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Editorial.

Effect of a Screen on Electromagnetic Waves.

IN the Correspondence columns of this issue we publish a letter received from Mr. D. Burnett, M.A., B.Sc., of Aberdeen University, calling in question some of the statements made in the Editorial in our February issue. He says that "one may be forgiven for criticising such statements as, 'a space may be screened from the electric field, but not from the magnetic field of a wave.'" He then attempts to show that such a thing is contrary to the fundamental electromagnetic laws, and we commend his letter to the careful attention of our readers, not because we think that he is right—we hope to show that he is wrong—but because, by the time that one has found out where and why he is wrong, one will have formed a clear conception of the action of the screen. With regard to Mr. Burnett's statement that he is not acquainted with any experimental work with screens such as are mentioned in the Editorial, we only need draw his attention to the paper by Mr. R. H. Barfield in the *Journal of the Institution of Electrical Engineers*, Vol. 62, p. 249, 1924, describing a large amount of experimental work on the subject, carried out under the auspices of the Radio Research Board. A brief account was also published in *E.W. & W.E.*, Vol. 1, p. 570 of the same year. Mr. Burnett will find in this paper and in the subsequent discussion a wealth of material for thought, and perhaps for criticism, but he will find definite experimental proof that it is possible to construct a wire cage in which the electromotive force induced in a loop is sensibly the same as it would be outside the cage, whilst the electromotive force which would be induced in a vertical wire or open aerial outside the cage is practically non-existent within it. This experimentally demonstrated fact shows that there is something wrong with Mr. Burnett's interpretation of the equations of electromagnetic theory, which leads him to the conclusion that "if the same magnetic field β exists inside the screened space, the electric field associated with it must still be given by the above equation and cannot therefore differ essentially from the electric field of the wave outside."

Let us assume that a hut of insulating material has a metal roof and floor connected by a conducting wire. The roof and floor are shown in Fig. 1, and an electromagnetic wave is sweeping past from left to right. The horizontal magnetic field at the moment shown will be directed away from the reader into the paper, the electric field, apart from any disturbing influences, being vertically downwards. The diagram illustrates the effect of the hut on the electric field, and since the energy of the wave is transmitted at right-angles to the magnetic and electric fields, the small arrows show how the energy tends to avoid the hut and pass above and below it. If Fig. 1 represents the moment when the field strengths at the hut are a maximum, the charges on the roof and floor will have their maximum values, there will be no current in the conductor connecting the roof to the floor, and it cannot therefore have any magnetic effect. Where then, is there anything which could possibly modify the magnetic field which is passing through the hut at the moment? This magnetic field will have its maximum value at the moment represented in Fig. 1. If it had not been for the hut the energy per cubic centimetre in the space would have been made up of two equal parts, viz., $B^2/8\pi$ ergs due to the magnetic field, and $\mathcal{E}^2/8\pi$ ergs due to the electric field. As it is, only the former energy exists in the space, and the small arrows in Fig. 1 show how the energy evades the space occupied by the hut. They also show that in the neighbourhood of the hut we are not dealing with a plane electromagnetic wave, and it is here that Mr. Burnett has been misled. One cannot put down the equations connecting B and $\mathcal{E}$ in a plane wave and expect them to hold in cases where the wave is not plane. One may ask, however, what it is that provides the magnetomotive force necessary to drive the magnetic flux through the hut; this question is based on a misconception; the lines of magnetic flux passing horizontally through the hut extend indefinitely in both directions and the mere removal of the magnetomotive force over a few feet would have practically no effect. Maxwell's equation gives the relation between the magnetomotive force and the flux density at any point in a plane wave, but does not imply that the flux density in any space is *due* to the magnetomotive force provided in that space; as a matter of fact, it is due to the resultant action of the whole wave. An analogous case is provided by a solenoid carrying a current. A relation can be worked out between the ampere-turns per cm. of length and the value of H on the axis. If now a small length is left unwound, as shown in Fig. 2, the number of ampere-turns per cm. over this length is zero, but the effect on the magnetic field at the point P is very small. It is also to be observed that the dimensions of the hut are assumed to be very small compared with the wavelength, so that the vertical displacement currents which may be regarded as producing the magnetomotive force are flowing downwards on the right and upwards on the left of Fig. 1, the hut itself being at the moment in the position of zero displacement current. It will be seen therefore that the magnetic field is practically unaffected by the presence of the screen, whereas the electric field is reduced to something very small compared with what it would be if the screen were not there. One may regard the electric field as the resultant of the original field of the wave and that due to the induced charges on the roof and floor as shown in Fig. 3. Just how small the resultant will be and the extent of the very small electric field depends on the efficiency of the screening.

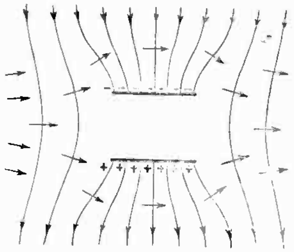


Fig. 1.

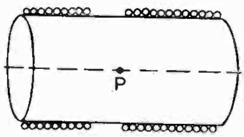


Fig. 2.

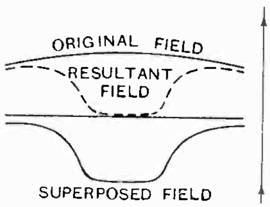


Fig. 3.

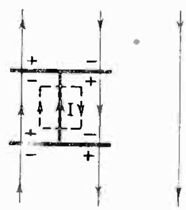


Fig. 4.

A quarter of a cycle later the fields at the hut will pass through zero; what little electric field there is will be somewhat as shown in Fig. 4. In this diagram we have shown the conductor connecting the roof and floor because at this moment the current in it will be at its maximum value in the direction shown. Its approximate value could be calculated from the strength of the field and the size of the screen. Fig. 5 shows qualitatively the nature of the original electric field and that of the field due to the small charges on the screen. The latter is still in the direction tending to neutralise the electric field of the wave within the screened space. A little consideration will show that any magnetic effect due to the current in the connecting conductor will be small except in its immediate neighbourhood and the direction of this field within the screened space will depend on the position of the conductor. In the central position shown in Fig. 4, its magnetic effect is obviously to strengthen the magnetic field of the wave within the screen.

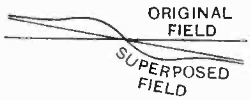
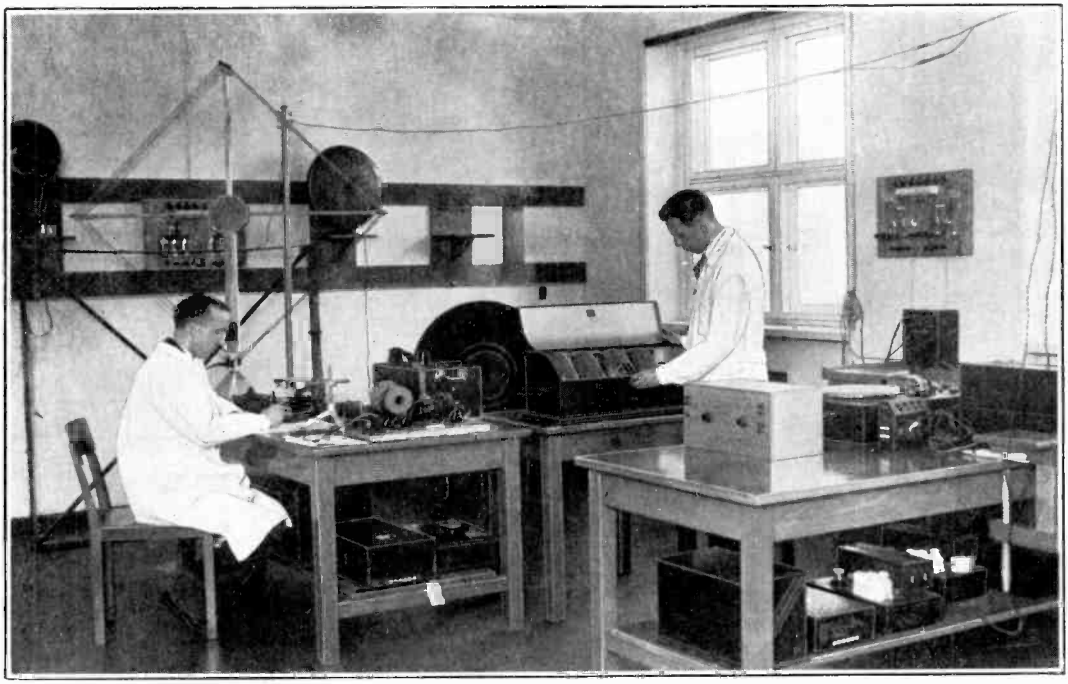


Fig. 5.

