 per cent. taking the crystal point contacts as they come without actually searching for them. That efficiency is at voltages above 0.5 volt of the high frequency input. At 0.1 volt input the efficiencies are in the neighbourhood, as a rule, of 10 per cent. Measurements in that neighbourhood however are rather vague, because one has to be prepared to measure something rather less than 1 microwatt of high frequency power, and that is not easy without elaborate instruments which one does not possess. There is one other little point in connection with the use of valve amplification after the crystal detector, and that is the question of the transformer ratio. Mr. Colebrook has shown in an article of his that the use of a transformer after a crystal need not by any means introduce distortion. Personally, I am of the view that the use of a transformer coupling between valves in low frequency work is, *for present-day practical purposes*, very nearly if not quite as satisfactory—in fact I will say quite as satisfactory—as resistance amplification, for reasons I do not want to fight out now.

Whatever one may think of transformer coupling between valves, there is very little doubt that transformer coupling after a crystal is, for all effective purposes, free from distortion. The ratio of the transformer for galena should be high, about 8 to 1 is a good ratio which I have worked out in practice.

Curiously enough, in a conversation with a well-known wireless engineer the other day, he told me he had been experimenting on the same thing and

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had found that a 2.7 to 1 transformer was the only one worth using after a crystal. We argued a long time about it before I found out that he was speaking of carborundum. Mr. Colebrook has not done any work on carborundum, which is a pity, but the input resistance of carborundum is known to be extremely high. What the R_c is I do not know, but I suspect, from what I know of carborundum, that that was the source of difficulty in the case mentioned. Whereas galena is 100 and perikon 500, I suspect that with carborundum it is about 3 000 or 4 000 ohms. There is a very nice point in this connection, as to whether one could increase the transformer ratio still further, but I am afraid that is too long a problem to go into now. One other point is that I think it would be interesting if Mr. Colebrook, when he has some spare time on his hands, would try the quantitative effect of applied D.C. voltages—potentiometer voltages—on the varying characteristics of a crystal.

Mr. E. H. **Robinson**: It has occurred to most of us at some time or other to use two detectors and make use of full cycle rectification, rectifying both halves of the H.F. cycle. The results of my own trials in this connection however have been negative: there has been no increase in signal strength; and it would therefore be interesting if Mr. Colebrook, from his own knowledge, could tell us whether there is any theoretical reason to expect an advantage from full cycle rectification with crystal detectors.

Mr. P. R. **Coursey**: The long time during which crystal detectors have been studied, really only emphasises the mystery underlying their action. Crystal detectors have been known for a good number of years, and research has been carried out on them for many years but we still seem to have a great deal to find out about them. There is only one point that I would like to refer to that was mentioned by Mr. Colebrook, namely, that it is not always best to put the polarising potential where one thought it should be, namely, where the change of curvature was greatest. In that connection I do not know whether he has noticed a paper which I read before the Physical Society some ten or twelve years ago in which that matter was experimentally investigated from the point of view of the relationship between the sensitiveness and shape of the second differential curve of the characteristic curve. In those cases tested at that time there was almost complete agreement; where the greatest sensitiveness occurred its curve of variation agreed almost exactly with the shape of the second differential of the static characteristic. That fact may have been due partly to the conditions of experiment that were common at that time. In those days I was working at a college laboratory, and one's views of the proper conditions for experimenting were different from what one has, perhaps, nowadays. It was then considered the proper thing to use a resistance in the output circuit—a telephone resistance or galvanometer resistance as the case may be—which never exceeded 100 or 120 ohm for galena and never exceeded 1 000 ohms with perikon, so that that would considerably affect probably the results obtained with different potentials supplied to the crystal. I certainly think that if more investigations of the type Mr. Colebrook has given us to-night were carried out we ought to learn more about the operation of crystal detectors.

Mr. **Colebrook** in replying to the discussion said: I was asked about carborundum. I have done a certain amount of work with this, but came to the conclusion that if in any circumstances it appeared to be a comparable substitute for the two types of detector I have mentioned, it can only be due to the fact that the whole circuit conditions were less inefficient for carborundum than for the others. In itself I think carborundum is likely to be inefficient compared with either of the other two, and the reason for that is easy to see—I think Mr. Turner practically gave it himself. The maximum continuous energy obtainable for a given single amplitude is obviously in the form

$$P = \frac{E_c^2}{4R_c}$$

That is the continuous current power you get when you make your load resistance equal to the internal resistance. It is obviously desirable therefore that R_c should be small, and that is the secret, actually, of the very high possible efficiency of the galena detector; I mean its high efficiency if it is properly used. This low internal resistance will be a positive drawback if it is *not* properly used and if the signal voltage is not suitably stepped down to reduce the load on the receiving circuit; but if it is properly used it is desirable that R_c should be low. Carborundum, as Mr. Turner has indicated, has an exceedingly high value of R_c. I have forgotten the figure but I think it is thousands of ohms, compared with hundreds of ohms in the case of galena.

Then with regard to the effect of full wave rectification with two detectors, mentioned by one speaker, I have not gone into it very thoroughly myself experimentally, but I think it is exceedingly unlikely that anything is to be gained by full wave rectification. Properly used, the single detector is capable of giving very high efficiency of transformation, and I do not think you can increase that efficiency, even under ideal conditions, by more than a few per cent. as the result of using full wave rectification, because you are either introducing twice the load or you only apply half the E.M.F., and the efficiency falls off as the E.M.F. is reduced. Therefore from both the theoretical and practical points of view and also from the point of view of simplicity, I do not think full wave rectification is likely to have very much advantage from the ordinary listener's point of view.

The effect of D.C. voltages is certainly an interesting point, and Mr. Turner asked what effect the applied potential would have under suitable load conditions. It is a matter that I certainly will go into, but I have sufficient faith in this ideal straight-line representation of the galena detector working under large amplitudes, to investigate it on the theoretical basis of that characteristic. I have faith in that characteristic because I have made a considerable number of experiments on actual detectors and compared the results with the results that would be deduced from simple straight-line characteristics of that kind; and provided your signal amplitude does not fall below half a volt, the theoretical and predicted results are in very close agreement. That is a considerable advantage from the practical point of view, because you can go on making all kinds of conditions and you can predict quite accurately what will be the effect of these conditions.

Mr. Coursey asks about something of the same kind, *i.e.*, the effect of potential on the detector, and spoke about the conditions of testing. Of course, any conclusions that are drawn from the operation of detectors with a maintained source of E.M.F. are likely to be quite misleading when you use a detector in the ordinary way across the tuning inductance of an aerial, because there the E.M.F. depends almost entirely on the load you are imposing by means of the detector, whereas with a maintained E.M.F., which is maintained in spite of the load you impose upon it, the conditions are totally different, and totally different conclusions would be reached. With a maintained E.M.F. a low resistance of the order, as Mr. Coursey said, of 200 or 300 ohms, would be the most suitable to use, because such a resistance would give you the maximum output energy, but if your input condition is not one of constant potential but one of constant energy, as it is mostly in the case of ordinary crystal reception, the analysis depending on the equivalent of internal and external resistance breaks down completely.

Mr. P. K. TURNER: In rising to propose a vote of thanks to Mr. Colebrook. I have to thank him not only for delivering a paper to-night but for utilising some very large resources and a considerable amount of his own brain-power for the space of about a year in order to prepare for this. We realise that there is a lot of fairly complicated mathematical analysis behind this paper, and there is also a very great deal of experimental work of a most difficult kind. I do not think I am—in fact I am sure I am not—giving away any secrets if I say that in the other part of Mr. Colebrook's recent work (which has not been dealt with to-night from the lack of time), namely, valve detection, the final conclusion which interests me personally more than any other is that in practically every workable condition the crystal is *the* distortionless detector provided it is used under proper conditions.

It is an interesting point that "the proper place to use a crystal is after a valve," where you have a large input and also you can have a circuit with maintained voltage by using reaction on the valve and thus compensating for the damping due to the crystal. That point is one which I should like to see brought thoroughly home to every member of this Society who is interested not only in long distance work but also in broadcast reception. The use of a crystal after a valve is the best way I know to get purity of tone, and I hope that the emphasis which has been laid on the crystal—which has always been rather looked down upon—by this paper to-night, by somebody who has been doing very difficult investigation work on it, will lead those of you who are interested in broadcast reception to try it, and for that reason above all others I think we should thank Mr. Colebrook very much.

Mr. FOGARTY: I should like to second the proposal that we give a very hearty vote of thanks to Mr. Colebrook for his very interesting paper. The crystal has been a subject for study for a very large number of years, as Mr. Coursey has pointed out, but we still seem very far from knowing all there is to know about it. Until recent years I think we have been perhaps a little too prone to rush to the valve as a solution of all difficulties in connection with reception, and it is therefore refreshing and good for us to be reminded that the older method still has something to recommend it. This is hardly the time to re-open the discussion, but I should like to say that perhaps we all agree with Mr. Turner that a crystal will give us less distortion in reception than the valve, and it may be that the reason it is not used as much as it might be is that whilst it gives us undisturbed reception while it works, it is inclined to go out of action and wants a lot of touching up or re-setting or tickling as it is called. That may be got over with special arrangements, some of which enable detectors to be worked in fixed positions. If that is so then I suggest it is high time that those who are engaged on these new developments should make them known to the Society by means of a paper. I am sure the Papers Committee will be very glad to give an opportunity for the early reading of a paper on this subject. With these few remarks I have much pleasure in seconding the vote of thanks to Mr. Colebrook.

The vote of thanks was carried with acclamation.

The CHAIRMAN announced the names of one transfer and three new members for election and one Society for affiliation and also announced that the next Ordinary Meeting, the final for the session, will be held on Wednesday, 24th June.

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Some More Valves Tested. [R333·009·

We have recently tested about a dozen valves, some of which are described below, the remainder being held over until our next issue. Those dealt with now are the A.R.D.E. H.F., the A.R.D.E. L.F., the P.V.5 D.E. and the P.V.6 D.E., all by the Edison Swan Electric Co., Ltd., and the D.E.3b, by the Marconi-Osram Valve Co., Ltd.

A.R.D.E. H.F. and A.R.D.E. L.F.

THE well-known Ediswan A.R.D.E. is now made in two modifications, intended respectively for H.F. and L.F. use. They are respectively distinguished by a red and green line on the bulb. The construction of the bulb and electrodes appears to be substantially the same as in the old pattern A.R.D.E., the bulb and the electrodes being cylindrical.

The difference between the two valves is presumably in the actual dimensions of the electrodes.

A.R.D.E.-H.F.

Fil. Volts. E_f	Fil. Cur. I_f	Sat. Plate Cur. I_s	Anode Impedance. R_a	Voltage Ampli. μ	Power Ampli. P $\left(=\frac{1\,000\mu^2}{R_a}\right)$	Filament Efficiency. F $\left(=\frac{I_s}{\text{Watts.}}\right)$
1.4	.25	1.6	50 000	8.3	1.4	4.5
1.6	.27	4	43 000	10.0	2.3	9.0
1.8	.285	9	28 000	9.3	3.1	17.5
2.0	.30	15	24 000	9.4	3.75	25.0

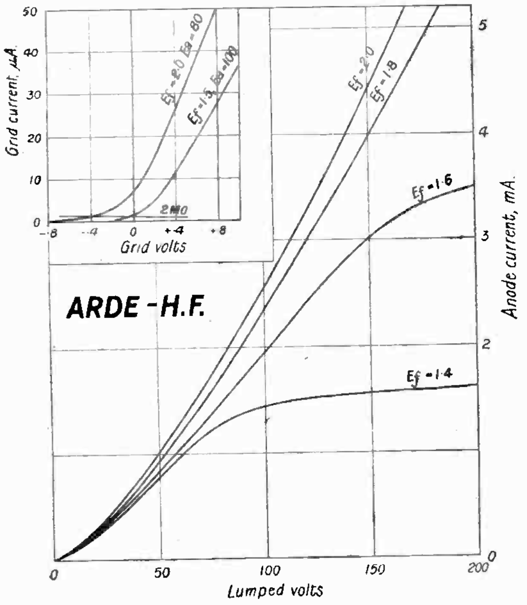
The rating of the filaments of both valves (which come in our 235 class) is the same—1.8-2.0 volts, 0.3 amp—while the anode ratings are 20-100 volts and 30-100 volts for the H.F. and L.F. respectively. They were both tested at four values of filament voltage, and the corresponding current consumption is shown in the accompanying tables. As will be seen, the makers' ratings are accurately borne out in practice.

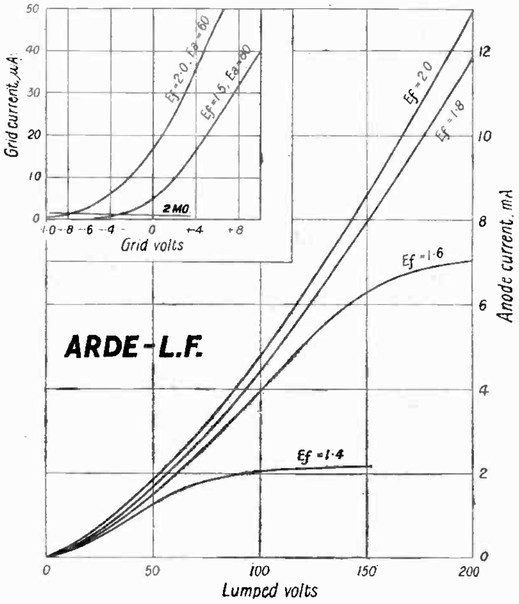
Dealing now with the H.F. valve it will be seen that the saturation plate current rose from 1.6 to 15mA. The impedance is on the high side, ranging from 50 000 to 24 000 ohms, but this is accounted for by the high magnification obtained, which is in the neighbourhood of 9 or 10. The corresponding power amplification rose to 3.75 at 2.0 volts on the filament.

Fil. Volts. E_f	Fil. Cur. I_f	Sat. Plate Cur. I_s	Anode Impedance. R_a	Voltage Ampli. μ	Power Ampli. P $\left(=\frac{1\,000\mu^2}{R_a}\right)$	Filament Efficiency. F $\left(=\frac{I_s}{\text{Watts.}}\right)$
1.4	.24	2.1	28 000	4.7	.78	6.2
1.6	.26	8.0	19 500	4.5	1.05	19.0
1.8	.28	13.0	13 000	5.2	2.1	26.0
2.0	.30	22.0	11 500*	5.3	2.5	37.0

* At 200V.

As this is an H.F. amplifier it will not have to deal with a very large amount of power, so that 1.8 volts on the filament would probably be quite suitable, especially as the increase of power amplification obtained by pushing up the filament voltage to 2 is not very great, and the curve for 1.8 volts shows a good straight portion. On the other hand, owing to the sudden rise in the impedance





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as the voltage is diminished from 1.8 to 1.6, the power amplification is much less at the latter voltage.

From the grid-current curve it will be seen that the valve should make a good detector, a 2MO leak being about correct.

The L.F. valve, as was expected, gave a higher output, rising from 2.1 to 22mA. The impedance was found to be much lower than in the case of the H.F. valve, as was also the voltage amplification, which ranged from 4.7 to 5.3.

The power amplification rose from 0.78 to 2.5. From the curves obtained it will be seen that the one corresponding to 2.0 volts on the filament begins to straighten out nicely at about 150 volts. If we assume a grid amplitude of 3 volts the grid must be biased to at least 4 volts. As the amplification factor is about 5, the corresponding plate voltage will have to be 150+(5×4), or 170 volts. The valve should then function well as a distortionless amplifier. From the grid current curves it will be seen that the H.F. valve will be by far the better detector. The two valves are priced at 14s. each.

P.V.5 D.E.

This is a dull-emitter power valve. The makers rate it as follows: Filament, 5.0 volts, 0.25 amp; anode, 50-150 volts. We should therefore class it as a "625" type valve.