We have indicated by dotted lines a square frame coil inside the hut, placed broadside-on to the alternating magnetic flux. At the moment shown in Fig. 4 the flux is zero, but a moment before it was away from the reader and the electromotive force induced in the coil is now a maximum in the direction shown. Whether the coil is there or not, the alternating magnetic field sets up electric forces in the screened space and the electric field will pass as shown in the figure, just as if the screen were not there. We think, however, that one is justified in saying that the electric field inside the screen is produced by the magnetic flux passing through the screen. There are, of course, all the intermediate stages between Figs. 1 and 4. It is seen that the screen is without any appreciable effect on the magnetic field, but that it excludes the electric field, except that electric field or curl of electric field which is necessarily associated with the alternating magnetic field. We trust that a consideration of these arguments will enable Mr. Burnett to acquit us of any attempt to "take liberties with the fundamental conceptions of electromagnetic theory."

G. W. O. H.

Heinrich Hertz Institute.



This photograph shows the short-wave reception laboratory of the new institute in Berlin which concentrates on electro-magnetic wave research.

Applications of the Method of Alignment to Reactance Computations and Simple Filter Theory.* Part III.

By W. A. Barclay, M.A.

(*Continued from page 189 of April issue.*)

§21. Combination of Filters.

THE laws of filter combination will now be considered. For any given frequency, let the two filters designated I and II have characteristic frequency functions a, b, c, d and $\alpha, \beta, \gamma, \delta$ respectively. If the filters are placed in series in the manner

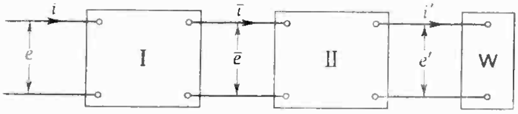


Fig. 17.—*Compound filter of two dissimilar stages, with load W.*

shown in Fig. 17, the input will be placed across I and the output will be taken from II. If, now, $\bar{e}$ and $\bar{\imath}$ be the voltage across and current passing the intermediate terminals, we shall have by definition

$$e = a\bar{e} + b\bar{\imath} \qquad \bar{e} = \alpha e' + \beta i'$$
$$i = c\bar{e} + d\bar{\imath} \qquad \bar{\imath} = \gamma e' + \delta i'$$

In these equations each filter has been treated separately, so that, e.g., the load current of filter I is $\bar{\imath}$ and that of filter II is i'. On eliminating $\bar{e}$ and $\bar{\imath}$ we obtain expressions for e and i in terms of the output voltage and current of filter II as follows:

$$e = (a\alpha + b\gamma)e' + (a\beta + b\delta)i'$$
$$i = (c\alpha + d\gamma)e' + (c\beta + d\delta)i' \qquad \ldots \quad (19)$$

Hence, if A, B, C, D be the filter characteristic functions of the compound filter considered as a whole, we may compare equations (19) with equations (2) and (6), (*vide* pp. 183-4), and write

$$A = a\alpha + b\gamma$$
$$B = a\beta + b\delta$$
$$C = c\alpha + d\gamma$$
$$D = c\beta + d\delta \qquad \ldots \quad \ldots \quad (20)$$

It will be observed that the arrangement of the small Greek and Roman letters denoting the characteristics of the individual filters is not symmetrical, so that in equations (20) lies the explanation of the fact noted above in §6 that the order in which different filter units are connected up is of importance in determining the filtering effect. In what follows we shall dispense with this source of confusion by assuming—as we may conveniently do—that all the individual stages of our compound filter are similar to each other. This will result in considerable simplification in the treatment.

§22. Compound Filter of Similar Stages.

Let us take as the characteristics of our typical single-stage filter the symbols A_1, B_1, C_1, D_1, and denote by A_r, B_r, C_r, D_r the characteristics of a compound filter made up of r such similar stages taken in series, as in Fig. 18. Then, since we may consider the filter as composed of $(r - 1)$ similar stages followed by one single stage, we may write by virtue of equations (20),

$$A_r = A_{r-1} \,.\, A_1 + B_{r-1} \,.\, C_1$$
$$B_r = A_{r-1} \,.\, B_1 + B_{r-1} \,.\, D_1$$
$$C_r = C_{r-1} \,.\, A_1 + D_{r-1} \,.\, C_1$$
$$D_r = C_{r-1} \,.\, B_1 + D_{r-1} \,.\, D_1 \qquad \ldots \quad (21)$$

It will be evident, therefore, that if the values of A_1, B_1, C_1, D_1 are known, we have in equations (21) a theoretical means of computing systematically the values of A_r, B_r, C_r, D_r for every integral value of r from 2 onwards. Practically, however, this procedure would be far too laborious,

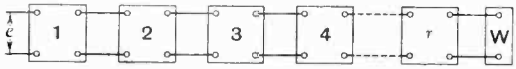


Fig. 18.—*Compound filter of r stages, all similar.*

and the analysis to be developed subsequently will provide a means of curtailing the arithmetical work involved, by the use of the hyperbolic functions. As not all readers may wish to follow the theory

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closely, it is proposed to anticipate the results of this analysis by describing shortly a graphical method of arriving at the performance of compound filters which is based upon it. The hyperbolic functions referred to are not required for this process, and the arithmetic is literally reduced to one simple multiplication and division sum—which can be effected on a sliderule (or even mentally !). The diagram, which is a form of Alignment Chart, enables the performance of a filter of two, three or four similar stages to be estimated when that of a single stage is known. It may be said that, considering the complexity of alternative methods, the present Chart (Fig. 20) is a striking instance of the efficacy and utility of the Alignment process.

§23. Graphical Derivation of Compound Filter Reactance.

In accordance with our previous terminology we shall denote by F_r the filter reactance of a filter of r similar stages when used with a load W at a given frequency. ($F_r = A_rW + B_r$). As usual, F_1 is the filter reactance of a single stage when used with the same load. We shall assume that F_1 is known, having been found as described in Part II. Let us now define the symbol ϕ_1 so that $\phi_1 = A_1 + D_1$. In the case of a filter each of whose stages are of T-type, the component reactances being P, Q and R, we shall have

$$\phi_1 = 2 + \frac{P + R}{Q}.$$

For convenience in obtaining values of ϕ_1 from this equation when dealing with this type of filter, the alignment chart of Fig. 19 has been prepared. Here the two outer supports give values of $(P + R)$ and Q, while the centre support has two scales for ϕ_1 which are to be used according as $(P + R)$ and Q do or do not differ in sign. Let us take as an example a compound T-type filter each of whose stages are similar to that shown in Fig. 13 of Part II (p. 186). Then, as there shown, we have, for 300 metres,

$$P = -1{,}000, \quad Q = +240, \quad R = -120$$

Whence $\phi_1 = -2.67$.

We now turn to the diagram of Fig. 20. In addition to the co-ordinate axes XOX^1 and YOY^1, this chart contains a vertical graduated scale H, and two curved scales K and L. To use the diagram we first compute the value of the ratio W/F_1, and seek a point corresponding to this value on the scale H. Join this point to the origin by a straight line (a). Next, obtain the value of ϕ_1 on either of the scales H, K or L according as there are two, three or four stages in our compound filter. Through this point ϕ_1, draw a straight line (b) parallel to that already drawn through the origin, and note its point of intersection with either XOX^1 or YOY^1. The graduation at which it meets the horizontal axis XOX^1 gives the value of the ratio F_r/W, while that at which it meets the vertical axis YOY^1 gives the value of F_r/F_1. Hence either of these points provides a means of obtaining F_r directly by multiplication, and one or other of them will generally prove convenient of access. In all cases the appropriate algebraic signs must be taken into account. Note that in practice the parallels (a) and (b) will not actually require to be drawn; their position may be conveniently indicated by sliding a set-square upon a fixed ruler.

§24. Example of the Use of the Diagram.

To illustrate the above we shall consider a four-stage T-filter, each of whose stages is similar to that of Fig. 13. It will be remembered that at 300 metres a single stage of this filter used in conjunction with a load of .0003μF had a filter reactance $F_1 = +1060$ apparent ohms. Hence the ratio

$$\frac{W}{F_1} = \frac{-530}{1060} = -\tfrac{1}{2}.$$

This value is then sought on the H scale of Fig. 20 and joined to the origin—*vide* dotted line (a). As we have seen, at 300 metres $\phi_1 = -2.67$. As there are four filter stages, this value of ϕ_1 is sought on the curve L. A line (b) through this point parallel to the line (a) cuts the vertical axis at -10.8, which is thus the value of the ratio F_4/F_1. Whence $F_4 = -11450$ apparent ohms. It should be noted that the scale H in Fig. 20 plays a dual role, being the support both of the ratio W/F_1 used for line (a) and also of the value of ϕ_1 for two stages, used for line (b).

This method, it will be seen, is simple and direct and does away completely with the intricate calculations usually associated with such work. Where a curve of F_1 with frequency has been obtained as in Fig. 14 of Part II, the variations in F_2, F_3 and F_4, when used with the same load, can easily be traced. The differences between these curves are remarkable, and show that the addition of one or more similar stages to an existing filter will not necessarily improve its performance, but may often do just the reverse.

The diagram of Fig. 20 may be used for compound filters of both T and π-type sections. Throughout these notes attention has been directed chiefly to the T-type filter, but the methods given are general, and may be adapted to filters of π-type. For example, the supplementary diagram for ϕ_1 (Fig. 19) may be used for π-type filters as well as for those of T-type. Since

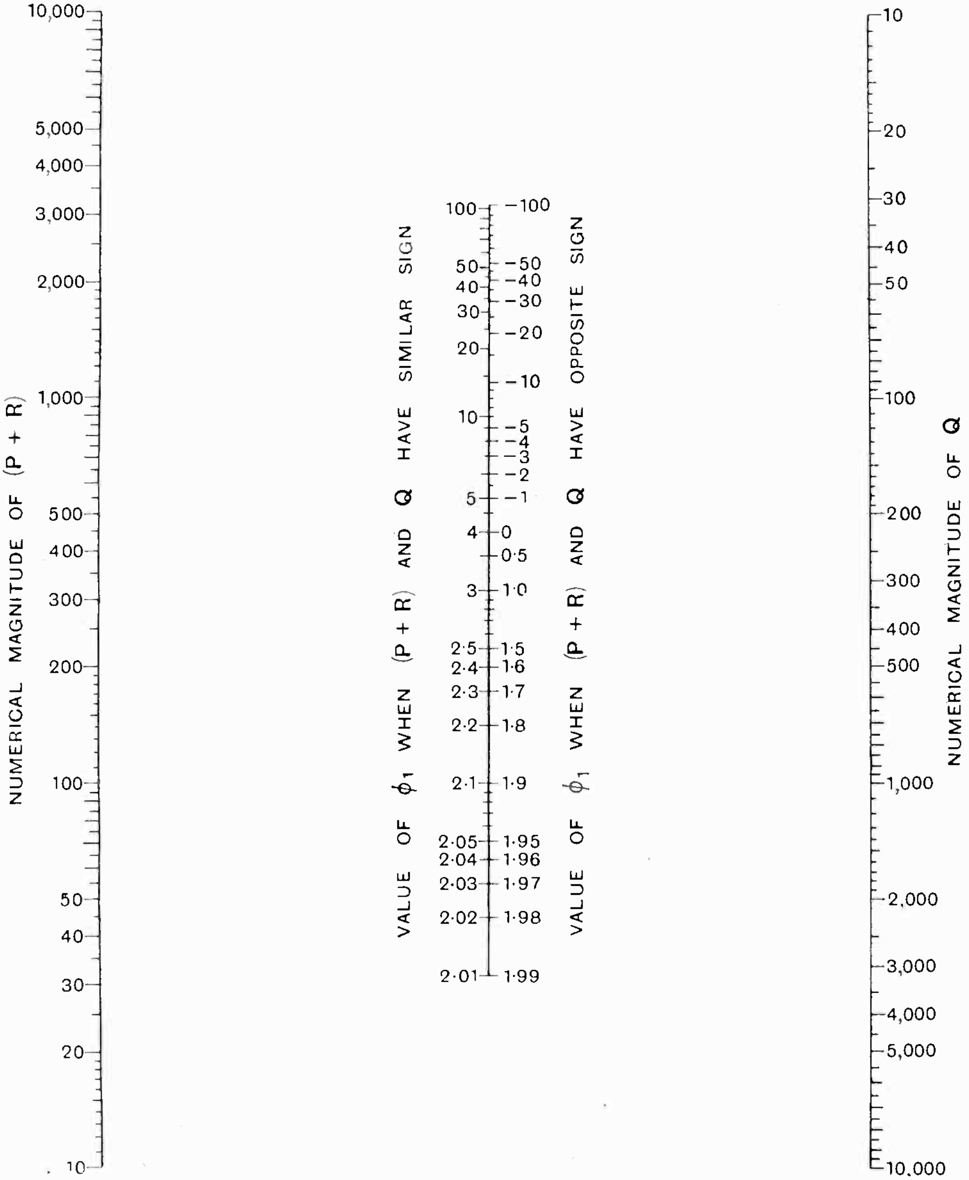

Fig. 19.—*Alignment chart, giving derivation of ϕ_1 from P, Q and R.*

for π-type filters (*vide* §15 above)

$$\phi_1 = 2 + U\left(\frac{1}{S} + \frac{1}{T}\right) = 2 + \frac{S + T}{\frac{ST}{U}}$$

we have only to seek the value of $(S + T)$ on the $(P + R)$ scale, and $\frac{ST}{U}$ on the Q scale.