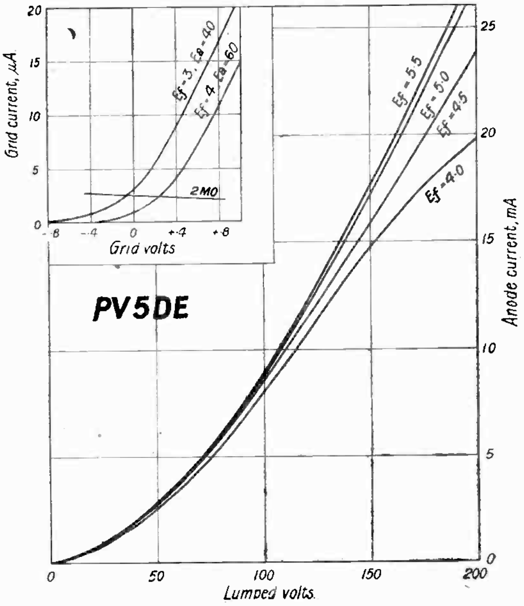
Fil. Volts. E_f	Fil. Cur. I_f	Sat. Plate Cur. I_s	Anode Impedance. R_a	Voltage Ampli. μ	Power Ampli. P $\left(=\frac{1\,000\mu^2}{R_a}\right)$	Filament Efficiency. F $\left(=\frac{I_s}{\text{Watts.}}\right)$
4.0	.25	25	7 000	4.2	2.5	25
4.5	.265	40	6 300	3.8	2.3	33
5.0	.28	70	5 000*	3.1	2.0	50
5.5	.295	100	4 600*	3.0	2.0	62

* At 200V.

The bulb is pear-shaped and rather squat, with a fairly large diameter. The electrodes are vertical, the anode and grid being large and flattened, as is usual with this type of valve. The filament is of the "hair-pin" type, with a special support fixed to a glass bridge piece held by wires extending from the anode and grid.

The valve was tested at 4.0, 4.5, 5.0 and 5.5 volts, and the first thing noticed was an exceptionally high output, the saturation plate current rising from 25 to over 100mA! In fact, the latter figure is quite conservative, as we could not make sure of the saturation current at this filament voltage. We were at first inclined to the belief that the valve was slightly "soft," but could see no trace of "blueing." We are now of the opinion that this high output is not due to softness, but to the construction of the valve.

It would be seen that though the impedance is low, the amplification factor is low also, with the result that the power amplification is below the average for this type of valve. However, in the last stage of an amplifier, where the ability to handle a large amount of power is essential, this valve should do well. Nothing much is gained by running the filament above about 4.5 volts, since the curve for this voltage shows a good straight portion round 150 volts on the anode. From the grid current curve it will be seen that the valve should make a fairly good detector, but the leak should be rather more than 2MO for best results. The price is 22s. 6d.



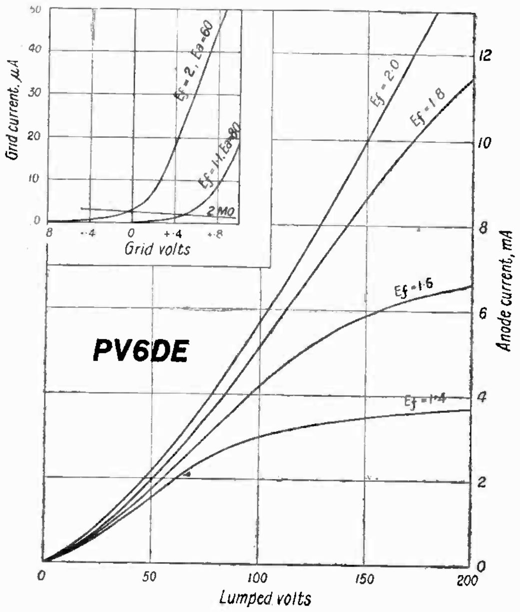
P.V.6 D.E.

This is a 2-volt power valve, intended for use in sets employing valves of the A.R.D.E. type in the other stages. The makers rate it: Filament 1.8-2.0 volts, 0.4 amp; anode 60-120 volts. It would therefore be put in our "240" class. The bulb is pear-shaped, and the electrodes are vertical and similar in construction to those of the R, A.R. or A.R.D.E. types, though, of course, different in dimensions.

We tested the valve at voltages of 1.4, 1.6, 1.8 and 2.0, and found the current consumption to be somewhat greater than the rating, bringing the valve, in fact, within the "245" class. The saturation current ranged from 4 to 22mA, the impedance falling from 25 000 to 10 700 ohms, and the μ ranging from about 3.3 to 6.2. The power amplification was greatest at 2.0 volts, being then 2.32.

Fil. Volts. E_f	Fil. Cur. I_f	Sat. Plate Cur. I_s	Anode Impedance. R_a	Voltage Ampli. μ	Power Ampli. P $\left(=\frac{1\,000\mu^2}{R_a}\right)$	Filament Efficiency. F. $\left(=\frac{I_s}{\text{Watts.}}\right)$
1.4	.40	4	25 000	3.3	0.45	7.2
1.6	.425	7.5	20 500	6.2	1.9	11
1.8	.45	14	14 000	5.6	2.24	17.5
2.0	.475	22	10 700	5.0	2.32	23

In all respects the valve is a normal member of its class. The rating of 60-120 anode volts is rather low, but as the curves obtained begin to straighten out nicely at about 100 volts (total) this should be roughly correct.



If we allow 4 volts grid swing, and bias the grid to —5 volts, the plate voltage should be 100+(5×5)=125 (assuming $\mu=5$). This is certainly an advantage, since a small high tension battery is an important consideration when using power valves, and those who need a small valve of this type, able to deal with a moderate power at a reasonable cost, should bear the P.V.6 D.E. in mind.

As a detector it should work very well, using 2.0 volts on the filament, and a 2MO leak. The price is 18s. 6d.

D.E.3b.

This valve is designed to hold the same relation to the D.E.3 as the D.E.5b does to the D.E.5. It is intended for use mainly in resistance-coupled L.F. amplifiers, where a high magnification in the valve itself is important, and the corresponding increase in impedance is not so detrimental. In construction it is similar to the D.E.3, and the rating is the same, namely: filament, 2.8-3.0 volts, 0.06 amp; anode 120 volts maximum. According to our classification, it is therefore a "306b."

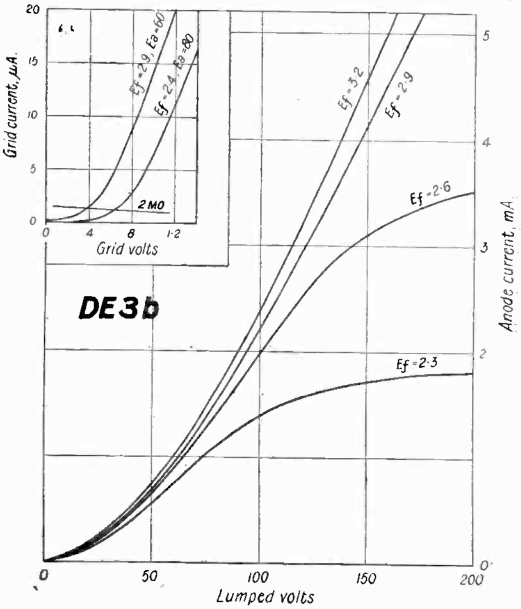
It was tested at filament voltages of 2.3, 2.6, 2.9 and 3.2, the current consumption ranging from 59 to 70mA. The output, which ranged from 2.0 to 11.0mA, is quite sufficient for this type of valve, as it is not intended to handle much power. The anode impedance fell from 50 000 to 22 000 ohms, the amplification factor ranging from 13.3 to 10.2 and the power amplification from 3.5 to 4.8.

Apparently nothing is gained by running the valve at a filament voltage greater than 2.9. Though the μ is high, it is not so high as that of the D.E.5b, which is in the region of 20. The impedance is correspondingly low for this type of valve.

From the curve for 2.9 volts on the filament, it is seen that at 130 volts (total) on the anode the valve will be working on a straight portion of its curve. We may assume a grid swing of only 1 volt from the previous valve, hence the bias need not exceed 1.5 volts, bringing the necessary plate voltage up to 145. This is above the maximum recommended by the makers, and should not be over-stepped, since this type of valve has a coated filament which is easily destroyed by bombardment should the residual gas in the valve become ionised. However, if the voltage is reduced to 120, no serious effect due to the slight curvature of the characteristic should be noticeable, especially as the effect of the high resistance in the anode circuit comes into play.

Fil. Volts. E_f	Fil. Cur. I_f	Sat. Plate Cur. I_s	Anode Imped-ance. R_a	Voltage Ampli. μ	Power Ampli. P $\left(=\frac{1\,000\mu^2}{R}\right)$	Filament Efficiency. F $\left(=\frac{I_s}{\text{Watts.}}\right)$
2.3	.059	2.0	50 000	13.3	3.5	15
2.6	.063	4	36 000	12.0	4.0	24
2.9	.067	7	26 000	11.2	4.8	36
3.2	.070	11	22 000	10.2	4.8	50

This valve could also probably be used as an H.F. amplifier, since it has a good high μ and the impedance is not unreasonably high. As a detector it should also function well with a 2MO leak—in fact, the only duty that it must *not* be expected to perform is that of an L.F. amplifier with ordinary transformer coupling. The price is 16s. 6d.



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Fading Measurements.

By E. A. Anson (20A).

[R113·1

In this and the succeeding article are given interesting data regarding the fading of signals in connection with various geological and meteorological conditions.

IT is well known to a large number of listeners that signals from the more distant stations are subject to variation in strength in a more or less regular manner. Unfortunately the ear can only detect large variations in sound intensity, and, in addition, different ears give varied results.

For useful measurements involving a space of time of, say, twenty minutes, the aural comparison is very crude, as the standard of sound strength at the end may be quite different from the standard at the beginning.

There are several methods of measuring signal strength by instruments. The Einthoven galvanometer, with a period of a few thousandth part of a second and capable of detecting .000 000 000 015 of an amp D.C., is probably the best. It is quite costly, however, about £100 or so.

As money was an important limiting factor in these tests, it was necessary to use a method in which quite cheap accessories, that might be found in most experimental stations, could be employed. There are several such methods ; one is to make use of grid bias in a valve receiver, such that when no signals are passing the plate current is zero, or near enough to give no reading on a microammeter. This meter, in series with the plate current circuit, will then indicate any flow of current caused by altering the grid potential.

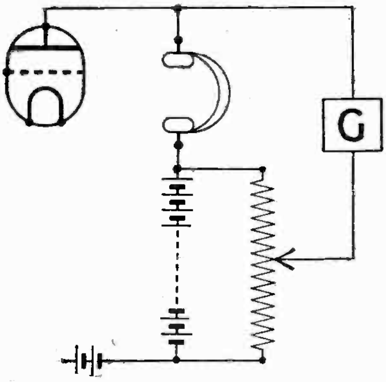

Fig. 1.

Yet another method is to balance out the steady D.C. plate current by a potentiometer across the H.T. battery, as in Fig. 1. Unless this potentiometer is of very high resistance (say, 10 000 ohms), however, the resulting readings on the galvo may be affected by the H.T. battery running down.

By these two methods fairly good comparison of signal strength from day to day may be made, but four or five valves are required to get results, and even then very weak signals are rather erratic in their effect on the circuit. For the tests discussed in this article it was only desired to compare signal strength for about a space of twenty minutes on any given station. The method adopted is shown diagrammatically in Fig. 2.

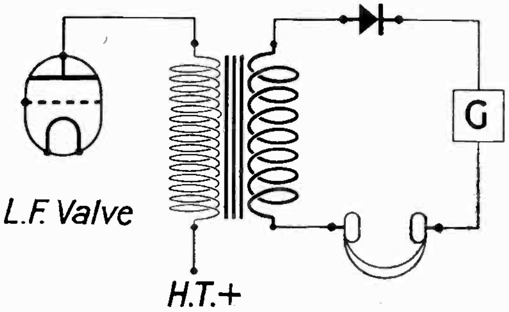

Fig. 2.

The H.F. part of the receiver is used in an oscillating condition to get a steady, audible beat with the incoming carrier wave, and a crystal detector is used to rectify the resulting alternating L.F. currents to D.C. Connected in series with the crystal is a microammeter. The particular one used gives full scale deflection for 15μA, and in series with this is a pair of headphones for tuning purposes. A complete wiring diagram is given in Fig. 3. The actual receiving instrument used had switching arrangements whereby the L.F. valve could be cut out and only the H.F. and detector used.

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This arrangement for measuring signal strength is very sensitive, in fact, signals that are quite weak in the phones give an appreciable reading on the meter.

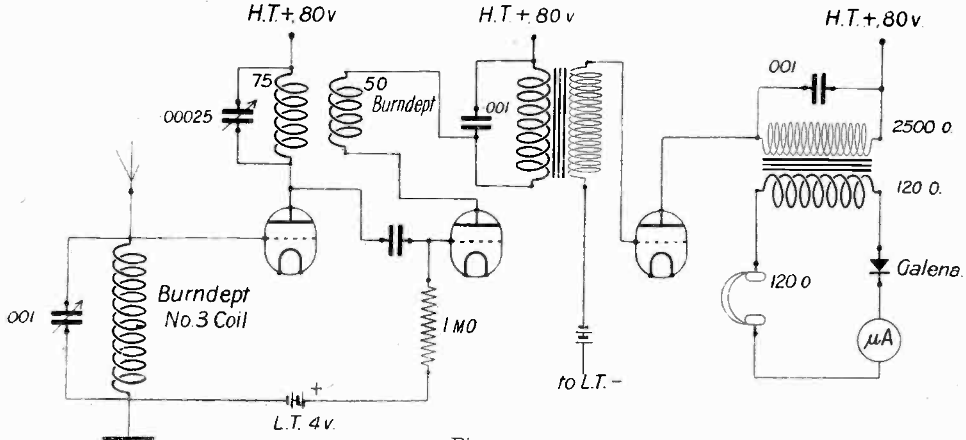
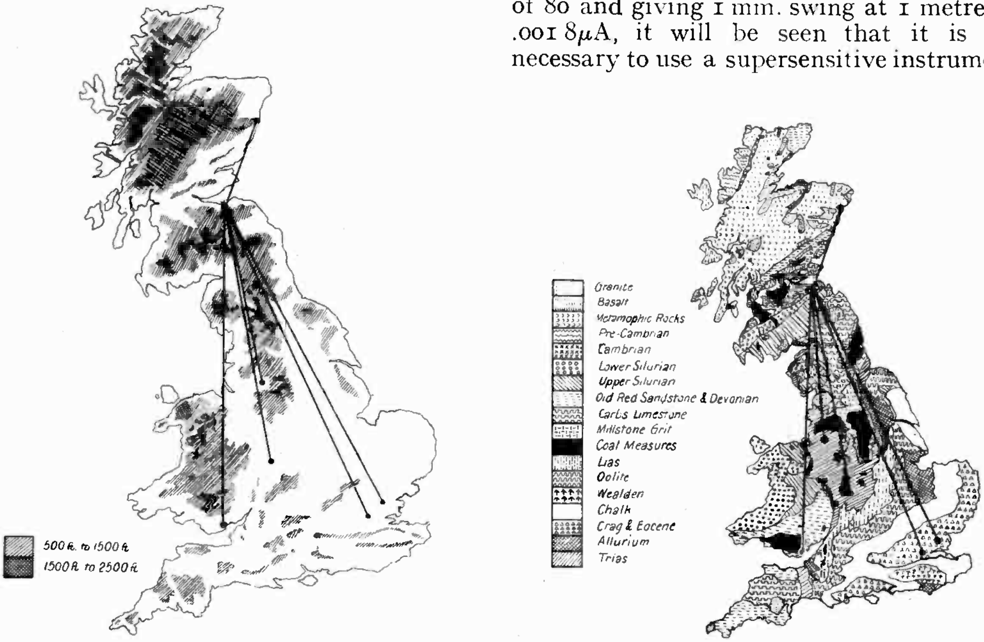


Fig. 3.

A3BQ, situated in Australia, gave a 10mm. (5μA) deflection on the galvanometer, and never dropped below 2μA for a period of five minutes. Most of the B.B.C. stations can be made to give full-scale deflection using two valves only, but reaction must not be adjusted too critically, otherwise mush, etc., affects the readings, while a quite small atmospheric gives a full deflection, and throws the needle off the scale.

The microammeter actually used is of the suspended coil type, and has a coil resistance of 103 ohms ; it is fitted with a pointer about 2 inches long, it has a period of 15 seconds, and a figure of merit about 6. Compared to a Cambridge AM galvo, with a figure of 80 and giving 1 mm. swing at 1 metre for .001 8μA, it will be seen that it is not necessary to use a supersensitive instrument.



The two maps referred to on page 648.

The instrument in question was obtained from Heayberd & Co.