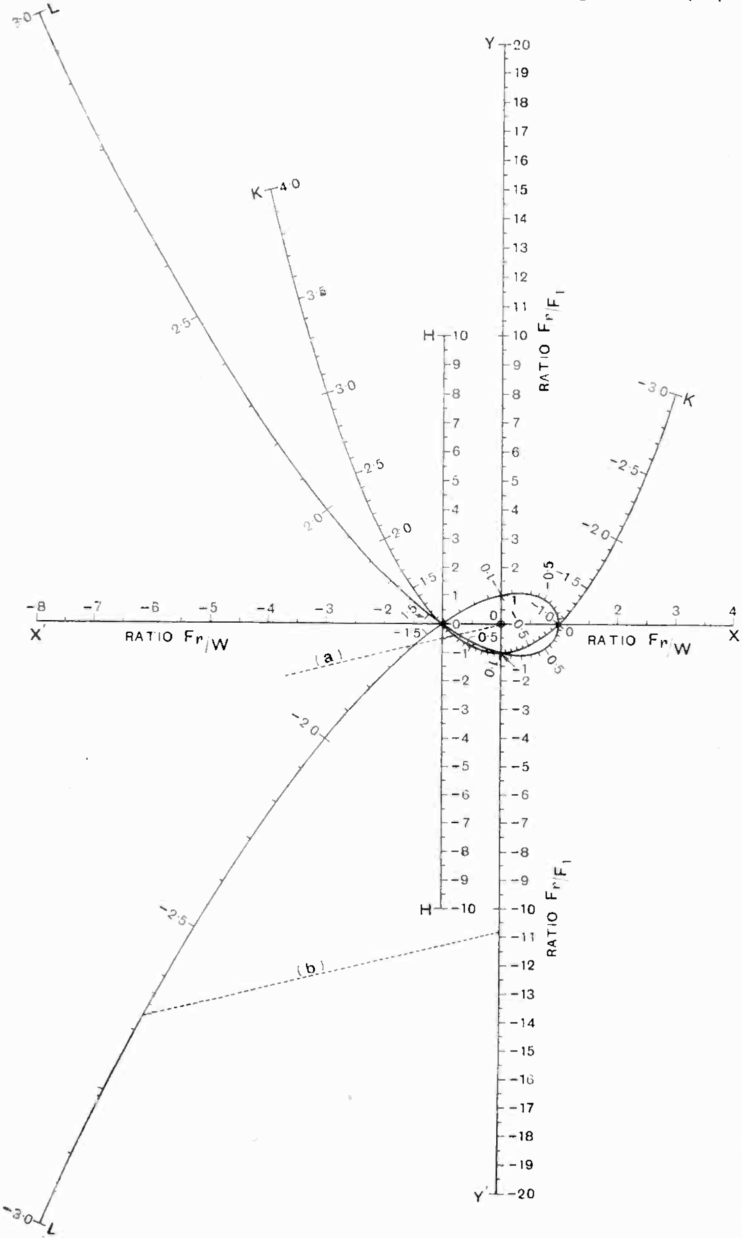

Fig. 20.—*Parallel-alignment chart giving derivation of F_r from F_1 for r = 2, 3 and 4.*

§25. Analytical Expression of Compound Filter Characteristics.

We shall now derive a convenient means of expressing A_r, B_r, C_r, D_r directly in terms of the characteristics A_1, B_1, C_1, D_1 of a single stage without the necessity of computing the values stage by stage from equations (21). Let us first re-write equations (21), substituting $r + 1$ for r.

$$A_{r+1} = A_r . A_1 + B_r . C_1$$
$$B_{r+1} = A_r . B_1 + B_r . D_1$$
$$C_{r+1} = C_r . A_1 + D_r . C_1$$
$$D_{r+1} = C_r . B_1 + D_r . D_1 \quad \ldots \quad (22)$$

We now introduce auxiliary functions ϕ_n. defined as follows:

$$\phi_n = \phi_{n-1} . \phi_1 - \phi_{n-2}$$

where

$$\phi_0 = 1,\ \phi_1 = A_1 + D_1.$$

Hence, $\phi_2 = \phi_1^2 - 1$,
$\phi_3 = \phi_1^3 - 2\phi_1$, etc.

Then we shall prove that

$$A_r = A_1 . \phi_{r-1} - \phi_{r-2}$$
$$B_r = B_1 . \phi_{r-1}$$
$$C_r = C_1 . \phi_{r-1}$$
$$D_r = D_1 . \phi_{r-1} - \phi_{r-2} \quad (23)$$

To do this we shall show that if these equations hold true for any particular value of r they will also be true for $r + 1$. From equation (22) we have

$$A_{r+1} = (A_1 . \phi_{r-1} - \phi_{r-2}) . A_1 + B_1 . \phi_{r-1} . C_1.$$

Substituting for C_1 by means of the relation (*vide* §16)

$$A_1D_1 - B_1C_1 = 1$$

we have

$$A_{r+1} = (A_1 . \phi_{r-1} - \phi_{r-2}) . A_1 + \phi_{r-1} . (A_1D_1 - 1)$$
$$= A_1 . \phi_{r-1} . \phi_1 - A_1 . \phi_{r-2} - \phi_{r-1}$$
$$= A_1 . \phi_r - \phi_{r-1},$$

which is of the same form as equation (23).

Again, from equations (22) and (23),

$$B_{r+1} = (A_1 \cdot \phi_{r-1} - \phi_{r-2}) \cdot B_1 + B_1 \cdot \phi_{r-1} \cdot (\phi_1 - A_1)$$
$$= B_1 \cdot (\phi_{r-1} \cdot \phi_1 - \phi_{r-2})$$
$$= B_1 \cdot \phi_r$$

Similar expressions for C_{r+1} and D_{r+1} may be obtained, all of similar form to equations (23). But these latter are true for $r = 2$. Therefore they are true for $r = 3$, and generally for all integral values of r.

§26. Use of the Hyperbolic Functions.

Having established the truth of equations (23), we may now go on to show how the labour of computing values of the auxiliary functions ϕ_n may be avoided. Let us express these in terms of a more general function θ, defined as follows:

$$\phi_1 = A_1 + D_1 = 2 \cosh \theta = e^{-\theta} \cdot (1 + e^{2\theta}) \quad \ldots \quad (24)$$

Then, by the defining equation

$$\phi_n = \phi_{n-1} \cdot \phi_1 - \phi_{n-2},$$

we may write:

$$\phi_2 = e^{-2\theta} \cdot (1 + e^{2\theta} + e^{4\theta})$$
$$\phi_3 = e^{-3\theta} \cdot (1 + e^{2\theta} + e^{4\theta} + e^{6\theta})$$
$$\cdots\cdots\cdots$$
$$\phi_r = e^{-r\theta} \cdot (1 + e^{2\theta} + e^{4\theta} + \ldots + e^{2r\theta})$$
$$= \frac{e^{-r\theta} \cdot \{e^{2(r+1)\theta} - 1\}}{e^{2\theta} - 1}$$
$$= \frac{e^{(r+1)\cdot\theta} - e^{-(r+1)\cdot\theta}}{e^{\theta} - e^{-\theta}}$$
$$= \frac{\sinh (r+1)\theta}{\sinh \theta}$$

Hence we can write down immediately the filter characteristics for an r-stage filter. Equations (23) become

$$\left.\begin{aligned} A_r &= \{A_1 \cdot \sinh r\theta - \sinh (r-1)\theta\}/\sinh \theta \\ B_r &= B_1 \cdot \sinh r\theta/\sinh \theta \\ C_r &= C_1 \cdot \sinh r\theta/\sinh \theta \\ D_r &= \{D_1 \cdot \sinh r\theta - \sinh (r-1)\theta\}/\sinh \theta \end{aligned}\right\} \quad (25)$$

Thus, from the simple defining equation (24) to determine the value of θ, the compound filter characteristics follow readily. It will, however, be necessary to ascertain more particularly the nature of θ, which (since $A_1 + D_1$ may have any numerical value, positive or negative) will in general be a complex quantity. If $\frac{A_1 + D_1}{2}$ is positive and greater than unity, equations (25) may be used as they stand with the aid of a table of hyperbolic functions. If $\frac{A_1 + D_1}{2}$ is fractional or negative, the defining equation (24) is inoperative, and the variable θ must be transformed in order to obtain workable values. Three cases are thus to be distinguished:

Case I. $\frac{A_1 + D_1}{2}$ is positive, and > 1.

Here θ is determined from (24) by hyperbolic tables, and equations (25) hold.

Case II. $\frac{A_1 + D_1}{2}$ is a proper fraction, either positive or negative. Here we may replace θ wherever it occurs by $\iota\theta'$ $(\iota = \sqrt{-1})$. Since $\cosh \iota\theta' = \cos \theta'$ and $\sinh \iota\theta' = \iota \sin \theta'$, the defining equation (24) becomes

$$A_1 + D_1 = 2 \cos \theta'$$

so that θ' is found from a table of ordinary trigonometrical functions. Equations (25) become

$$\left.\begin{aligned} A_r &= \{A_1 \cdot \sin r\theta' - \sin (r-1)\theta'\}/\sin \theta' \\ B_r &= B_1 \cdot \sin r\theta'/\sin \theta' \\ C_r &= C_1 \cdot \sin r\theta'/\sin \theta' \\ D_r &= \{D_1 \cdot \sin r\theta' - \sin(r-1)\theta'\}/\sin \theta' \end{aligned}\right\} \quad (26)$$

Case III. $\frac{A_1 + D_1}{2}$ is numerically greater than unity, but negative. Here we may replace θ wherever it occurs by $(\theta' + \iota\pi)$. Then, since $\cosh (\theta' + \iota\pi) = -\cosh \theta'$, and $\sinh (\theta' + \iota\pi) = -\sinh \theta'$, the defining equation (24) becomes

$$-(A_1 + D_1) = 2 \cosh \theta'$$

so that θ' is obtained from hyperbolic tables. Equations (25) become

$$\left.\begin{aligned} A_r &= (-1)^{r-1} \cdot \{A_1 \cdot \sinh r\theta' + \sinh (r-1)\theta'\}/\sinh \theta' \\ B_r &= (-1)^{r-1} \cdot B_1 \cdot \sinh r\theta'/\sinh \theta' \\ C_r &= (-1)^{r-1} \cdot C_1 \cdot \sinh r\theta'/\sinh \theta' \\ D_r &= (-1)^{r-1} \cdot \{D_1 \cdot \sinh r\theta' + \sinh (r-1)\theta'\}/\sinh \theta' \end{aligned}\right\} \quad \ldots \quad (27)$$

It is to be observed that the three cases above give the general solution of the characteristic functions for all types of compound reactive filter.

§27. An Example.

To illustrate the hyperbolic method of computing characteristics let us refer again to the compound T-filter of four stages of para. 24. For a single stage of this filter, at 300 metres, $P = -1000$, $Q = +240$, $R = -120$

$$A_1 = 1 + \frac{P}{Q} = -3 \cdot 17$$

$$B_1 = P + R\left(1 + \frac{P}{Q}\right) = -620$$

$$C_1 = \frac{1}{Q} = 0.0042$$

$$D_1 = 1 + \frac{R}{Q} = 0.5$$

Hence, since $\frac{A_1 + D_1}{2}$ is negative, and > 1

$$\cosh \theta' = -\frac{A_1 + D_1}{2} = 1.333$$

$$\therefore \qquad \theta' = 0.795$$

$$\therefore \qquad \sinh \theta' = 0.880$$

$$\therefore \sinh 3\theta' = 5.36 \text{ and } \sinh 4\theta' = 12.0$$

Hence, from equations (27),

$$A_4 = \frac{(-)\{(-3.17) \times (12.0) + 5.36\}}{0.88} = +37.1$$

$$B_4 = \frac{(-)(-620)(12.0)}{0.88} = +8450$$

These values may be used to check the result already obtained for the filter reactance at 300 metres when used with a load of $0.0003\mu F$.

Since $W = -530$,

$$F_4 = A_4W + B_4 = -11200$$

agreeing closely with the value obtained in §24 by inspection of Fig. 20.

§28. Symmetrical Compound Filters.

If the individual filter stages are symmetrical, very important simplifications of equations (25), (26) and (27) are obtained. We have, $A_1 = D_1$, whence $A_r = D_r$.

Case I. $A_1 > 1$ and positive. Put $A_1 = \cosh \chi$.

Then equations (25) reduce to

$$\left.\begin{aligned} A_r &= \cosh r\chi \\ B_r &= \frac{B_1 \cdot \sinh r\chi}{\sinh \chi} \\ C_r &= \frac{C_1 \cdot \sinh r\chi}{\sinh \chi} \\ D_r &= \cosh r\chi \end{aligned}\right\} \quad \ldots \quad (28)$$

For *Case II* when $+1 > A_1 > -1$, put $A_1 = \cos \chi$

Then
$$\left.\begin{aligned} A_r &= \cos r\chi \\ B_r &= \frac{B_1 \sin r\chi}{\sin \chi} \\ C_r &= \frac{C_1 \sin r\chi}{\sin \chi} \\ D_r &= \cos r\chi \end{aligned}\right\} \quad \ldots \quad (29)$$

For *Case III*, when $A_1 < -1$, put

$$A_1 = -\cosh \chi$$

Then
$$\left.\begin{aligned} A_r &= (-1)^r \cdot \cosh r\chi \\ B_r &= (-1)^{r-1} \cdot \frac{B_1 \sinh r\chi}{\sinh \chi} \\ C_r &= (-1)^{r-1} \cdot \frac{C_1 \sinh r\chi}{\sinh \chi} \\ D_r &= (-1)^r \cdot \cosh r\chi \end{aligned}\right\} \quad \ldots \quad (30)$$

§29. A Useful Check.

The equation

$$A_rD_r - B_rC_r = 1 \quad \ldots \quad \ldots \quad (31)$$

will often prove useful as a check on the working. To prove it we proceed as follows:

From the definition of ϕ_n,

$$\phi_n = \phi_{n-1} \cdot \phi_1 - \phi_{n-2}$$

$$\therefore \quad \phi_1 = \frac{\phi_n + \phi_{n-2}}{\phi_{n-1}} = \frac{\phi_{n+1} + \phi_{n-1}}{\phi_n}$$

$$\therefore \quad \phi_n^2 - \phi_{n+1} \cdot \phi_{n-1} = \phi_{n-1}^2 - \phi_n \cdot \phi_{n-2} = \ldots \ldots = 1$$

since this equation, true for all values of n, is in fact true for $n = 2$.

By actual multiplication of equations (22) it may be shown that

$$(A_rD_r - B_rC_r) = \phi_{r-1}^2 - \phi_r \cdot \phi_{r-2}$$

$$\therefore \quad A_rD_r - B_rC_r = 1.$$

(To be concluded.)

Measurement of the Performance of Loud Speakers.*

By E. J. Barnes, A.C.G.I., A.M.I.E.E.

THE distortion which may be produced by the electro-acoustic chain between the microphone and loud speaker is of three main kinds: (*a*) Amplitude-frequency distortion, (*b*) Distortion due to non-proportionality of input and output of any link, (*c*) Transient and phase distortion. Of these three, in most parts of the chain (*a*) gives the most noticeable effect, although (*b*) is serious if any of the parts, particularly the amplifiers, are overloaded. It can be avoided by designing all the parts with ample power-handling capacity. As regards (*c*), it is chiefly noticeable on long transmission lines, but can be compensated. However, in, say, a loud speaker or microphone, if there is great amplitude-frequency distortion there will probably be phase and transient distortion also. Therefore, means by which the frequency-response characteristics of electro-acoustic apparatus may be measured are of great importance. This article gives a description of apparatus developed by the author and his colleagues as applied to the testing of loud speakers, and describes some typical results, and I am indebted to the Engineer-in-Chief of the Post Office for permission to use the information.

Considering the various parts in order, as the source of testing current a heterodyne oscillator is used. Oscillators of this type were set up in 1923, and one constructed in 1924 and described in a paper by Cohen, Aldridge and West before the I.E.E. in April, 1926, is still in use. Since then, however, further investigations have been made into the operation of these oscillators, and various improvements embodied in later models. The circuit arrangement now adopted is shown in Fig. 1.

The two high-frequency oscillators are contained in two screened compartments. The two high-frequency amplifiers and rectifiers are mounted together in a third compartment. The low-frequency amplifier and the remaining parts are also separately screened; each section of the filter has a separate small compartment.