A full deflection of 30mm. ($15\mu A$) is obtained from a central zero or, put differently, the metre will measure up to 200 megohms insulation resistance at 100 volts. For instance, my aerial resistance to D.C. current on a damp day is 80 megohms,

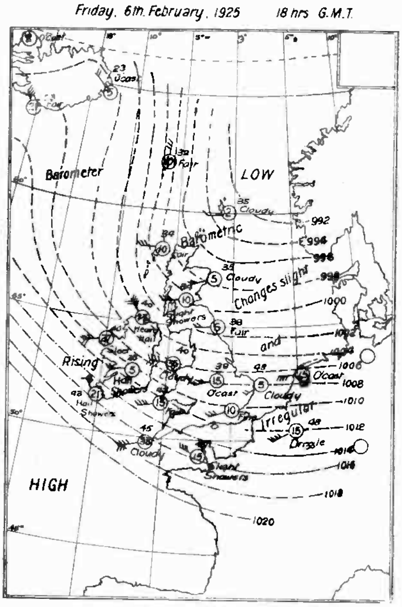

Friday, 6th February, 1925 18 hrs G.M.T.

Chart I.

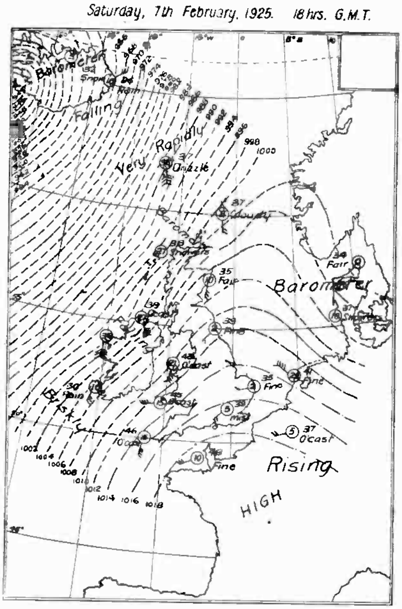

Saturday, 7th February, 1925. 18 hrs. G.M.T.

Chart II.

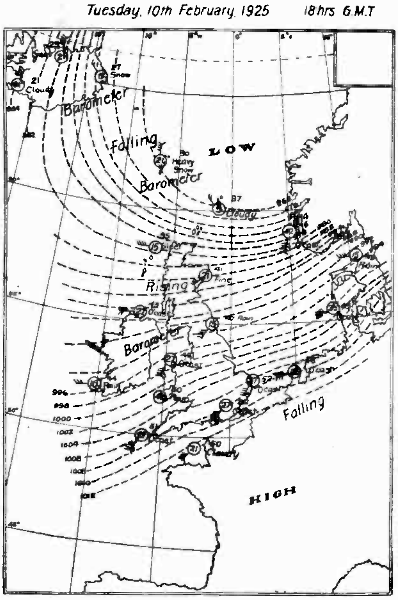

Tuesday, 10th February, 1925 18hrs G.M.T.

Chart III.

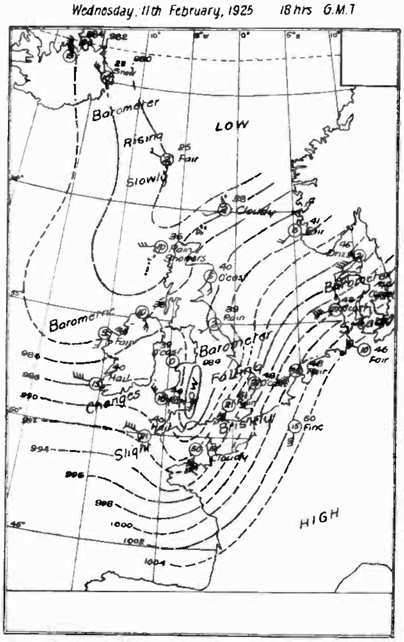

Wednesday, 11th February, 1925 18hrs G.M.T

Chart IV.

giving a deflection of 1 microamp at 80 volts. The insulators are of glass, and the lead-in enters through a hole in a pane of glass. The aerial consists of 100 ft. 7/22 single copper, and is at an average height of 30 ft. The earth, which consists of 6 7/22's buried under the aerial and earthed to the water supply at the far end, has a resistance of about 15 ohms at 300 metres.

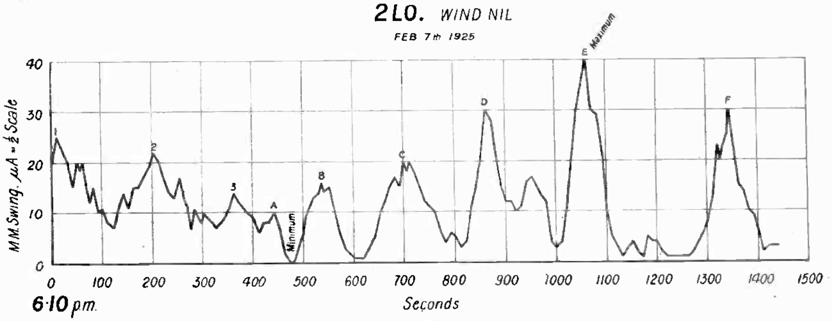


Fig. 4.

The locality at which the tests were made is on the seaboard, flat and treeless and rural. In an area of 40 square miles north of the station there are no other receivers, as this area covers the Firth of Forth. In three or four square miles to the southward there are only four or five other receivers, and none of these is within a mile. Such tests as these cannot be carried out in congested areas, as local oscillation causes erratic results. In order to assist readers in comparing the various geological conditions, etc., two maps are given (see p. 646). These show the geological features and mountain systems that the waves traverse. It will be noted that the ground contains coal at the receiving end; in fact, this area is riddled with coal mines, and the coal in places lies only a few yards from the surface.

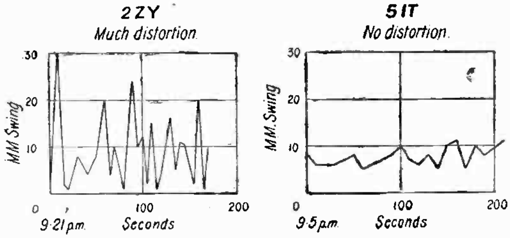


Fig. 5.

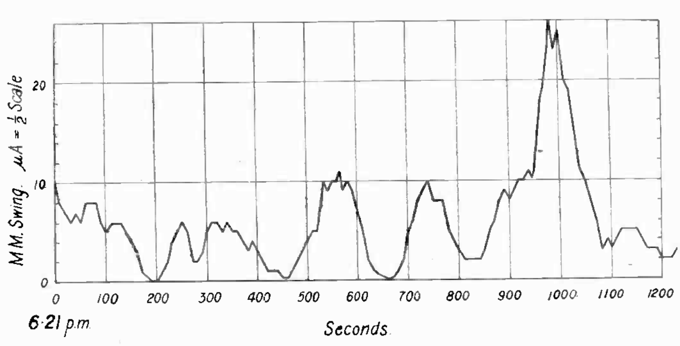


Fig. 6.

As regards practical operation, a certain amount of patience is required to get good records, as the crystal sometimes goes on strike after a few minutes and refuses to rectify. However, once a good spot is found it will remain operative for hours. A thermocouple of 40 S.W.G. Eureka and copper was tried, but was found nowhere near as sensitive as the galena crystal.

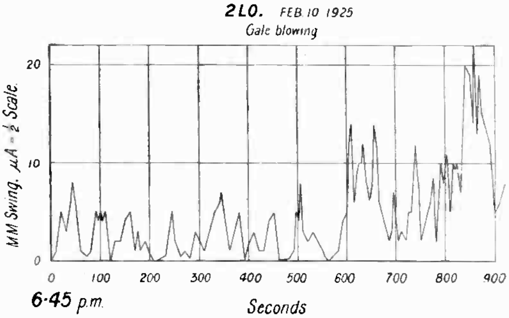


Fig. 7.

Some very interesting fading curves were obtained. These should be studied in conjunction with the weather maps (Charts I, II, III & IV), which show the weather conditions at the time the curves were made. The weather conditions on the evening before the tests were made are shown in Chart I, the pressure S.W. of the British Isles being high, and low to the N.E. It will be noted that these conditions are much the same in all the charts, except that the high and low areas move slowly eastward.

A fading curve for 2LO for 27th February, 1925, taken for a period of twenty minutes, is shown in Fig. 4. The most notable feature about this curve is that the maximum peaks follow each other with a certain regularity, much like the behaviour of a pendulum would do under a suitable impetus regularly applied. Peaks A, B, C and D steadily increase until a maximum is reached at E, when the maximums begin to diminish as at F, probably falling away in the manner shown at 1, 2 and 3.

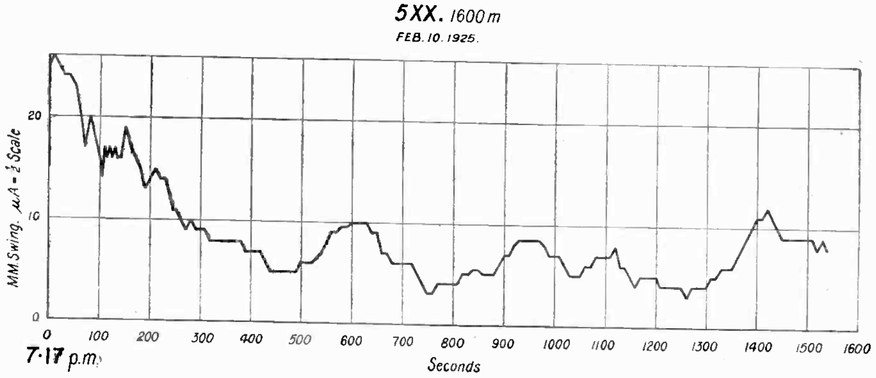


Fig. 8.

This gives a time interval from maximum peak to maximum peak of about 23 mins. The rises appear to be more irregular than the falls; also it is perhaps noteworthy that the signals appear to *recover after* a "fade" more rapidly than the original fading took place. I think this is quite noticeable even on the loud-speaker or the phones.

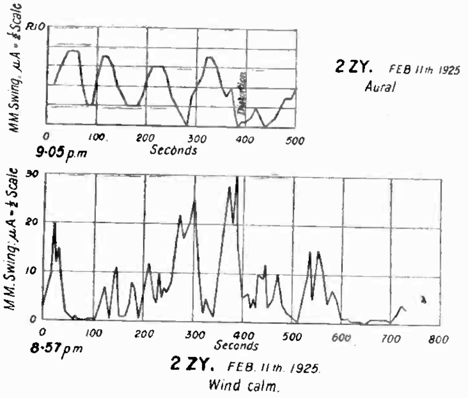


Fig. 9.

Fig. 5 gives a curve for 2ZY and 5IT, both taken on the same evening and at nearly the same time. 2ZY fades so suddenly and frequently that speech is at times much distorted and chopped; 5IT is much steadier and speech is clearer.

A further batch of curves was taken on 10th February. On this date there was a strong gale blowing, whereas on 7th February the wind was almost nil. Probably tuning-capacity variations, due to a swinging aerial, account for the erratic minor variations in these curves, but distinct rhythm at the peaks is noticeable. It is remarkable that 5WA (Fig. 6) gives a much steadier curve than 2LO (Fig. 7), although they were taken within 30 minutes of each other and with the same gale of wind. This curve behaves like that of 2LO on 7th February, but the maximum to maximum period is about 17 minutes, as compared to 2LO's 23 minutes.

Even the high power station is not immune from fading; in fact, at times speech on the loud-speaker becomes much distorted. Its curve (Fig. 8) is steadier and varies slowly and definitely. The maximum to maximum period appears to be about 45 minutes.

On 11th February the weather chart (IV) shows slightly more complication over England, as one of those secondary depressions is doing its best to get a hold on Wales. For this date 2ZY's curve (Fig. 9) is remarkable for the peculiar double-fade effect on the top of all the peaks. The maximum to maximum period would appear to be 17 minutes.

An aural curve of this last station is shown as an interesting comparison. Whilst it is fully realised that these few efforts on this baffling problem of fading do not appear to lead anywhere, it is thought that there is a little that can be learnt from the various curves, which also serve to show that quite interesting results may be obtained with simple circuits and instruments.

Some Recent Observations on Periodic Fading and the Night Effect.

By Paul D. Tyers.

[R113·1

ALTHOUGH the phenomenon of fading has been known for considerably more than ten years, there appears to have been but little systematic observation if one is to judge by the scant amount of literature available. This is due, no doubt, to the fact that it has been nobody's particular business to investigate the subject, and it is only within recent years that the radio engineer has realised that a satisfactory solution of the problem is likely to prove of paramount importance. Associated with short-period variation of field intensity, or simply "fading" or "swinging" as it is more popularly termed, is the "night effect" or distortion of a modulated carrier wave. This distortion is of a peculiar nature, and is more easily appreciated by actual hearing than by an attempt to define it.

While it seems probable that a satisfactory explanation of the phenomenon is more likely to be derived from definite organised systematic observations carried out at a large number of different points, than from a few isolated records, there seems to be no reason why the latter, when correlated with other records, should not prove of value. As the writer was recently fortunate enough to observe some rather peculiar effects, the following short notes have been prepared in the hope that they may prove of interest to those who are at present investigating the subject.

The observations were made on several British broadcasting stations, and in addition, on some of the Continental stations. Those detailed here have been picked out from a large number as being the most interesting. As it was desired to note both the variations in field intensity and the quality of the modulation, means were provided for measuring the rectified current, and subsequently amplifying it, a loud-speaker being included in the output circuit of the amplifier.

The fundamental circuit which was employed for these observations is shown in Fig. 1, and it will be seen that the method consists essentially in amplifying the received oscillations by a valve *V*. The anode circuit of this valve contains the circuit *LC*, which is shunted by a crystal rectifier *D* and microammeter *M*. It is important when making observations on signal strength to ensure that any tendency to self-oscillation in the valve receiving system is reduced to a minimum, as variation in conditions might materially increase any inherent reaction effects, which would be liable to introduce error in recording the rectified current. The resistance of the crystal rectifier and the microammeter which is shunted across the circuit *LC* lowers the resonance peak of that circuit considerably, and consequently the arrangement is very stable. It will be noticed that a frame *F* tuned by a condenser *K* was used for the input circuit; this point will be referred to later.

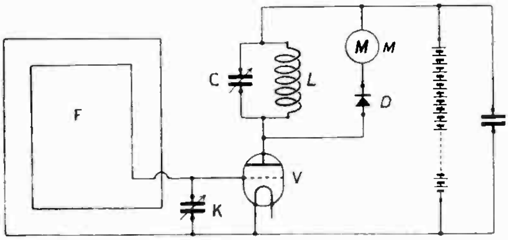


Fig. 1.

The complete circuit employed is shown in Fig. 2, and it will be seen that a resistance *R* is included in the rectifier circuit. The microammeter *M* measures the steady value of the rectified current, while the audio-frequency variations cause potential differences to be set up across the resistance *R* connected to the input of a resistance-coupled amplifier containing a loud-speaker in the output circuit. By this means it was found possible to observe any change in the quality of the speech or music simultaneously with the change in the received current.

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A brief account of some of the results obtained will now be given, and any deductions which can be drawn will be left to the end of these notes.

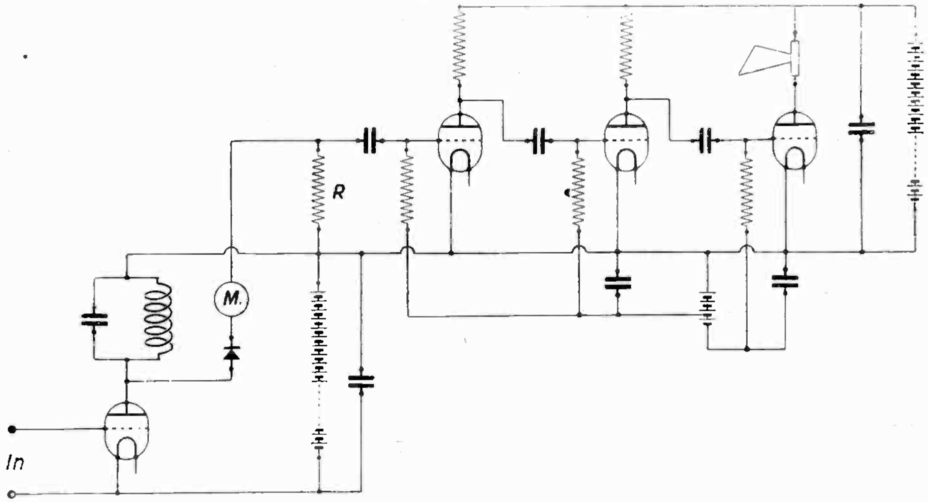


Fig. 2.

The receiving apparatus was installed at Watford, which is some twenty miles NNW of London, and the first observations were made on the Bournemouth station of the British Broadcasting Company, and the harmonic of a neighbouring C.W. station, which happened to be of similar frequency to that of the Bournemouth station, which is of the order of 780kC.

Fig. 3*a* is a diagram of the received current from the Bournemouth station, while Fig. 3*b* is that of the received current from the harmonic of the C.W. station. The form of the curve of Fig. 3*a* is periodic: it shows a regular periodic variation, but the interesting feature is that the received current is substantially constant for a period of thirteen seconds, when it undergoes a sudden diminution lasting for approximately three seconds. This periodic variation was perfectly constant for about an hour, after which the three-second variation which occurred every thirteen seconds became considerably less in magnitude, until the received current became almost constant. It will be noticed that the curve is not complete, the peak values being shown dotted. Owing to the rapidity of the cut-off and the lag in the microammeter, the exact turning point could not be found, although the received music as reproduced by the loud-speaker was just audible throughout the whole cycle. During the intervals marked *X* and *Y* on the current curve, that is, where the rate of change of current with respect to time is high, very clearly defined night distortion was present, but over the sections marked *A* the music was perfectly pure. The advantages to be gained by amplifying the received current and reproducing it by a loud-speaker are obvious, as the curve shown in Fig. 3*a* of course does not give any indication of night distortion. By this method it is possible to observe the relation between night distortion and received current.

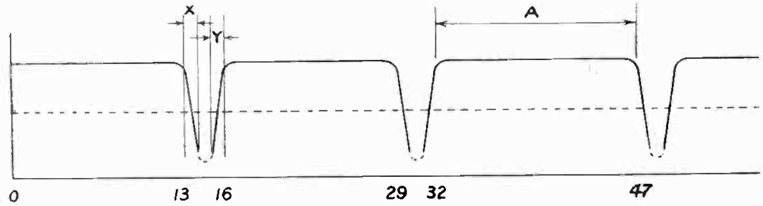


Fig. 3*a*.

While dealing with the subject of acoustic observations, the amateur experimenter should be careful not to record false observations by depending only upon audible signal strength. While it cannot be denied that the volume of sound from a loud-speaker or telephone receiver is proportional to the received current, it is of little use to endeavour to plot a curve of received current by estimating the variation in volume of the sound. Although the human ear is very sensitive to variation of intensity in sound, the accuracy of the observations depend upon the rate of change of sound with time, and can only be relied upon when this exceeds a certain value. I have found that it is possible for the received current to increase by 100 per cent. over a long period without any perceptible change being noticed by the ear, while an almost instantaneous increase of some 15 or 20 per cent. can be immediately detected by the ear. There is little to be said with regard to curve 3b, which shows that the received current is practically constant.

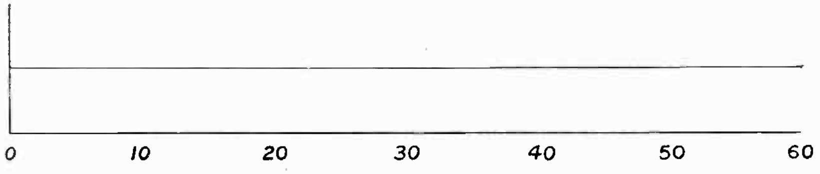


Fig. 3*b*.

Fig. 4 is a rough map which shows the relative position of the two transmitting stations with respect to the receiver. They actually subtend an angle of 15°, and the C.W. station is only 25 miles nearer the receiver. Before commenting upon these results some brief details of another set of observations will be given.

These observations were made chiefly on the Birmingham, Manchester and Glasgow stations of the British Broadcasting Company. The most important of these was the Birmingham station, the frequency of which is not far from 600kC. The received speech and music from the Glasgow and Manchester stations were quite normal both with regard to quality and strength. The reception of the Birmingham station was extremely peculiar. In the first place, the average strength was about a quarter normal, and the general nature of the reception was very similiar to that of a transatlantic broadcasting station. It was subject to fluctuating, but more or less clearly defined periodic fading of considerable magnitude. Unfortunately the recording device was not in operation, and it was therefore impossible to take an actual curve. A more peculiar feature of the reception, however, was the extraordinary night distortion which existed throughout the whole transmission. The observation was made for about an hour only, that is, until the station closed down, and it was only with the greatest difficulty that the identity of the station could be established, as the announcer's remarks were almost completely unintelligible. In fact, it was thought for some little while that it was not a British station which was being received. Both the Manchester and the Glasgow stations have been associated with the reception of the Birmingham station because they lie on a line nearest to that passing through the Birmingham station and the point of reception. However, a number of other stations, both British and Continental, were quickly received, or in other words reception was noted from stations in entirely different directions. In no case could any perceptible fading, or the slightest trace of night distortion, be observed; several of the Continental stations being particularly pure. Fig. 5 is a rough map which shows the directions of the various stations.

The details of these observations may at first sight appear rather peculiar, but an attempt will be made to examine them a little more definitely with the idea of determining whether or not there is really anything strange or abnormal.

Several general theories have been put forward to account for the phenomenon of fading, the most popular of which, I believe, is that reflection takes place from the Heaviside layer, which gives rise to plural path transmission. In other words, it is assumed, for example, that a signal may be received direct from the transmitting station, and also by reflection from the Heaviside layer. Optical interference effects would then occur, which, it is suggested, would explain many of the observed effects. Of course there is no reason to assume that only plane reflection takes place, because since we are dealing with a three dimensional medium, something like refraction may also be expected to occur.

If we examine the effects observed in connection with Fig. 5 in the light of this theory alone, it seems that they are really not wholly explained. I think it will be agreed that the results obtained point very strongly to extremely local influence. We find, for example, that reception from Glasgow, that is along the line *GR*, is perfect. A similar result is obtained from Manchester along the line *MR*, which is inclined to the line *GR* at an angle of about 3 degrees. Reception from Cardiff, which is nearly at right angles to the previous direction, is quite normal, as is also the reception from several of the Continental stations. When we turn through only about 15 degrees to Birmingham, we at once find very strong fading and night distortion. An important point to note is that Birmingham is less than one hundred miles away, while Glasgow, for example, is some three hundred miles distant. Apparently the converse of what would be expected is taking place, because the nearer the station the more acute the angle of incidence and the less would be the interference expected. Even if it is agreed that the conditions which bring about the particular fading and distortion observed are extremely localised we have yet to determine the nature of these conditions.

Another suggestion which has been put forward as accounting in part for many of the observed periodic fading effects of short duration, is that the intensity of the received energy is determined by varying local absorption. In other words, it is suggested that the absorption along the given signal path may be determined by purely local conditions, which give rise to varying amounts of absorption. If this is the case, many of the records of signal intensity show that this varying absorption may, or may not, be rhythmic. In the case of the Birmingham reception in this particular instance the signal intensity was very erratic, whereas in the case of the Bournemouth station the swinging was decidedly periodic. It seems probable that this absorption would be due to local ionisation in the atmosphere. Pickard in America, I believe, has suggested that the absorption might be due to formation of banks of ionised particles which might drift about in cloud-like masses. If we assume therefore that these form something similar to the well-known diffraction grating and drift about according to local wind currents, it seems quite likely that the effects which are described in these notes would be more easily explained.

Turning again to Fig. 3*a*, which is the receiving diagram for the Bournemouth station, it will be obvious that the expression for the curve can be resolved by a harmonic analysis into expressions which would represent the movement of one or more banks of ionised particles. For example, it is quite possible that the variation observed on the Bournemouth station could be caused by two "gratings" moving at different rates or in different directions with respect to each other.

It will be remembered that these observations were made on a semi-directional system, a large external loop being employed, as this had been set up for some other experiments. If interference effects were caused by a diffraction grating it seems possible that there might be a change in direction of wave front which would obviously affect a directional aerial system, and influence still further the variation in the received current.

If we assume that the effects are due to local absorption, we can gauge roughly the extent of the localisation by reference to Figs. 4 and 5. Referring first to Fig. 4, the lines *BR* and *CR*, which represent the signal path from the broadcasting and C.W. stations respectively, subtend an angle of about 15 degrees. Along the path *BR* we

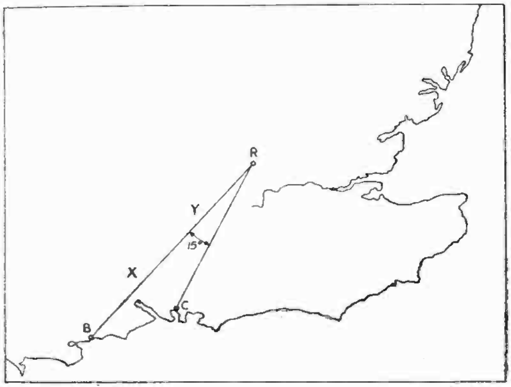


Fig. 4.

find fading and distortion, while pure reception is obtained along *CR*. As the lines converge at *R* at a comparatively small angle, we are justified in assuming that the two lines are common for all practical purposes for some appreciable distance from *R*. Similar reasoning holds good in the case of Fig. 5 with the lines *GR* and *MR*; and to a less extent with *MR* and *BR*. It seems highly probable that in the case of Fig. 4 the disturbing conditions occur in the region marked *X*, although they might equally well exist between *X* and *Y*. In the case of Fig. 5 it would appear that the influencing conditions exist within the region *Z*. Whether we are justified in assuming that the fading and distortion is due entirely to local absorption effects, or not, it is impossible to tell from the existing data. There is no reason, however, why varying absorption should not occur and at the same time be preceded or followed by reflection or refraction from the Heaviside layer. However, I think it will be agreed that the foregoing experiments do lend support to the varying local absorption theory, but of course it would be totally unscientific to suggest that they form anything approaching conclusive proof.

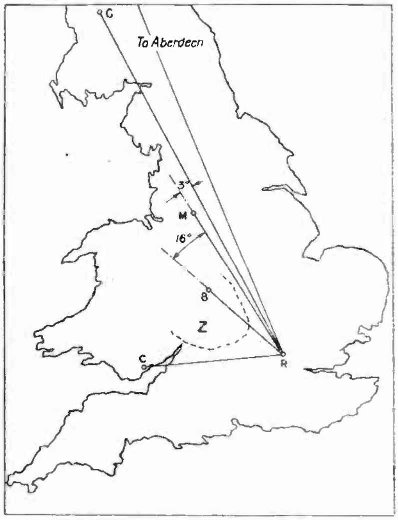
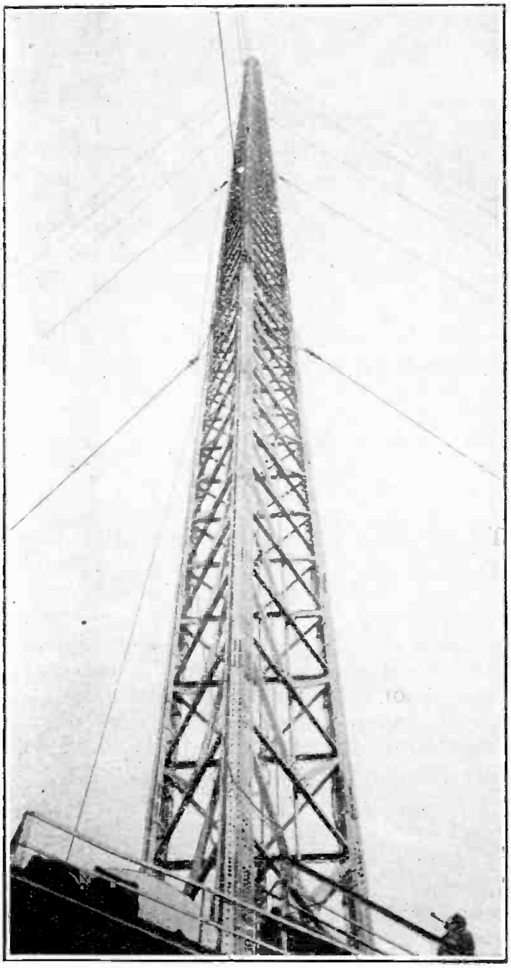


Fig. 5.



An unusual view of one of the eight giant masts at the new Rugby station. Each of these is 200 feet high and stayed by 15 insulated guys.

Long-Distance Work.

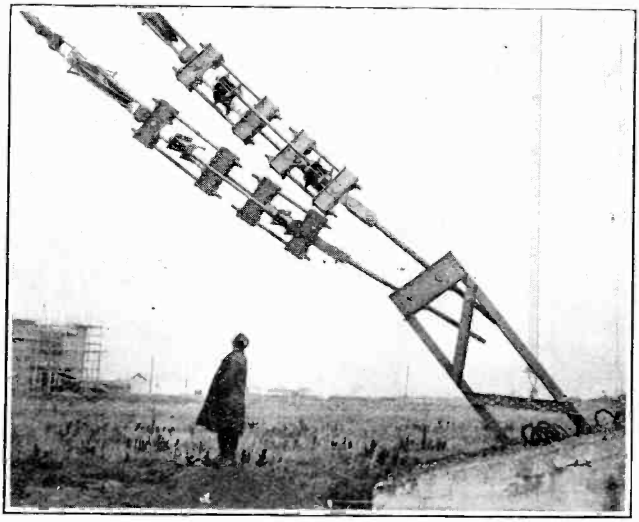
By Hugh N. Ryan (5BV). **[R545·0092**

It is extremely satisfactory to find that, even so late in the year, our work is proceeding with only little more difficulty than during the winter. It is interesting to note in this connection, too, that last year no British signals were heard in America after 2nd June, while two-way working ceased some time before that date. This year two-way working is still conducted with ease in the middle of June, and bids fair to continue right through the summer.

The factor which has brought about this change is, of course, the use of the shorter waves, notably those around 40 metres. American 90-metre signals can still be heard fairly often, but they are not at all reliable, and the Americans apparently can no longer hear us on that wave. It would appear that we have at last found, in the 40-metre region, the ideal wave-length for purely DX work.

In the past we have found every drop in wave-length attended by better DX results, but this improvement appears to cease somewhere around 40 metres. The waves around 20 metres will evidently travel over great distances, but are somewhat uncertain and less successful over shorter distances. Their most valuable property is their usefulness in daylight, which unfortunately is absent at night. The 40-metre waves, on the other hand, while at their best at night, appear also to travel quite well by day, even in the summer. It seems likely that in the winter trans-atlantic, and possibly trans-world, work will be possible day and night on 40 metres, or thereabouts.

With our present limited knowledge of waves of 20 metres and less, it is somewhat early to prophesy, but I think one may venture the opinion that general, reliable DX work will in future be conducted day and night, all the year round, on about 40 metres, while some wave, or waves, around 20 metres will be used for special purposes. Waves below 20 metres may, on investigation, prove useful, but it is impossible to say what we shall discover there.



One of the stay anchors for the masts at Hillmerton.

Although, as I have said, conditions still allow of our work continuing unabated, the summer weather naturally exerts a retarding force on the operator, even if not on his signals. Hence the amount of work wanes month by month, but a surprising number of stations are still in regular operation, and at least one new country has arrived "on the air." A station signing BG1 has for some time been working in Iceland, using the intermediate "Ic." The first British station to work him was 5TZ, of the Isle of Wight, who did so as long ago as April. As far as I know, no other British station has established contact, although BG1 has heard a number of us, and is himself to be heard fairly often. He works on the 90-metre band, with an A.C. note.

Last month I said that 5LF's outward voyage to America (as 6YM) was somewhat disappointing from our end. The reason was that he had unavoidably to abandon his 20-metre and 90-metre schedules and work almost entirely on 45 metres. As a result his signals were often coming in at great strength on 45 metres while many stations were calling him on 90.

I discovered this myself during his homeward voyage, and worked him for several nights, when his signals were excellent. 2KF worked him continuously throughout the double voyage on 45 metres, while 2KZ worked him with 90-metre telephony, 6YM replying on the shorter wave. 5TZ and 2GO, among others, worked him during the outward voyage, the latter using only 3½ watts when 6YM was 1 100 miles out.

Another amateur at sea is F. H. Schnell (u. 1 MO-1 XW and traffic manager of the A.R.R.L.), who is aboard the U.S. warship *Seattle* in the Pacific. During his voyage from San Francisco to Hawaii he worked England (2KF), Australia (2DS) and New Zealand (2AC) as well as many Americans. 5NN and 2FU also report hearing him in London. At Hawaii, Schnell was joined by another well-known American amateur, 6TS. They are using the call sign NRRL on 20, 30, 40, 50 and 80 metres.