All the coils in the oscillators and filter are small slab coils about 2⅝in. external diameter and ⅛in. thick, of the inductances shown. As loose a coupling as possible is used between the various coils.

The high-frequency amplifiers are not required for actual amplification but enable the coupling between the oscillators to be reduced to almost zero, so that they will oscillate within one cycle in 2 or more seconds of the same frequency without pulling into step.

Contrary to the arrangement adopted by other experimenters, the two oscillators are adjusted to give approximately the same output. The combined output is delivered from the plates of the H.F. amplifiers to the rectifier by the three-electrode differential condenser. This enables the output to be adjusted from almost zero up to its maximum without any steps or effect on frequency. This arrangement is better than stud switches. By making the adjustment at the beginning of the L.F. stages the wave form is slightly improved at the lower outputs.

It is often assumed that a bottom bend rectifier has an anode current-grid volt dynamic curve consisting of a fairly straight portion with a more or less sharp bend at the bottom. Actually, however, it is usually of approximately parabolic form over the working range. In the case under consideration the input consists of the sum of two more or less pure waves and not, as in the case of a receiving set, of one H.F. wave modulated by a number of L.F. waves simultaneously, *i.e.*, the input consists of $a \sin A + b \sin B$ if the waves are pure, or of

$$a' \sin A + a'' \sin 2A + a''' \sin 3A + \ldots$$
$$+ b' \sin B + b'' \sin 2B + b''' \sin 3B + \ldots$$

if the waves are impure.

In the case of a modulated wave the input consists of $a \sin A(1 + b \sin B)$ if only one L.F. is present.

* MS. received by Editor, March, 1929.

For simplicity, if we consider the input to contain second harmonics only, the part of the output with which we are concerned will be (assuming the rectifier characteristic to be parabolic)

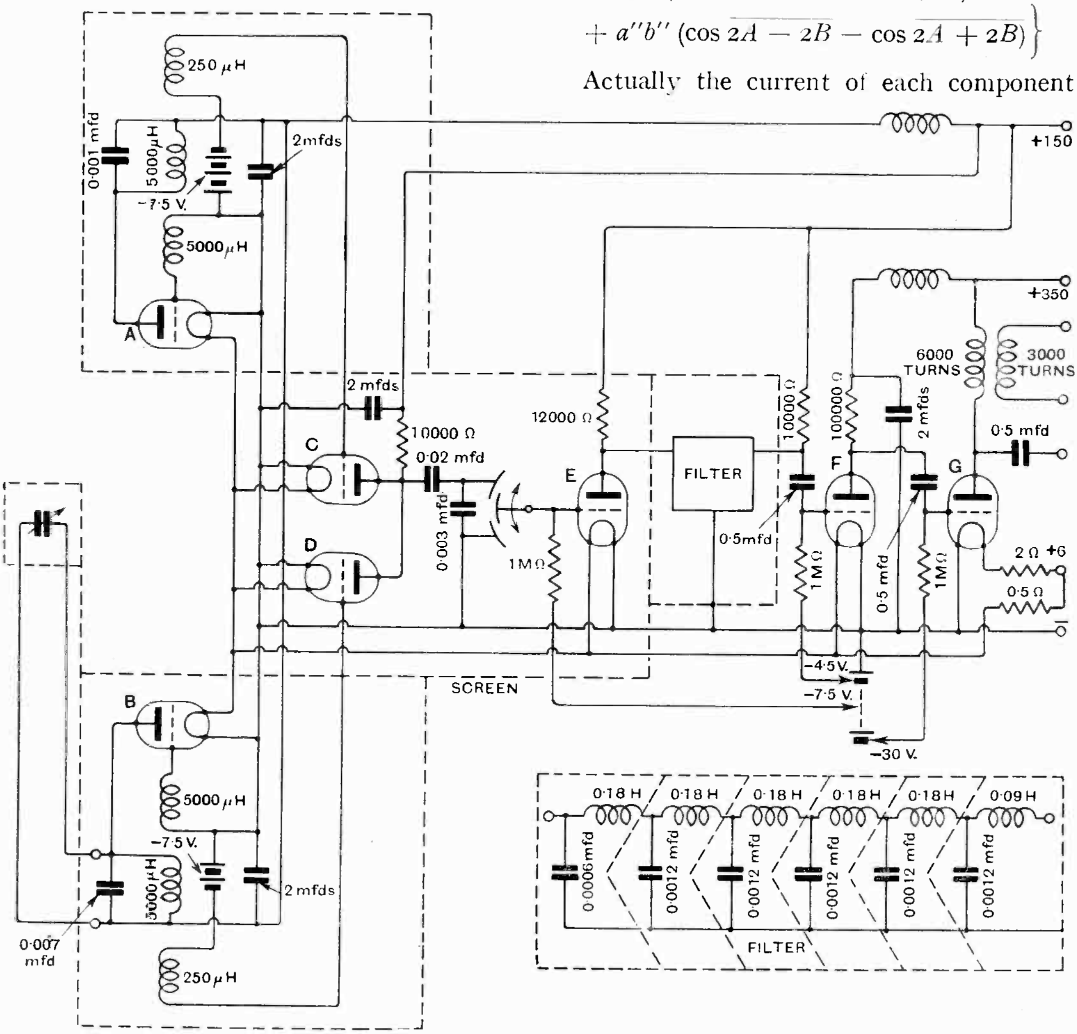

Fig. 1.—*Heterodyne oscillator.*

$$K(a'\sin A + a''\sin 2A + b'\sin B + b''\sin 2B)^2$$

$$= K\left\{\frac{a'^2}{2}(1-\cos 2A) + \frac{a''^2}{2}(1-\cos 4A)\right.$$

$$+\frac{b'^2}{2}(1-\cos 2B) + \frac{b''^2}{2}(1-\cos 4B)$$

$$+ a'a''(\cos\overline{-A} - \cos 3A)$$

$$+ b'b''(\cos\overline{-B} - \cos 3B)$$

$$+ a'b''(\cos\overline{A-2B} - \cos\overline{A+2B})$$

$$+ a''b'(\cos\overline{2A-B} - \cos\overline{2A+B})$$

$$+ a'b'(\cos\overline{A-B} - \cos\overline{A+B})$$

$$\left. + a''b''(\cos\overline{2A-2B} - \cos\overline{2A+2B})\right\}$$

Actually the current of each component frequency flowing and the voltage produced will be determined by the impedances of the valve and its circuits at that particular frequency. All the above waves will be eliminated by the filter except

$$a'b'\cos\overline{A-B} + a''b''\cos\overline{2A-2B}$$

The output passed on to the first L.F. amplifier therefore consists of the desired beat note and its second harmonic only, but the latter is reduced in the ratio $\frac{a'b'}{a''b''}$ so that if the two input waves are reasonably pure the beat note will be very good and there will be no need to purify one more than the other, nor to have one strong compared with the other.

obtained. Originally a three-stage filter was used, but it was possible to get appreciable H.F. voltages at the plate of the second L.F. amplifier, so the number of sections was increased to six, which eliminated this possible source of trouble. The first and last stages are made half-sections and both ends

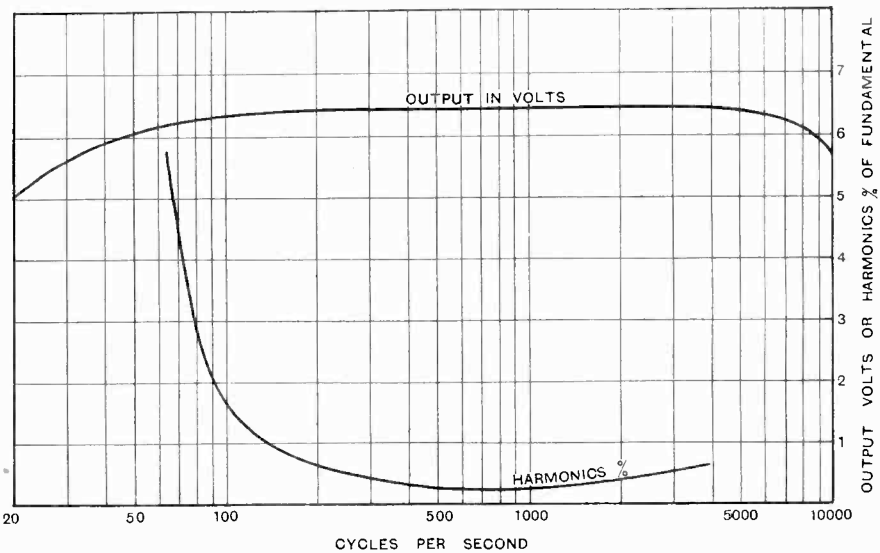

Fig. 2.—*Heterodyne oscillator—output.*

On the other hand, as is well known, if one wave modulates the other, even if both are originally pure, it is necessary to have one very weak in order to avoid the production of combination tones by the rectifier, unless this has a long, very straight part to its characteristic. With telephony, using the ordinary amplitude modulation method, a parabolic rectifier curve will always produce combination tones of all the frequencies present in the side-bands. In the special case of the oscillator the arrangement adopted produces the desired result without the necessity of any special means of purifying one H.F. wave with its attendant extra adjustment.

It is necessary that the two H.F. amplifiers should not interact and should work on the straightest possible part of their characteristics. For this reason low impedance valves worked with only a small grid swing are used. It might perhaps be of some advantage to separate their plate circuits, but with the arrangement adopted very good results are

of the filter are closed through 10,000-ohm resistances (actually 12,000 and the rectifier in parallel at the input end). If the filter is not terminated approximately by its characteristic impedance the attenuation will vary with frequency, and the output from the oscillator will vary accordingly.

The plate supply to the L.F. amplifier is made as high as practicable in order to get the best possible wave form. The output is taken *via* a transformer to suit the load. For non-reactive loads of 200 to 2,000 ohms a suitable winding consists of 6,000 turns primary to 3,000 turns secondary on stalloy stampings 1in. square in section with a window 3in. × 2in. Each winding consists of slab coils, the primary and secondary windings being arranged alternately. A number of transformers are available with different secondaries. The output may also be fed *via* a transformer into a push-pull power amplifier when large outputs are required.

Using the transformer described above, the output at various frequencies is shown in Fig. 2. If the transformer primary (secondary on open circuit) is used as a choke the voltage rises slightly at high frequencies.

The purity of the wave form has been measured. The method of doing this may be of interest. A circuit as shown in Fig. 3 was set up. The output is taken *via* a potentiometer and screened transformer to the "frequency bridge." The latter is a standard arrangement made up in compact form and always used for measuring the frequency when required. The two non-reactive resistances R_1 and R_2 are equal to one another and are simultaneously adjustable by dials. $C_1 = C_2$ ($= 1\mu$F.) and $2P = Q$ ($= 100\Omega$). Under these conditions $2\pi f = 1/R_1C_1$, when the bridge is balanced. The values of R_1 and R_2 have been chosen so that at any setting of the dials, which are connected in parallel, the frequency for which the bridge is balanced can be read off directly.

This bridge is fully described in the *Post Office Engineers' Journal* for July, 1923.

Provided the input wave is pure, the resistances accurate, and the condensers good (as is the case in the instrument used) the balance is very sharp (the actual instrument is made to read within 5 cycles per sec.). Any harmonics in the input will, however, be passed on to the amplifier and rectifier and operate the galvanometer.

To analyse the wave form the bridge is set to any desired frequency and the oscillator accurately adjusted until the galvanometer deflection is a minimum and the reading is noted, the potentiometer being at its maximum setting. By temporarily setting the bridge to twice the first frequency the oscillator can be set to that of the second harmonic of the first. Then with the bridge restored to its first setting the potentiometer is adjusted to get the same reading as before on the galvanometer. The potentiometer, which has a low impedance compared with the transformer feeding the bridge, then gives directly the percentage harmonic present at the frequency first used. It is necessary, of course, to get an accurate balance and to eliminate stray currents. It is also assumed that the losses in the bridge and transformers and the amplification at all the harmonic frequencies present are the same as those at that of the second. But this error is small, as it was found that when the oscillator is working properly the impurity present is almost entirely the second harmonic.

The results of some of the measurements made are shown also in Fig. 2. They could not be carried above 4,000 nor below about 60 cycles per second with the apparatus available at the time. The rise at the very low frequencies is due to the oscillators tending to pull into step.

It should be noted that any inaccuracy in the balance of the bridge tends to give too high a reading for the harmonic content, the figures given are therefore, if anything, on the high side.

It will be seen that the harmonics in the wave do not exceed 1 per cent. between 150 and 4,000 cycles per second and may be much less. They are probably under 0.5 per cent. over a great proportion of the range. It was found that if the L.F. amplifier anode supply was reduced to 250v., or if with 350v. the output was doubled by increasing the oscillator coupling, the impurity in the wave was increased from 2 to 3 times. This emphasises the importance of the ample capacity required in amplifiers in order to minimise the distortion (*b*) men-

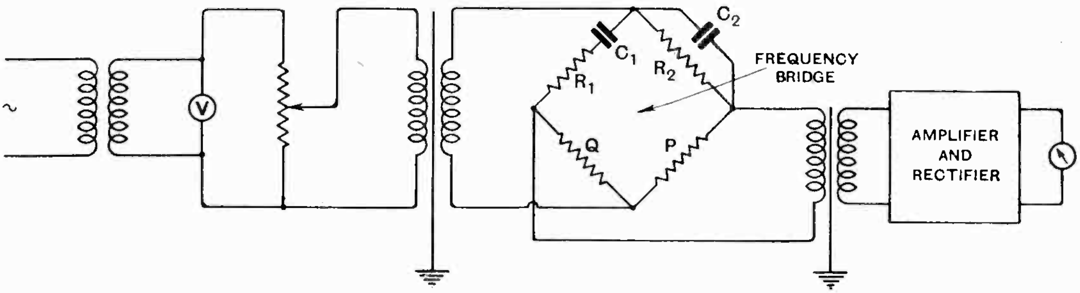

Fig. 3.—*Circuit for wave-form measurement.*

tioned in the opening paragraph. For tests of apparatus where the output at medium frequencies may be 100 or more times that at lower frequencies the use of a very pure wave is essential if false measurements are to be avoided.

The Testing Chamber.

In order that the output from the loud speaker as measured may be truly representative of its performance, very careful consideration must be given to the testing chamber. Except when used out of doors well away from buildings and the ground, as may sometimes occur with public address systems, the sound at any point in the sound field will be more or less affected by the surroundings. As it is usually inconvenient to test out in the open, some form of testing chamber must be provided which will as nearly as possible produce the effect of an infinite space surrounding the loud speaker.

A large number of experiments have been made with various materials and arrangements in order to get a chamber which would be large enough to contain a fairly large instrument and be as free as possible from standing waves due to sound reflection from the walls.