By the time this appears in print, a third amateur-bearing ship will have sailed. The Macmillan Expedition ship *Bowdoin*, so famous last year as WNP with Donald Mix as operator, is sailing again this year with John L. Reinartz (1XAM) aboard. We in Europe hope to keep in touch with him as well as the Americans this year.

Few London stations are working regularly now. 5NN has received a confirmed report of his 20-metre signals in Melbourne on 26th April, this establishing him as the first British station heard in Australia on the very short waves.

6LJ has at last taken a rest from the intensive reception for which he is famous, but has nevertheless compiled a good log of stations heard on 20 metres, including u. 6AWT and Argentine CB8.

5AX has moved from Walton to Wallingford, and his station there is already "reaching out" on low power. 6UV is now firmly established on 45 metres, on which wave he has worked nearly every American district, and is heard in America in daylight.

5BV is working seldom, but when he does, he uses a pure D.C. note—sometimes. 5TZ has been struggling with a Master Oscillator, which now, I think, he has mastered. 2KK (Staffs) is still carrying on good receiving work, and will shortly be transmitting.

6JV has been experimenting extensively with various receiving circuits (in the course of which experiments he has worked most European countries), and avows his lack of faith in superheterodynes. I hope he will dislike them less some day. He has worked telephony to Holland with 7 watts.

6YR has worked nearly all Europe with an input of the order of three watts, and has been heard in America on the same power. As a "stunt" he has worked over 22 miles on less than a thousandth of this power.

Before concluding, I should like to mention an interesting organisation which has recently been formed. A number of non-transmitting members of the Cambridge Radio Society, feeling that they did not "get a look in" where DX was concerned, have formed an "experimenters' section" for the purpose of co-operating with transmitting men and furnishing them with reports when required.

This seems to me an excellent idea. Real experimenters (as distinct from purely "distance-hams") often do require reports based on careful and systematic observations. This experimenters' section aims at furnishing such reports to pre-arranged schedules, and attracting other interested amateurs and BCL's into a similar service.

The idea is not yet in full swing, but should be so early next winter. I commend it to transmitting experimenters.

Please let me have reports for the next survey by 10th July.

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For the Esperantists.

Abstracts of Articles in E.W. & W.E., June, 1925.

Resumaro de Artikoloj en E.W. & W.E.

Junio, 1925.

[R800

A GLIMPSE AT ESPERANTO.

The Alphabet.

A B C Ĉ D E F G Ĝ H Ĥ I J Ĵ K L M N O P R S Ŝ T U Ŭ V Z.

No Q, W, X, or Y.

Pronunciation.

The Vowels :	**A**	**E**	**I**	**O**	**U**
	bah	there	pier	pore	poor

The **Consonants** sound as in English, except **C** like **ts** in **bits**, *e.g.*, **caro** like *tsaro* ; **acido** like ah-tsee'-doh. **Ĉ** like **ch** in **church**. **G** like **g** in **go**. **Ĝ** like g in **gem.** **J** like **y** in **yes**, *e.g.*, **jaro** like *yaro* ; **bojo** like *boyo*. **Ĵ** like **z** in **azure**. **S** like s in **so**. **Ŝ** like **sh** in **show**. **Ĥ** (guttural, very seldom used) like **ch** in **loch**.

AJ, OJ, as in **my boy**. **EJ,** as in **obey. UJ,** as in **hallelujah. Ŭ** is the Esperanto **W**, as in **well, how** ; **AŬ** as **ow** in **cow. EŬ,** as in **they were.**

Accent always on the second last syllable. Phonetic spelling.
-O is the ending of the **NOUN. ADJECTIVES** end in **-A.**
Nouns and Adjectives form the **PLURAL** by adding **-J.**

The simple **VERB** endings :—

Infinitive.	Present.	Past.	Future.	Conditional.	Imperative.
I	**AS**	**IS**	**OS**	**US**	**U**

N marks the **ACCUSATIVE** (direct object). **ADVERBS** end in **E**.

NO IRREGULARITIES. NO EXCEPTIONS.

ANTEN-AGORDILA DESEGNADO.

W. B. Medlam, B.Sc., A.M.I.E.E., kaj
U. A. Oschwald, B.A.,

[R141

UNUA parto de interesa artikolo pritraktanta la plej bonajn proporciojn de antenagordaj induktanco kaj kapacito, post sufiĉa enkalkulo pri la antenaj konstantoj kaj la ŝarĝo alportita de la detektoro.

Nombro da cirkvitoj estas analizitaj teorie, kaj la rezultoj de eksperimentoj montritaj konfirme.

Oni diskutas tri specialajn ekzemplojn, nome : (I) la antena cirkvito senŝarĝita, (II) la efekto de ŝarĝa rezistanco, kaj (III) la efekto de paralela kapacito.

La aŭtoroj montras, ke nur tre malofte ŝajne sin pravigas la paralela agorda kondensatoro.

Rilate al la efekto de ŝarĝa rezistanco de

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kristalo, oni faris nombron da eksperimentoj ĉe kristalcirkvitoj, kun agordo per seria kondensatoro. Oni konektis mikrometron serie kun la kristalo, kaj aranĝis komutatoron, tiel ke oni povu legi la kristalan kurenton kun la bornoj de la 4000-omaj telefoniloj kunligitaj. Oni mezuris la tension trans la antenagorda induktanco per termiona voltmetro. La variadon de kristala kurento rilate al la induktanco oni montras per du grafikaĵoj; ĉe unu oni ricevis la kurvojn mallongigante la cirkviton de la telefoniloj, kaj ĉe alia per la telefoniloj serie kun la kristalo. Oni provis diversspecojn de kristaloj. Oni ankaŭ provis la efikon de valva detektoro.

Por resumi, oni povas konstati, ke la antenagorda kondensatoro estas ordinare malhelpo. En okazo kiam estas ŝarĝo (ekzemple, detektoro) ĉe la cirkvito, ekzistas klare difinita plej bona valoro de la antenagorda induktanco, pligrandiĝanta kun la rezistanco de la ŝarĝo. Aparte ĉe kristaloj, ĉi tiu "plej bona" valoro de induktanco ne sufiĉas, por ke oni povu agordi ĝis la ondolongo bezonita ĉe ordinaraj antenoj. En tia okazo, estus plej bone pligrandigi la kapaciton de la anteno mem kiom eble, kaj se tio ne sufiĉos, pligrandigi la induktancon, prefere ol uzi paralelan kondensatoron. Se oni faros tion, estos avantaĝo konekti la kristalon trans parto nur de la induktanco.

LA PERFEKTA APARATO. [R342·4

Refleksaj Cirkvitoj.

Serio de artikoloj, kies celo ĝis nun estas klarigi kelkajn el la ĉefaj principoj de detektado kaj alt- kaj malalt-frekvenca amplifado. La nuna artikolo pritraktas refleksajn cirkvitojn. Al du Germanoj apartenas la kredito pro la elpenso pri la unua refleksa cirkvito kiun ili patentigis en la jaro 1913a. Estas interese noti, ke nur negravaj plibonigaĵoj estas faritaj ĉe tiu cirkvito eĉ ĝis la nuna tago. En Britujo s-ro. Voight faris multon por disvolvigi kaj popularigi la cirkviton.

La aŭtoro emfaze kritikas la ideon, erare esprimitan diversloke, ke ĝi estas "fantazia" cirkvito, kaj ke ĝi estas senutila por "DX" komunikado, aŭ por brodkastado, k.t.p.

La aŭtoro procedas, pere de du diagramoj, montri kiel facile ortodoksa altfrekvenca transformatore kuplita amplifikatoro kun nedifinita detektoro povas esti konvertita al refleksa cirkvito nur per malkonekto de ĉiu bateria fadeno kaj enmeto de malaltfrekvenca komponaĵo, dum la antaŭaj "elmetaj" bornoj estas rekondukitaj pere de transformatoro al la unua krado.

Li tiam diskutas la diversajn ŝanĝojn produktitajn de la konvertigo, kaj je altfrekvenca kaj malaltfrekvenca amplifado, kaj klarigas kiel oni povas forigi la malavantaĝojn. Li aludas la popularan eraron pri "trivalvaj refleksaj" cirkvitoj, kiuj ordinare konsistas nur el detektoro, unu altfrekvenca kaj malaltfrekvenca duala valvo, kaj unu altfrekvenca valvo; tio estas, "unu-valva refleksilo kun detektoro kun unu altfrekvenca." Vera "3-valva refleksilo," t.e., aparato kun 6 ŝtupoj de amplifado, 3 altfrekvencaj kaj 3 malaltfrekvencaj, estas tute alia afero.

Tre grava punkto estas la ebleco de interago interne de la valvo inter la altfrekvenca kaj malaltfrekvenca komponaĵoj. Li pruvas, ke eĉ malgranda aŭ modera kurbiĝo de la valva karakterizo, kvankam nesufiĉa por produkti rimarkeblan malaltfrekvencan distordon pro sia primaria efekto, povas tamen malstabiligi refleksan cirkviton pro moduliĝo de la altfrekvenca kurento kaŭzita per troŝarĝo ĉe la valvo. La leciono, kiun oni povas lerni per ĉi tio, estas uzi nur bonajn valvojn, kaj ne troŝarĝi ilin.

Unu grava limiĝo ĉe la refleksilo, kiu, tamen, havas grandan avantaĝon por la brodkasta aŭskultanto, estas la fakto, ke ĝi ne estas taŭga cirkvito por mem-heterodina ricevo de kontinuaj ondoj. Se oni pligrandigas la reakcion ĝis osciligo, la aparato ordinare ululas laŭtege. Tial, ĝi estas beno ĉe la brodkasta aŭskultanto—aŭ plivere al lia najboro—ĉar ĝi signifas, ke li ne povas senintence oscili sen tuja ekscio.

Unu granda virto de la refleksilo estas, ke ĝi estas aparte taŭga por kristala ricevado; la kristalo donas plibonajn rezultojn je telefonio, kaj havas utilan efikon por stabiligi la altfrekvencan amplifikatoron.

PROVOJ PRI IZOLECO.

DE H. C. STEPHENSON. [R280·0122

Priskribo pri simpla metodo por provi proksimume per orfolia elektroskopo la izolajn ecojn de diversaj materialoj uzataj ĉe senfadena laborado. Kvankam ne preciza instrumento, ĉi tiu simpla speco de elektroskopo, konstruita je malmulta kosto, povas diferencigi inter bonaj, malbonaj kaj nebonaj izolatoroj.

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La elektroskopo konsistas el du malgrandaj strioj de orfolio, kiuj pendas vertikale de fino de bone izolita metala vergo. La foliojn ĉirkaŭas metala skatoleto, por ŝirmi ilin kontraŭ aerblovetoj. Se oni frotetas je maniko pecon de ebonito, kaj per ĝi tuŝas la metalan vergon, la folioj elektriĝas kaj malkonverĝas ĝis ili formiĝas inversita V. Ili restas tiel ĝis la ŝarĝo elfluas tra la izolatoro. Tiumaniere oni povas havigi proksimuman indikon pri la izola eco de materialo se oni tenos unu finon per la fingroj kaj metos la alian finon kontraŭ la metalan vergon, al kiu la folioj estas ligitaj. Ĉe bona konduktoro, la folioj kolapsas tuj ; tamen, ĉe bona izolatoro oni povas rimarki apenaŭ ian efikon. La tempo kiu pasas, ĝis la folioj kolapsas, montras proksimume la izolan econ de la materialo provita.

Nombro da eksperimentoj montris surprizajn rezultojn. Oni unue provis diversajn fragmentojn de ebonito, polurita kaj nepolurita. La folioj falis treege malrapide, dum pli ol 30 sekundoj. Sekvis provoj ĉe tri specoj de valvingoj—hejmefarita el ebonito, kaj mulditaj specoj kun kaj sen flanĝo. La speco hejmefarita donis la plej bonan rezulton, la lasta speco la plej malbonan. Oni ankaŭ laŭvice provis, kun diversaj rezultoj, bobeningon, varieblan kaj fiksan kondensatorojn, valvojn, kaj kradelfluan rezistancon.

Oni alvenis al la konkludo, ke, aŭ la materialo uzita por la kondensatoraj kovriloj, valvaj izolatoroj, valvingoj, k.t.p., ne estas sufiĉe bona kiel izolatoro, aŭ altgrada ebonito por paneloj kaj aliaj komponaĵoj ne estas absolute necesa.

La artikolo finiĝas per priskribo pri konstruo de elektroskopo, por tiuj, kiuj deziras fari similajn eksperimentojn.

KOMUNIKADO JE ONDLONGOJ NEORDINARE UZATAJ. [R800·650

Lekcio je la Radio-Societo de Granda Britujo, de S-ro. G. G. Blake, M.I.E.E., A. Inst.P., je la 22a Aprilo, 1925a.

La parolanto diris, ke lia lekcio estos mallonga historio de eksperimentoj faritaj pri telegrafio kaj telefonio je ondlongoj eteraj krom tiuj eltrovitaj de Hertz, kun nombro da montraĵoj kaj lumbildoj por ilustri la lekcion.

Oni nuntempe konas 53 oktavojn en la etera spektro, sed per niaj okuloj estas videbla nur unu oktavo. Inter la oktavoj, kiuj troviĝas en la spektro, estas la X-radioj, lumo, mallumo, varmo, Hertzaj ondoj, kaj senfadenaj ondoj.

Pro manko de tempo, la lekciisto decidis pritrakti nur infraruĝajn radiojn, videblan lumon, kaj ultraviolajn radiojn. Li estis desegninta aparaton, kiu montras, ke elektra sparko povas esti la fonto de ultraviolaj radiadoj, la tuto de la videbla spektro, malhelaj varmecaj ondoj, kaj Hertzaj ondoj. Li faris demonstracion pri tiuj ondlongoj, unuope kaj samtempe.

Kondensatora sparko estas riĉa je mallongaj ultraviolaj ondoj, sed malriĉa je similaj longaj radiadoj. Karbona arko estas ĝuste mala ; tungstena arko riĉa je ĉiu ondlongo; kvarca hidrarga vaporlampo tre riĉa je ultraviolaj radiadoj.

La ekzisto de ultraviolaj radioj en lumo de karbona arko estis montrita per vitraĵa filtrilo "Chance" a, kaj la fluoresko de "Willemite" (la mineralaĵo en kiu troviĝas zinko). Oni ankaŭ demonstraciis per zinka sulfido, baria platino-cianido, urania vitraĵo, kandelo, butero, k.t.p.

Poste oni montris per lumbildoj kelkajn fotografaĵojn faritajn (1) per nefiltrita lumo de tungstena arko, (2) en tute malluma ĉambro sole per la nevideblaj ultraviolaj radioj, (3) per ultraviolaj radiadoj sole el hidrarga vaporlampo. Pluan fotografaĵon oni montris, kun ĉiuj fluoreskaj objektoj forprenitaj for de la grupo.

La lekciisto diris, ke dum la milito oni sukcese uzis ultraviolajn radiadojn por signalado, kaj por helpi al ŝipoj en eskorto vojaĝi kune laŭ siaj relativaj pozicioj. Pere de hidrarga arko, kiel sendilo, entenita en tubo de "Chance"a vitraĵo—kiu emisiis nur ultraviolajn radiojn—estis eble, fokusante la radiojn ĉe skreno de baria platino-cianido, vidi la fluoreskon tiel naskitan je distanco de kvar mejloj. Aliajn eksperimentojn antaŭ kaj dum la milito li priskribis, montrantajn kiel oni uzis la ultraviolajn radiojn, inter ili la elsendo de sonoj.

La lekciisto poste diskutis la signaladon per blanka lumo, kiu konsistas el sep koloroj, ĉiu reprezentanta malsaman ondlongon.

Jam en la dek-unua jarcento oni utiligis en Alĝerio la heliografion, aŭ la metodon de signalado per la sunradioj. Multaj urboj interkomunikadis per la sunradioj reflektitaj de speguloj konstruitaj sur la supraĵoj de altaj turoj. En la sama lando lastatempe

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francaj inĝenieroj sukcesis signali trans distanco de 170 mejloj, kaj en California, Usono, oni atingis 190 mejlojn.

Selenio estis poste pritraktita. Frue en la 19a jarcento, oni montris, ke selenio povas konduki elektron plibone kiam ĝi estas hele lumigita, ol kiam ŝirmita for de la lumo. Kelkaj aliaj substancoj, kiel ekzemple, natura antimona sulfido, kupra oksido, k.t.p., estas ankaŭ sensitivaj je lumo.

En la jaro 1878a, Bell kaj Tainter montris, ke luma radio estas modulebla per la sonondoj el homa voĉo, kun la helpo de selenia ĉelo. Oni nomis la instrumenton uzitan, la Fotofono. La modulo, tamen, estis tre nebona. Oni faris multajn eksperimentojn per la Fotofono, uzante korkon, lignopecojn, fluidaĵojn, kaj gasojn,—eĉ cigarfumo povas produkti sonojn.

La lekicisto montris cirkviton, elpensitan de si, en kiu selenia ĉelo reguligas la kradon de oscila valvo. Oni povas uzi ĉi tiun cirkviton (a) por funkciigi relajon por kabla telegrafio, (b) por indiki la transiron de stelo trans la vidkampon de teleskopo, (c) sur ŝipo, kiam proksima je lumturo, por fari laŭtan signalon kiam la lumtura radio transpasas la vidkampon de la ĉelo, (d) por fotometraj celoj, normigo de kandelpotenco, (e) por komparo kaj mezuro de kvantoj aŭ radiadoj de radiumo, k.c., (f) la travidebleco de objekto je lumo, (g) la denseco de korpoj de diversaj pacientoj rilate al la X-radioj, (h) kiel nevidebla sentinelo por militŝipaj, armeaj, kaj policaj celoj, (i) malproksima reguligo de aerŝipoj; kaj por multaj aliaj aferoj.

Post kelkaj rimarkigoj pri la uzo de infraruĝaj radioj, la lekciisto finis sian paroladon.

Sekvis diskutado, en kiu partoprenis la fama sciencisto, D-ro. E. E. Fournier d'Albe.

DIREKTEMECOJ DE RICEV-ANTENOJ.

R. L. Smith-Rose, Ph.D., M.Sc., kaj
R. H. Barfield, M.Sc. [R115

Priskribas kelkajn eksperimentojn, per kiuj oni havigis difinitajn ekvaciojn por determini la rilatojn inter la orientado de la ricevanteno kaj la rezultanta signalforteco.

Marconi kaj aliaj eltrovis, ke la plej simpla speco de direktita anteno, nome, la inversita "L" anteno, estas plej efika, kiam ĝia horizontala longo kuŝas sur linio kunliganta sendilon kaj ricevilon, kun sia libera finaĵo montranta *for de* la sendilo; dum ĝi estas malplej efika, kiam ĝia libera finaĵo montras *al* la sendilo.

La aŭtoroj prenis sur sin la taskon esplori, kaj teorie kaj eksperimente, ĝis kiom la direkta efekto estas grava ĉe la ordinaraj specoj de anteno nuntempe uzataj, ekzemple, kiel la simpla brodkasta anteno, sub statoj de mezuroj kaj ondlongoj kiel eble plej diversaj.

La direkta efekto de anteno estas difinebla, kiel la diferenco je la antena kurento ricevita per turno de anteno for de ĝia malplej efektiva ĝis ĝia plej efektiva pozicio. Tiun ĉi kvanton oni esprimas per la meza valoro de la du kurentoj.

Post diskutado pri l'afero laŭ simpla teoria vidpunkto, oni alvenis al la konkludo, ke ne estas eble determini la direktecon de anteno per ĉi tiu metodo, escepte se la aŭtoroj estus pretaj enĵeti sin en komplikitan matematikan analizon de antenkurenta distribuo.

Oni tial decidis determini tion eksperimente, per radiogoniometro, tia kia estas uzata ĉe la Bellini-Tosi sistemo de direktotrovado. Oni treege zorge konstruis du antenojn, identajn rilate al siaj elektraj ecoj.

Oni provis nombron da antenoj de diversaj grandecoj, kaj havigis ĉiuokaze la valoron de la direkta efekto, je ondlongoj inter 365 kaj 7000 metroj. Oni pretigis tabelon montrantan la direktemecon de diversaj antenoj. El la kvin ondlongoj, pri kiuj oni faris provojn, tiu de 750 metroj, kun antena longo de 200 futoj kaj alteco de 10 futoj, montris la plej grandan direktan efekton, 0.60; dum je ondlongo 365 metra, kun anteno 80 futojn longa kaj 20 futojn alta, la plej malgranda efekto estis montrita, 0.23. Kvankam la direkta efekto ĉe la plimallonga ondlongo estas malgranda, ĝi estas prikonsiderinda, kiam estas necese atingi la plej bonan rezulton el la anteno por brodkasta ricevado.

La konkludoj ricevitaj estas, ke la inversita "L" anteno havas direktajn karaterizojn, kaj ke la direkta efekto estas pliganda ĉe mallongaj ondoj ol ĉe longaj, kaj ke ĝi pligrandiĝas laŭ la proporcio longeco/alteco de la anteno.

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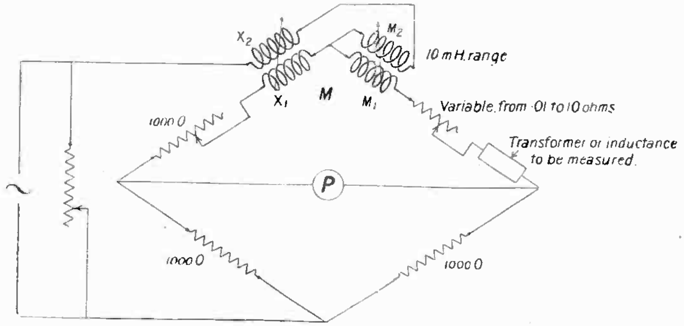
Correspondence

Letters of interest to experimenters are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

Inductance Measurements.

The Editor, E.W. & W.E.

SIR,—On page 694 of your September, 1924, issue, Mr. Dye gives a diagram of connections used in measuring the inductance of a transformer primary. I do not follow the connections of the inductometer "M." Should not the two right-hand coils (M_1 and M_2 in my sketch) be the coils of the inductometer proper? If so, are the two left-hand coils (X_1 and X_2 in my sketch) put there to balance that arm of the bridge? Again, if that is so, are the coils X_1 and X_2 variable with regard to each other; if not, and assuming that they are in fixed relation to each other, what was the value of the mutual inductance of the coils X_1 and X_2 used in the author's experiment?



I trust I am not asking too much, but I follow your articles very closely, and would like to thank you for such a thorough journal as E.W. & W.E.

R. K. LLOYD.

Warwick.

The Editor, E.W. & W.E.

SIR,—The inductometer used in these measurements is of the Campbell type as made by the Cambridge Instrument Co. Full particulars of the principles of this inductometer will be found in their catalogue and also in the article in the *Dictionary of Applied Physics*, Vol. II., on "Inductance and its Measurement." The arrangement of the coils is as follows:—

X_1 and M_1 are two equal secondaries on two bobbins. The coils marked X_2 and M_2 are in reality only one coil and induce approximately equal and opposite voltages into X_1 and M_1 respectively. The arrangement saves the necessity of introducing an inductance coil into the left-hand half of the bridge such as would be necessary to balance the secondary of the mutual inductance if the whole of this were in the right half.

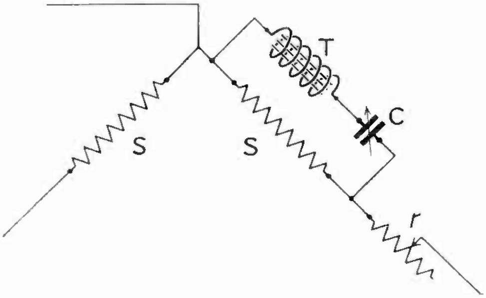
There are thus really two mutuals acting,—$M/2$ on the left-hand half of the bridge and $+M/2$ on the right-hand half.

It is, of course, not necessary to use this type of mutual inductance in the method, which would work just as well if all the mutual were in one half and a balancing coil were used in the other half of the bridge. Again, a variable self-inductance could be used if so desired instead of a mutual inductance. In such a case, however, since we cannot have a negative self-inductance, it would be necessary to transfer the inductance from one arm to the other of the bridge when it was required to make "L" negative.

These measurements of inductance of transformer windings can be made without the aid of any mutual inductance at all by the following modification:—

A variable condenser C is connected in series with the winding T under measurement and the two together are shunted across S. Balance is effected by adjustment of "C" and "r." If R_0 and L_0 are the effective primary inductance of the transformer T as defined in my paper, then

$$R_0 = \frac{S^2}{r} - S, \text{ and } L_0 = \frac{1}{C\omega^2}$$



The drawback to the method is that frequency must be known to first order accuracy in order to measure L_0 and also that for low frequencies C becomes rather large.

N.P.L., Teddington. D. DYE.

An Unusual Offence.

The Editor, E.W. & W.E.

SIR,—On several occasions during the last few months we have had fixed condensers returned to us for inspection, which have obviously been tampered with, in that the capacity markings have been altered from the original as issued from our factory.

We have been endeavouring to trace the exact sources of supply of these condensers with a view to taking legal action against the firm or firms responsible for tampering with our products, but so far we have been unsuccessful.

The last occasion on which we had a condenser of this nature brought to our notice was in the month of May, this year, when we received one for test which was stamped 0.000 3μF but was obviously not of our marking. On test, this condenser proved to have a capacity of 0.005μF. We therefore wrote to the gentleman who returned the condenser stating the exact circumstances, and sending him a replacement. We asked him if he would kindly give us the name of the firm from whom he purchased the condenser, and we received a reply from him on the 21st May, copy of which we enclose.

We feel that full publicity should be given to all cases of this nature, as it is in the interests of both the radio industry and the buying public to emphasise the necessity for dealing only with firms of repute, and we are sure that you will give us your editorial support in this matter, as this will considerably enhance the value of our "warning" advertisement, which is appearing in your journal.

For and on behalf of
The Dubilier Condenser Co., Ltd.
E. F. BATES.

Victoria Road,
North Acton.

[*Copy.*]

123, Tennyson Road,
Luton.
May 21st, 1925.

DEAR SIRS,—I have yours of the 18th inst., and having enjoyed your courtesy in the receipt of a new 0.000 3mF condenser, am very reluctant to refuse your request that I should furnish you with the name of the dealer who supplied the condenser returned to you for examination.

The man in question is well-known to me and is struggling to make a living in the face of serious ill-health, a circumstance which in any case would make one hesitate to take a step which might result in some injury to him. I have, however, had a talk with the man about the matter and can assure you that any tampering which the condenser in question may have been subjected to was not done by the person of whom I bought it. He was most certainly not the culprit, but rather the victim. Having satisfied myself on this point, will you forgive me for withholding information which would not help you much in reaching the person against whom both you and I have a grievance. I appreciate the seriousness of the offence against you and your products, but any information I could offer in this case would supply no remedy, but might injure an innocent man.

Again thanking you for your goodness and trusting to be excused by you, I beg to remain,

Yours faithfully,
(Sgd.) JOHN BURGOYNE.

The Australian DX Record.

The Editor, E.W. & W.E.

SIR,—With reference to the recent short wave transmissions to Australia, I have just received confirmation by the first mail of the reception of my signals on 18 metres at 4.45 p.m. Melbourne time on the 26th April, strength 6. This you will note precedes by one day Mr. Simmonds' transmission, which was taken as being the first to Australia in daylight, and also it was on a much shorter wave-length, as you will observe. The reception was carried out by the senior engineer on the staff of Amalgamated Wireless, whose name, by the way, is B. Pringle.

In view of the importance of this achievement I am looking to you to give the fullest publicity that you can possibly manage to this announcement, as you will be aware that it was absolutely impossible for me to know before this, as unfortunately Mr. Pringle did not cable me, but simply wrote by the first mail. The time checks exactly with my log and both the letter and my log are open for examination at any time should they be required, in view of the circumstances.

The equipment in use at 5NN was a somewhat unusual circuit, which I shall be pleased to describe should you require any further details at a later date. The valve in use was a Mullard 0.250C, with 200 watts of rectified and smoothed A.C. on the plate; aerial is 37 ft. long, 30 ft. high, counterpoise 40 ft. long, 10 ft. above ground. The aerial, as a matter of fact, is the lead-in of my old 90-metre aerial and is worked on the second harmonic; it lies right in between two houses, and is totally shielded except in one position; the top of the aerial does not come to the top of the house, but about 3 ft. or 4 ft. below. The receiver in use when the signals were picked up in Melbourne was, according to the information received, a low loss two valve tuner, with detector, and one stage of L.F. amplification.

I trust you will give the fullest notice possible to this achievement, since, instead of making me second across it gives me the privilege of being first across on ultra short waves in daylight, and also with the shortest wave-length that has ever been used for long distance transmission in any part of the world.

J. H. D. RIDLEY (5NN).

S. Norwood, S.E.25.

Noises from Electric Light Wires.

The Editor, E.W. & W.E.

SIR,—In houses wired for electric light and heating it is quite possible for the broadcast reception to be marred by a humming noise in the headphones due to induction on the wiring. With crystal sets and a 50-cycle supply this may be so loud in comparison with the broadcast signals as to be irritating to the listener, while on a 100-cycle supply, such as exists in certain towns, it becomes a recognised nuisance.

There are various systems of wiring houses for electric light, in some of which the insulated conductors are covered with a metal sheath, while in others there is no such metal coating. As this metal sheathing is connected to earth one would expect houses wired with the metal sheathed wiring systems to be less subject to this interference with wireless signals than those where the wires are not so protected, but to obtain definite data on the point, a simple experiment has been carried out in these laboratories, the results of which may interest your readers.

About 50 yards each of Henley Wiring System twin cable and a similar length of twin insulated cable not metal sheathed were disposed about the laboratory and connected to the two sides of a 2-way switch which enabled one or the other to be connected to a 250 volt 50 cycle supply. The headphones of a crystal set placed within a few feet of the cables gave perfect silence with the Henley cable connected, but a perceptible hum with the unprotected rubber. On connecting a 3-valve amplifier and loud-speaker to the output of the crystal set, the induction from the rubber-covered cable developed into a loud note which would spoil any broadcast programme, while when we switched over to the Henley wiring only the faintest note could be detected, and this was evidently due to other wiring about the laboratory, probably lamp flexibles, as it was present whether the switch was open or closed.

It is evident then that in order to avoid interference with wireless receiving sets a metal-covered house wiring system has considerable advantages over the unprotected rubber-covered wire.

P. Dunsheath.

Research Laboratories,
W. T. Henley's Telegraph Works Coy, Ltd.
Gravesend, Kent.

Are Aerials Directional?

The Editor, E.W. & W.E.

Sir,—The conclusions arrived at by R. L. Smith-Rose and R. H. Barfield in their article on "Directional Properties of Receiving Aerials" in your June number is not borne out in practice; and in wireless, theory is sometimes misleading.

The following experiment, carried out in the cold weather by the writer in India, proves that L aerials, consisting of a single horizontal wire, 70 feet in length, with a down lead of 30 feet (total length of aerial 100 feet) are directional.

The receiving station was erected on a lawn in the centre of India, for the purpose of hearing Calcutta broadcasting on 425 metres, at a distance of 650 miles, a 3-valve reflex circuit being used.

Great care was exercised in making a good "earth" at either end of the aerial, the earthing systems being identical. The earth lead was only two feet in length from the set to the surface of the earth, but the earth plate was carried down four feet, and the surrounding ground saturated with water. The earth resistance was approximately 45 ohms, whereas it is believed that it is only 25 ohms in England.

It was found that with the aerial directed with its free end towards Calcutta, the reaction coil had to be placed 50 per cent. closer to the aerial coil than was necessary with the free end of the aerial pointing away from Calcutta.

Similar experiments have been carried out in England by another experimenter, the results proving that aerials are directional.

Norman P. Roe.

Hayes,
Middlesex.

The Editor, E.W. & W.E.

Sir,—In reply to Mr. Roe's letter, we have to state that the conclusions reached in our article were obtained from experimental results, and it is therefore not clear to us in what way our conclusions are "not borne out in practice." Mr. Roe has evidently not appreciated that it was shown in our article that the directional properties of a receiving aerial depend upon the specific resistance of the earth at wireless frequencies and not upon the actual resistance of the aerial circuit, which may have any value between wide limits, say, from 0.1 to 100 ohms. It was clearly stated that our results were established for working in this country, where the specific resistance of the earth is known from our own measurements at several places in England. In the absence of any knowledge of the corresponding values for India it is difficult to state exactly what results would be obtained, but there is reason to believe that the results would not differ very markedly in a place where it is possible for vegetation to grow.

We trust that Mr. Roe will not think us disrespectful in saying that before we form definite ideas on the subject we should like to have some more scientific results than those obtainable on a 3-valve reflex receiver, in terms of the closeness of the reaction-coupling.

R. L. Smith-Rose.
R. H. Barfield.

Directional Wireless Receiving Station,
Langley, Bucks.

Station News.

The Editor, E.W. & W.E.

Sir,—The following are the times of tests I am desirous of making with amateurs of Great Britain:—

Calling: CQ, GO, A4L, Oxenham, Chemist, Capetown, K., and a code for verification. Times: nightly from 20th June until 10th July, 9 p.m. G.M.T., and at 11 p.m. G.M.T. Sundays, 21st and 28th June, and 5th July. Wave-length 85-90 metres.

All reports will be much appreciated and will be QSL'd. I will listen for replies as soon as I have finished transmitting. Power 50 watts, output .9 to 1 amp, Meissner circuit, 4-wire aerial 36 ft. high, 4-wire fan counterpoise.

Robert Oxenham.

136, Long Street,
Capetown, South Africa.

The Editor, E.W. & W.E.

Sir,—Would you kindly insert a brief note to say that the call sign, G5AX has been allocated to me at the address given below. All QSL cards are answered, and are very welcome.

With every good wish for your excellent paper.

F. Walker.

Crowmarsh,
Wallingford,

The Editor, E.W. & W.E.

Sir,—This station is now active on 175-185 metres, C.W.; input usually 5 watts. I shall be glad of reports, all of which will be promptly answered. I am anxious to get in touch with someone within a hundred miles who can work me on low power in the afternoon between 1 p.m. and 3 p.m. one or two days a week and shall be glad to hear from any of your readers who can help.

Ernest H. Robinson
(5YM).

Langmead,
Pirbright, Surrey.

The Editor, E.W. & W.E.

Sir,—The P.M.G. has authorised me to use, in addition to the 150-200 and 440 wave-bands, the following wave-lengths :—

3.7 to 5 metres and 23 and 45 (both fixed).

I shall be on the air shortly on the 3.7 to 5 metres band and should welcome reports.

Robert R. Pecorini.

Fern Villa,
Mortlake, London, S.W.14.

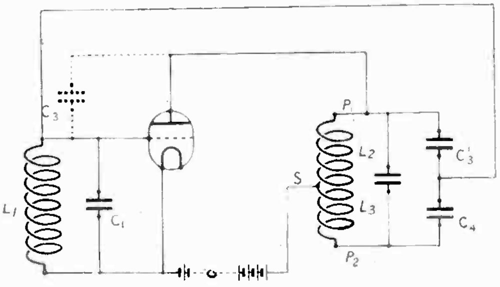


Fig. 1.

The Editor, E.W. & W.E.

Sir,—Please note that the call-sign 2QJ has now been allotted to me.

John F. Warren.

Pollards,
Gerrards Cross, Bucks.

The Stabilisation of H.F. Amplifiers.

The Editor, E.W. & W.E.

Sir,—A very interesting article in your April issue by O. F. Brown deals with the neutrodyne and bridge methods of stabilising H.F. amplifiers. It appears, however, to have escaped notice that the neutrodyne method itself is a Wheatstone Bridge arrangement.

Fig. 1 below reproduces a neutrodyne circuit such as that shown in Fig. 13*, page 439, of your April issue and Fig. 2 below shows the same circuit redrawn in Wheatstone Bridge form. It is thus seen that the neutrodyne is as much a bridge method as the other "bridge" methods. The only difference is that in the neutrodyne the filament-grid path is a diagonal of the bridge, whereas in the "bridge" method the filament-anode path is a diagonal.

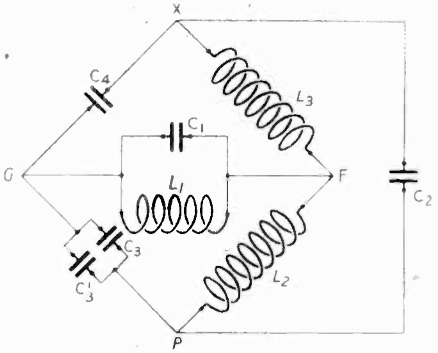


Fig. 2.

* There appears to be an error in Fig. 13, p. 439, April, as there is no stabilising connection to grid.

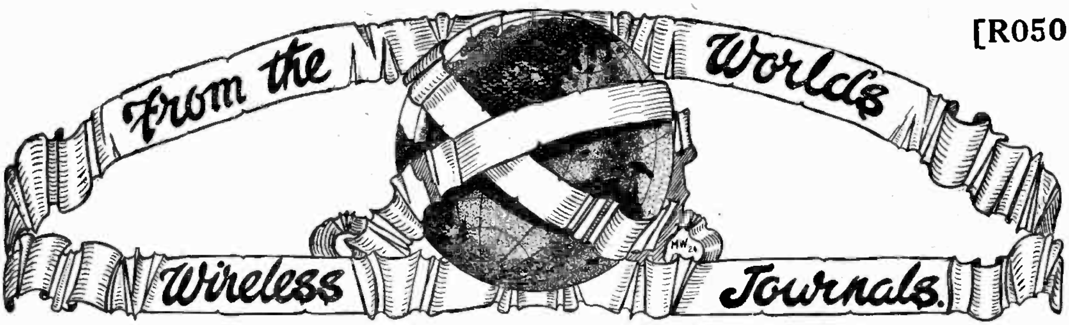
The Editor, E.W. & W.E.

Sir,—I agree that the variation of the neutrodyne circuit referred to by your correspondent can be equally well classed as a "bridge" arrangement. I regret the error in Fig. 13 he points out. The connection between the condensers C'_3 and C_4 should be taken to the grid of the valve as shown in the redrawn diagram herewith.

O. F. Brown.

Wendover,
13, Hampstead Way, N.W.11.

[R050



R100.—GENERAL PRINCIPLES AND THEORY.

R115.—DIRECTIONAL PROPERTIES OF RECEIVING AERIALS.—R. L. Smith-Rose, M.Sc., Ph.D., and R. H. Barfield, M.Sc., A.C.G.I. (*Exp. W.*, June, 1925).

An account of an investigation made to ascertain the extent to which an ordinary inverted L aerial is directional. Early investigators found that the best results were obtained when the horizontal top of the receiving aerial pointed away from the transmitting station. The effect is particularly pronounced when the length of the aerial is more than ten times its height, and the effect is also more pronounced on short wave-lengths than on long ones. For the average broadcast receiving aerial on 365 metres this directional effect is small; it may be just worth taking into consideration when the very most is to be made of the receiver, but in most cases it is probably outweighed by other considerations.

R141.—AERIAL TUNER DESIGN. Part I.—W. B. Medlam, B.Sc., and U. A. Oschwald, B.A. (*Exp. W.*, June, 1925).

The authors analyse mathematically the relation of optimum aerial tuner inductance to the constants of the aerial and the input impedance of the receiver connected to it. They follow up their analysis with some practical data, derived principally from observations made on a local broadcasting station.

R143.—THE OPTIMUM DAMPING IN THE AUDITIVE RECEPTION OF WIRELESS TELEGRAPHIC SIGNALS.—L. B. Turner, M.A., and F. P. Best, M.Sc. (*Journ. I.E.E.*, May, 1925).

A paper read before the Wireless Section of the Institution of Electrical Engineers.

R148.—GEOMETRISCHE DARSTELLUNG DER BEGRIFFE MODULATION UND SCHWEBUNG.—Dr. Fritz Fischer (*Telefunken Zeitung*, March, 1925).

An interesting but simple geometrical construction for the waveform of a modulated sine wave is described. As is well known, a pure, simple harmonic motion may be represented by considering a point moving with constant linear velocity round the circumference of a circle whose radius is equal to the maximum amplitude of the oscillation. The radius from the centre of this circle of reference to the point on the circumference has a uniform angular velocity of ω. The projection of this point on any straight line in the plane of the circle executes a simple harmonic motion, which, extended along a linear time axis, gives the familiar sine-wave form. Now suppose the original oscillation has its amplitude modulated in accordance with another harmonic variation of different frequency, the original circle of reference is modified as follows: Make the moving point on the circumference of the original circle the centre of another circle having a radius equal to the modulating amplitude and round which a point is travelling with an angular velocity corresponding to the frequency of modulation. This second point, then, is moving round a circle whose centre is itself moving round a circle, and the projection of this point on a straight line gives the modulated harmonic motion. The latter, when extended along a linear time-axis, shows the modulated wave-form. By means of this construction various interesting cases of modulation (such as over-modulation) may readily be analysed graphically.

R200.—MEASUREMENTS AND STANDARDS.

R251-2.—ETALONNAGE D'UN SYSTÈME THERMO-ELÉMENT-GALVANOMETRE.—M. Abadie (*Onde Elec.*, April, 1925).

Methods of calibrating thermoammeters are described in considerable detail. Errors arising from various causes are dealt with.

R270.—SIGNAL STRENGTH MEASUREMENTS.—H. J. Round, T. L. Eckersley, K. Tremellen and F. C. Lunnon (*Electn.*, 8th May, 1925).

A report on some experiments made over great distances during 1922 and 1923 by an expedition sent to Australia.

R270.—EINE ANORDNUNG ZUR MESSUNG DER ABSOLUTEN EMPFANGS-ENERGIE IN DER DRAHTLOSEN TELEGRAPHIE.—Dr. L. Bergmann (*Telefunken Zeitung*, March, 1925).

Description of a Telefunken method of absolute signal-strength measurement.

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R300.—APPARATUS AND EQUIPMENT.

R342.4.—Reflex Circuits.—P. K. Turner (*Exp. W.*, June, 1925).

The fundamental essentials of dual amplification circuits are dealt with. The electrical effects of superimposing H.F. and L.F. signals in the same valves are discussed with regard to the considerations of efficient amplification, freedom from distortion and stability from self-oscillation. The writer regards dual-amplification as a logical economy and not as a "freak."

R343.—Nouveau Dispositif de Réglage de la Réaction.—E. Fromy (*Onde Elec.*, April, 1925).

An ingenious method is described of controlling reaction in a regenerative valve receiver. The oscillating circuit has fixed magnetic reaction-coupling, such as the Hartley circuit, and the tendency to oscillate is controlled by varying the effective resistance of the circuit. This is effected by connecting a special condenser across the tuned circuit. It is a double condenser controlled by one knob and so arranged that as the capacity of one half is increased that of the other half is decreased by the same amount. One half is connected straight across the inductance while the other is connected through a fixed damping resistance. The result is that as the knob is turned the total effective capacity remains constant while the effective resistance is continuously and smoothly varied. This controls the tendency of the set to oscillate. Variation of tuning is accomplished by means of a separate, ordinary condenser across the inductance also. A diagram is given showing how the principle may be embodied in a two-valve tuned-anode receiver.

R357.—A New Method of Generating High Frequency Currents.—Prof. G. W. O. Howe (*Electn.*, 8th May, 1925).

An account of some of the recent work carried out in Germany on iron-core frequency raisers. Their action depends essentially upon the distortion of the wave-form of comparatively low-frequency oscillations by the saturation effects in iron-cored coils. This distortion gives rise to harmonics, one of which may be selected and used for radio transmission. Contrary to what would be expected these frequency raisers can be made quite efficient. A generator producing an A.C. output at, say, 5 000 or 10 000 cycles may be connected to a cascade of these multipliers to provide power on a wave-length as low as 600 metres. In view of recent developments the writer considers that the H.F. alternator will still compete with the thermionic valve.

R376.—Some Acoustic Experiments with Telephone Receivers.—Prof. E. Mallet, M.Sc. and G. F. Dutton, Ph.D. (*Journ. I.E.E.*, May, 1925).

A Rayleigh disc was used to find the resonant frequency and decay factor of a telephone receiver under different circumstances as regards diaphragm clamping and air cavity behind the diaphragm. The field of sound in front of a resonator tube and a telephone receiver is investigated by the Rayleigh disc and by a device for measuring sound pressures, and direct measurements are made of the over all acoustical-electrical efficiency of a telephone receiver. It is illuminating to find that this efficiency is of the order of only 0.7 per cent.

R382.1.—A Further Note on Parasitic Losses in Inductance Coils.—Raymond M. Wilmotte, B.A. (*Exp. W.*, June, 1925).

A discussion of the effect of dielectrics in the form of insulation and formers in radio-frequency tuning coils. The general conclusion reached is that the effects of dielectric loss are not very serious as long as reasonably good materials are used.

R400.—SYSTEMS OF WORKING.

470.—Die Entwicklung der Hochfrequenztelephonie über Hochspannungsleitungen durch Telefunken.—Dr. W. Moser (*Telefunken Zeitung*, March, 1925).

A short account of the work of the Telefunken Co., of Germany, on the transmission of high-frequency carrier-current telephony along high-tension power lines. It has been found possible to transmit modulated high-frequency currents for a number of miles along such conductors without interfering with their normal functions. The attenuation of signals transmitted in this manner is comparatively small; a case is cited where good communication was effected with a power of only 5 watts over a 100 000-volt line 140 kilometres long. Received currents were found to be a maximum when the wave-length used was some odd fraction ($\frac{1}{3}$, $\frac{1}{5}$, etc.) of the length of the line, *i.e.*, when the line was worked on a harmonic of its own fundamental wave-length. A curve is given which shows how the received current varies with wave-length; the best values for the particular case illustrated appear to lie between 4 and 10 km. Various forms of inductive and capacitative coupling between the signalling apparatus and the power line are indicated, any form of direct conductive connection to the power line being, of course, out of the question. One of the troubles encountered in the use of such lines is the interference from power-leaks at faulty insulators which take the form of aperiodic spark discharges and shock excite the system over the whole radio-frequency spectrum.

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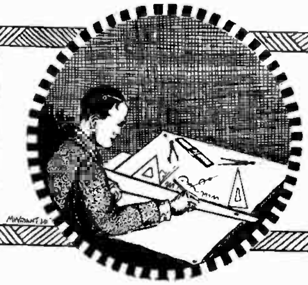


Some Recent Patents

(The following notes are based on information supplied by Mr. Eric Potter, Patent Agent, Lonsdale Chambers, 27, Chancery Lane, W.C.2.)

R008

CONDENSER DIELECTRIC.

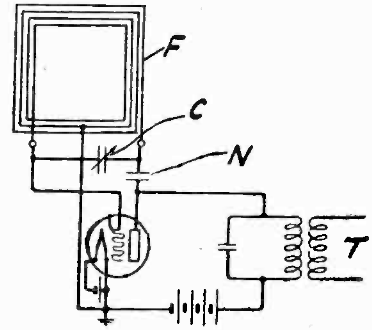
Application date, 28*th February*, 1924. *No.* 230,978.)

The Telegraph Condenser Company, Limited, S. G. Brown and W. J. Cole describe in the above British Patent a rather interesting condenser dielectric. Paraffin wax is largely employed as a dielectric in the "paper type" of fixed condenser. There is one disadvantage, namely, that the wax has a negative temperature coefficient in relation to the S.I.C. In other words, as the temperature rises the S.I.C. of the wax falls. This difficulty is overcome by the use of a substance which has a positive temperature co-efficient, and it has been found that the condition of 3 to 5 per cent. of gum dammar to the paraffin wax produces a dielectric which has a substantially constant S.I.C. at all temperatures.

AN INTERESTING FRAME AERIAL CIRCUIT.

(*Application date*, 29*th November*, 1923. *No.* 230,150.)

Those who have experimented with frame aerials will probably have experienced considerable difficulty in preventing self-oscillation owing to the low damping which exists in the grid circuit of the first valve. A rather interesting scheme is described in British Patent No. 230,150 by the Western Electric Company, Limited, and is illustrated by the accompanying diagram. Essentially the invention consists in providing a balancing capacity which tends to neutralise any reaction effects.

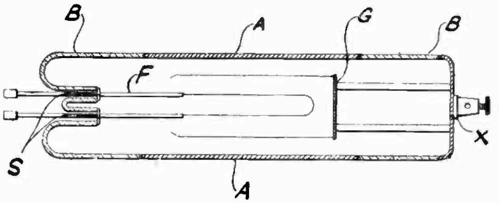


Thus in the accompanying illustration a frame *F* is tuned by a condenser *C*, the grid circuit of the valve being connected between one end of the frame and its mid-point. The other end of the frame is connected to the anode of the valve through a small condenser *N*, which has substantially the same capacity as that which exists between the anode and grid of the valve. The aerial circuit of the valve in this case contains a transformer *T*, but, of course, any other device may be included, or the valve may be caused to function as a rectifier. In practice we find that the scheme works exceedingly well, and should prove of considerable value to experimenters.

A SHORT WAVE POWER VALVE.

(*Application date*, 20*th June*, 1923. *No.* 223,276.)

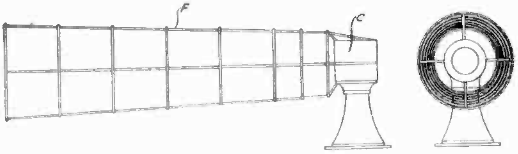
The construction of a high power valve suitable for operating at exceedingly high frequencies is described by C. S. Franklin in British Patent No. 223,276. In a valve of the usual construction the grid and filament connections are brought out at the same end, and signals at very high frequencies escape through the exceedingly concentrated high tension field acting on the glass around the grid and filament. As a result of this the voltage has to be reduced, and therefore the valve cannot be worked on full power. This difficulty can be overcome by the following method of construction, illustrated by the accompanying diagram. Essentially the invention consists in sealing the filament in at one end of the valve, and the grid at the other end of the valve. This construction is simplified in the case of an "all metal" type of valve. Thus in the illustration a tubular anode *A* has sealed to it at each end a glass bulb *B*. One of these bulbs carries the filament *F*, which is sealed in at *S*, while the other end carries the grid *G*, sealed in at *X*. Hence it will be seen that the path between the grid and filament seal is exceedingly long, and no intense field can exist between the two.



DIRECTIONAL CONTROL.

(*Application date*, 12*th January*, 1924. *No.* 229,820.)

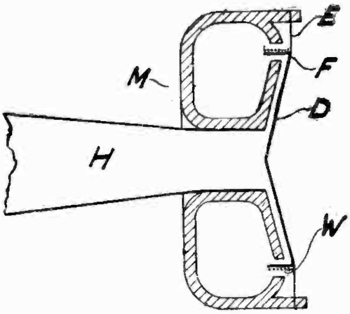
A method of directing a ship or other moving body in a fog is described in British Patent No. 229,820 by J. D. Roots. The essence of the invention lies in providing an ultra short wave transmitter situated at a fixed point and so arranged that it will project a beam along a path which may vary in altitude and azimuth as desired. The vessel is provided with a receiver which is located in a metal compartment C in a conical metal framework F of the shape shown in the accompanying illustration. The metal compartment and the conical framework F act as a screening device to the beam, unless its axis is coincident with that of the beam. In this case the receiver will be affected, and accordingly the vessel can be steered to the fixed point simply by keeping the axis of the receiving framework and the beam coincident.



A "ROUND" LOUD-SPEAKER.

(*Application date, 29th November*, 1923. *No.* 229,759.)

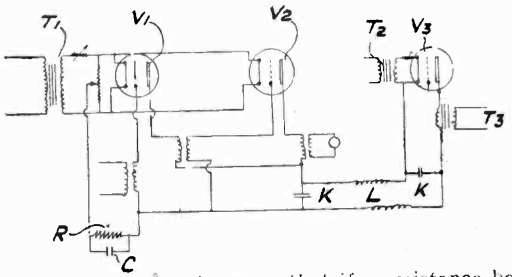
H. J. Round describes in the above British Patent the construction of a loud-speaker which is illustrated in the accompanying diagram. The diaphragm D, which may be of conical shape, is supported by a ring of elastic material E, which, it is stated, is preferably impervious to air. The diaphragm supports a flange F, round which is wound a coil W. This flange is arranged so that it lies between the poles of a large magnet M, which is intended to be energised by a winding not shown. The magnet in one modification takes the form indicated, and the centre of the diaphragm is here shown in front of the end of a horn H, which is attached to the magnet M. Thus it will be seen that on applying speech currents to the windings W the magnetic field between the magnet and the diaphragm coil will cause the diaphragm to move, and thus produce sound through the horn.



AN A.C. AMPLIFIER.

(*Convention date, France, 10th February*, 1923. *No.* 211,160.)

Another alternating current amplifier scheme is described in the above British Patent by R. Depriester. The chief sources of trouble which arise when alternating current is used for filament heating are occasioned by the variation of the mean potential of the grid with respect to that of the filament owing to the voltage drop along it, and the variation of the temperature of the filament. The inventor states that trouble is also produced by the influence of the external impedance of the grid and filament circuit in relation to the curve of the grid characteristic. An amplification scheme is illustrated in the accompanying diagram which, it is stated, overcomes these difficulties. $V1$ and $V2$ are two amplifying valves, the filaments of which are fed by a transformer $T1$. $V3$ is a rectifier valve, of which the filament is fed by a transformer $T2$, while the transformer $T3$ supplies the anode voltage. The valve $V3$ functions as an ordinary two-electrode rectifier, and the output passes through the filter circuit KLK. The novelty of the invention lies in the method of polarising the grids and also the input transformers.

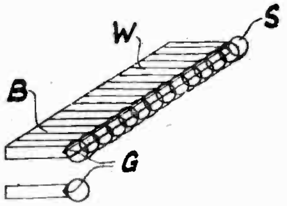


It is well known, of course, that if a resistance be included in the anode circuit the steady anode current flowing through it will cause a potential drop across the ends. This method is employed, and accordingly a resistance R is included in the negative lead of the high tension supply. In order to prevent oscillations occurring, the resistance, of course, is shunted with the condenser C. The input transformers, it is stated, are wound with very thick wire and have an exceedingly small magnetic leakage. As we have not experimented with the system we cannot say to what degree it is successful, but our own opinion is that for successful A.C. work an equi-potential cathode valve is a simple solution of the problem.

THE GRID OF THE "SHORT PATH" VALVE.

(*Application date, 18th December*, 1923. *No.* 231,225.)

A rather interesting system of grid construction is described in British Patent No. 231,225 by E. Y. Robinson. When it is desired to produce a valve in which the grid is comparatively near to the other electrodes difficulty has previously been experienced owing to the lack of rigidity. Accordingly the distance between the filament and the anode, for example, is necessarily increased in order to ensure that the grid does not come into contact with either. The object of the invention is to produce a grid which is substantially rigid, and one therefore which can be fitted into a small space without



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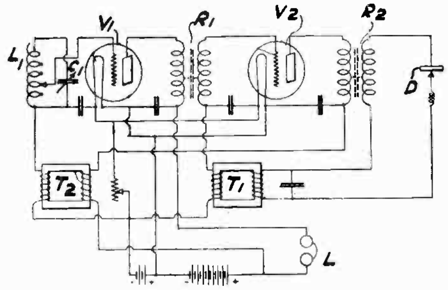
fear of touching the other electrodes. An ordinary spiral grid is employed, but this is attached to a rigid support in the following manner. Referring to the accompanying illustration it will be seen that a spiral grid S is made from tungsten or molybdenum wire, and this is fixed to a supporting block B. This may be of similar material, and is made rectangular in shape and provided with a groove G, in which the grid rests. Each turn of the helix is lashed to the support by means of wire W. The grid is almost as rigid as the solid block of metal and accordingly the supporting block B can be assembled with the rest of the valve with almost engineering precision. The patent provided for several other modifications and alternative methods of construction of the grid.

THE GRIMES INVERSE REFLEX CIRCUIT.

(*Convention date, U.S.A., 1st December, 1923. No. 225,579.*)

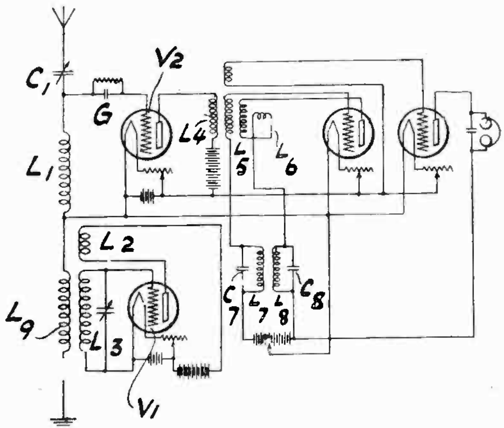
Details of the Grimes inverse reflex circuit are described in British Patent No. 225,579 by the Grimes Radio Engineering Company Incorporated and D. Grimes. In the usual form of reflex circuit a series of valves connected in cascade amplifies signals at radio frequency, after which the radio frequency energy is rectified and the low frequency currents are subsequently amplified by the valves in the same order. According to this invention, after the signals are detected the low frequency currents are amplified by the series of valves in inverse order. It is stated that this method tends to reduce the amount of oscillation and to equalise the load on the valves. Thus in the accompanying diagram high frequency energy is applied to the valve $V1$ by means of the circuit $L1$ $C1$. The anode circuit of this valve contains a transformer $R1$, the secondary of which is connected to the input of the valve $V2$. The amplified energy is passed on through the valve $V2$ by means of a transformer $R2$, across the secondary of which is a crystal detector D. The detector D is also in series with the primary of an iron core transformer $T1$, the secondary of which is also included in the grid circuit of the valve $V2$. The valve $V2$ therefore acts as the first stage low frequency amplifier. The output circuit of the valve $V2$ also contains the primary winding of the transformer $T2$. The secondary of the transformer $T2$ is also included in the input circuit of the valve $V1$, which therefore acts as a second stage low frequency amplifier. The anode circuit of the valve $V1$, of course, includes the telephones or loud-speaker L.



A SUPERSONIC SUPER-REGENERATIVE RECEIVER.

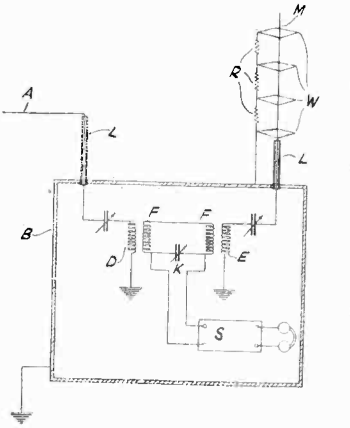
(*Application date, 9th August, 1924. No. 229,938.*)

A very ingenious system of reception is described by the Westinghouse Electric and Manufacturing Company in the above British Patent. There are two rather serious drawbacks to the use of super-regenerative receivers. In the first place there is liable to be considerable radiation from the aerial system, which will give rise to interference to neighbouring receivers, and secondly they do not operate efficiently with damped waves. Both these defects are obviated by the following method: The received signals are first combined with a local source of oscillation, and the resulting beat frequency of 2 000 or 3 000 metres is rectified in the normal way, as in the usual supersonic receiver. The output of this valve rectifier is then applied to the super-regenerative amplifier. This output is comparable with a modulated continuous wave, and accordingly operates the super-regenerative part of the receiver with the usual efficiency. Thus referring to the accompanying illustration it will be seen that the aerial circuit is tuned by a condenser $C1$ and inductance $L1$ to the incoming spark frequency. A valve $V1$ produces oscillation by virtue of a coupling between the two coils $L2$ $L3$, and these oscillations are transferred to the aerial circuit by means of a coupling circuit $L9$, which also forms part of the aerial circuit. The valve $V2$ rectifies these beats by means of a grid condenser and leak G. The anode circuit of the valve contains an inductance $L4$ which applies the beats to the super-regenerative system. This consists of the usual two valve arrangement. The ordinary regenerative coils are shown at $L5$ and $L6$ respectively, while the quenching frequency oscillator consists of the tuned circuits $L7$ $C7$, $L8$ $C8$, the usual batteries, telephones, etc. being shown in the usual way. We should imagine that this arrangement would be highly efficient, and should prove of great value to experimenters who are troubled with the radiation problem. The possibility of radiation from the local oscillator, however, must not be overlooked, but in any case this is not likely to be nearly so strong as that obtained from the normal super-regenerative amplifier.



AN ATMOSPHERIC ELIMINATOR.

(*Convention date, U.S.A. 17th August,* 1923. *No.* 220,660.)

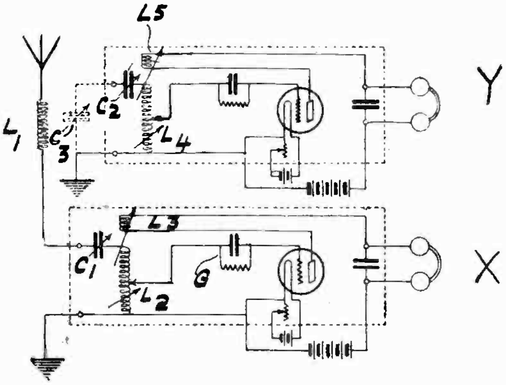


A rather interesting system of interference elimination is described in British Patent No. 220,660 by Marconi's Wireless Telegraph Company, Limited, and J. Weinberger. The system employs two aerials. It is known that a low horizontal aerial, with its vertical down-lead shielded, will respond only to electric fields, while the ordinary type of vertical aerial responds both to magnetic and electric fields. In an ordinary received wave the magnetic and electric fields are equal in magnitude, but in the case of a stray the electric field changes very rapidly, and the magnitude is dependent upon the rate of change, hence the magnetic field may be regarded as being exactly 90 degrees out of phase with the electric field producing it. In other words, the fields of a stray are those of a local stationary field while the fields due to a signal are those of a travelling wave. In this case two currents are introduced in the same circuit by action of the electric and magnetic fields of a stray respectively and neutralise each other, thereby eliminating the stray, while the electric field of the signal is detected. Thus, in the accompanying illustration, the aerial *A* has its down-lead shielded by a lead-in conduit *L*. The second aerial *M* is for the purpose of collecting magnetic fields, and consists of a vertical aerial surrounded by a Faraday cage. This consists of squares of wire *W*, arranged at intervals of a foot along the aerial, and connected together periodically by resistances *R* to earth. This prevents electric fields reaching the aerial, but magnetic fields pass through it readily. The entire receiver is contained within a shielded building *B* which is earthed. The receiver functions in the following manner: In the aerial *A* the electric fields of both signals and strays cause currents to flow through the coil *D*. The magnetic field in the coil due to the signal is 90 degrees out of phase with the electric field, while the magnetic field in the coil *D* is 90 degrees out of phase with the electric field of the stray. In the aerial *M* the magnetic fields of the signal and stray also cause currents to flow through the coil *E*. The magnetic field of the coil *E* due to the signal magnetic field is 180 degrees out of phase with the latter, and therefore 90 degrees out of phase with the magnetic field simultaneously produced in the coil *D*. The current in the coil *E* due to the magnetic fields of strays is similarly 180 degrees out of phase with the latter, but in phase with the magnetic field simultaneously produced in the coil *D*. Thus the stray fields balance out in the circuit *FKF*, leaving only signal currents which are passed on to the receiver *S*. Other methods of bringing about the same result can, of course, be employed.

SELECTIVE RECEPTION.

(*Convention date, U.S.A., 24th July,* 1923. *No.* 219,660.)

A rather peculiar method of selective reception is described in the above British Patent by Marconi's Wireless Telegraph Company, Limited, and E. E. Bucher. Briefly the invention consists in providing two regenerative receivers both coupled to the same aerial, the effect of one regenerative receiver being to reduce the resistance of the aerial circuit to such an extent that by coupling the other receiver quite loosely exceptionally loud signals and excellent selectivity are obtained. One method of carrying the invention into effect is shown in the accompanying illustration, in which there are two receivers *X* and *Y*. There is a common aerial circuit *L*1 *C*1 *L*2. The input circuit of the receiver *X* is taken across part of the inductance *L*2, and a regenerative coil *L*3 and grid condenser and leak *G* are provided. A similar receiver is shown at *Y*. The input circuit consists of an inductance *L*4, a capacity *C*2 and another capacity *C*3, the latter being adjusted to be substantially equal to that of the aerial circuit. In operation the receiver *X* is tuned to the desired signal, and the reaction coil is brought nearly to the point of oscillation. A coupling coil *L*1 is shown in the aerial circuit for the purpose of energising the receiver *Y*, but it is stated that it is frequently only necessary to place the receiver *Y* in the vicinity of the aerial lead. The receiver *Y* is now tuned and the required amount of regeneration is introduced by means of the inductance *L*5. According to the specification the operation of the system is due to the lowering of the aerial resistance by virtue of the regenerative action of the first receiver, but it is not quite clear to us why the first receiver *X* need be used. If the action is merely due to the lowering of the aerial resistance by virtue of the regenerative effect of the first receiver, it would seem obvious that the same effect could be obtained merely by introducing the action into the aerial circuit from a separate regenerative valve, without necessitating the trouble of arranging a separate receiver.



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