The action of sound-absorbing material is perhaps not so well understood as is desirable. When a sound wave falls on some porous material more or less will pass into the interior of the substance, the remainder being reflected. If it be assumed that the surface of the material is a perforated wall, then Lord Rayleigh has shown (Rayleigh: *Theory of Sound*, § 351, Vol. II) that the reflection will be small even if the ratio of solid wall to area of holes is moderate (*e.g.*, if the ratio of solid wall to hole is 1, *i.e.*, if half the wall is cut away, the fraction of sound energy reflected is 1/9). This assumes that no further reflection takes place within the material. However, it will be seen that if some soft woolly material not too tightly packed is used the reflection from its surface will be small. The sound passing into the material will pass on until it is either absorbed, allowed to pass out the other side, or is reflected by a denser surface. Suppose (as is usual) the absorbent is placed adjacent to the hard reflecting wall of the chamber, the unabsorbed sound will be reflected and form a standing wave with a velocity loop at a ¼ wavelength from the wall. Now it is the motion of the air particles in the pores of the material which causes the degradation of the sound energy to heat: therefore, the material situated about ¼ wavelength from the wall has the most effect; that near the wall or at ½ wavelength, where the sound pressure is a maximum and the velocity zero, will have very little effect. Therefore, in order to absorb waves of all frequencies, the material must extend from the wall to at least ¼ the longest wave it is desired to absorb, *e.g.*, at 100 cycles per second material about 2½ft. thick or more is required. This effect has been proved experimentally by moving a pad of material to different points in a standing wave in a tube and measuring the absorption. When the absorbing material in a room consists chiefly of draping near the walls, speech and other sounds appear low pitched. The reason is obvious in view of the above.

The amount absorbed with any material will depend on the density of the packing of the material, *i.e.*, the denser the packing the greater the absorption but the greater the reflection from the surface. The absorption will increase with frequency up to a maximum. The most economical use of a given quantity of material could probably be made by making the packing increase in density the nearer it is to the surrounding walls.

The actual chamber which has been used for loud speaker tests is not ideal but as will be seen later is reasonably good. It is about 7ft. × 5ft. 6in. in plan, and about 5ft. 6in. high internally. The walls consist of cotton waste built up with fish-netting on a wire-netting frame to a thickness of about 1ft. The floor (concrete) is also covered to about 1ft. deep and the door is made similarly to the walls. It stands nearly in the middle of a large wooden hut, the walls of which are draped loosely with several thicknesses of hessian.

In order to test its freedom from standing waves a sound source was set up on the centre line of the chamber about 1ft. from the wall. The source consisted of a piston (about 3in. diameter) driven by a moving coil, and was supplied with a very pure alternating current at various frequencies between 145 and 4,000 cycles per second. Sound radiation from the back of the piston was prevented by a cylindrical box filled with wool. The input current was kept constant at each frequency, and readings were taken of the output from a condenser microphone at various distances from the source. If the source of sound be equivalent to a true point source, and if there be no reflection from the walls, then the product of the distance and the output voltage (which for a given fre-

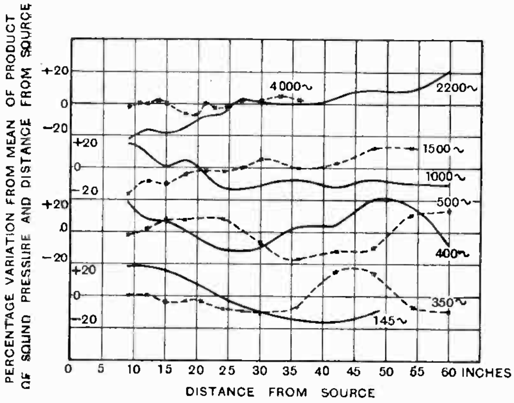

Fig. 4.—*Standing waves in the Testing Chamber.*

quency is proportional to the sound pressure at the diaphragm of the condenser) will be constant.

For each frequency an average value of the product was taken, and the percentage difference of the product from this average was calculated for each distance. These variations are plotted against distance in Fig. 4.

It will be seen that up to distances as great as 5ft. the variations of the product do not exceed 20 per cent., so that errors greater than this are not to be expected. Although it would be desirable to reduce this, for tests of loud speakers in their present state of development errors of this order can be neglected.

It may be noted that measurements should always be taken at a distance from a loud speaker such as is likely to be used in practice. If the distance is too small there is a diffraction effect depending on the size of the radiating surface and the frequency which causes an alternate rise and fall in acoustic pressure. This effect, however, is easily avoided with most loud speakers. The effect of distance will be further discussed when considering the results of tests.

The Sound Detector.

As a sound detector a condenser microphone has been used of the type with a highly stretched thin diaphragm placed very close to a back plate. The stretching and the trapping of air between the diaphragm and plate enable a very smooth output-frequency characteristic to be obtained. A full description of the theory and calibration of microphones of this type is given by E. C. Wente, in the *Physical Review*, Vol. 10, 1917, and Vol. 19, 1922.

Independent calibrations have, however, been carried out under conditions which more nearly represent those under which the microphone is used. As a fundamental means of measuring the sound input to the microphone the Rayleigh disc has been adopted. A full description of the methods by which the disc itself is calibrated is given in a paper by Mr. W. West and myself in the *Journal I.E.E.*, Vol. 65, p. 871, 1927. The disc of mica about 0.8 cm. diameter is suspended a short distance from a source of sound. A little farther away is placed the microphone to be calibrated. The whole is enclosed in a box about 4ft. cube lined with about 8in. thickness of gamgee tissue. The arrangement of this chamber is somewhat the same as described by Mallet and Dutton in the *Journal I.E.E.*, Vol. 63, p. 502, 1925. From the deflection of the disc as disclosed by a reflected beam of light, the alternating velocity of the air particles, due to the sound, at the position of the disc can be calculated. From this the sound pressure existing at any point in the neighbourhood of the source can be found (in the absence of any reflecting surface). When the microphone is placed in position the sound will cause it to generate an e.m.f. which can be measured by an amplifier and voltmeter. The e.m.f. will be determined in terms of the sound pressure which would exist in the absence of the microphone, any alteration in this pressure caused by reflection from the face of the microphone or other causes due to the microphone will be included as part of its characteristic. Extensive tests have been made to ascertain what errors are likely to occur, and it has been found that with suitable precautions it is possible to obtain calibrations accurate to within 10 per cent. or less from 300 up to about 5,000 cycles per second. With a larger and better cabinet and a more powerful source of sound, so that all the distances could be increased, this accuracy could be much improved. Most of the errors are due to having to work at distances between the source, disc and microphone of the same order as the dimensions of the sound source and microphone. Some of the errors can be eliminated by check tests at different distances.

Below 300 cycles/second the reflections from the walls of the cabinet become increasingly serious. Fortunately, at frequencies somewhat below 500 the effect of the reflections from the microphone itself become negligible and another method may be used. The microphone is made to form part of the wall closing one end of a tube. A source of sound is placed in the opposite end of the tube. A Rayleigh disc is suspended at its middle point. The sound source is supplied with current which is adjusted in frequency until the tube resonates with a velocity loop at the centre and pressure loops at the ends. This will occur at frequencies which make the tube length equal to multiples of $\frac{1}{2}$ wavelength. At these frequencies the sound energy present in the tube will practically all appear in the form of pressure at the ends of the tube and velocity at the centre; there is therefore a simple relation between the velocity at the centre as measured by the disc and the pressure on the microphone, $\frac{p}{v} = \rho c$, where p = excess pressure (dynes/cm.^{2}); v = particle velocity (cm./sec.); ρ = density of air; c = velocity of sound; ρc = about 42 under normal atmospheric conditions. By altering the length of the tube a number of points on the characteristic can be obtained. It is possible with the apparatus available to obtain calibrations of microphones from about 50 to 5,000 cycles per second accurate to within about 3 per cent.

The accuracy is practically limited by the accuracy to within which the various meters and the disc deflection can be read.

As mentioned above, below 500 cycles per second the reflections from the microphone are negligible, so that calibrations by the two methods agree; above 500, however, there is an increasing divergence. In the open, at a distance from the sound source where the wave front is plane, half the energy in the sound exists as variations of pressure and half as kinetic energy due to the motion of the particles. When a wave is reflected the kinetic energy causes a pressure on the obstacle which adds to that due to the pressure component, and, hence, in the case of a microphone, at very high frequencies the pressure, as indicated, will be twice that existing in its

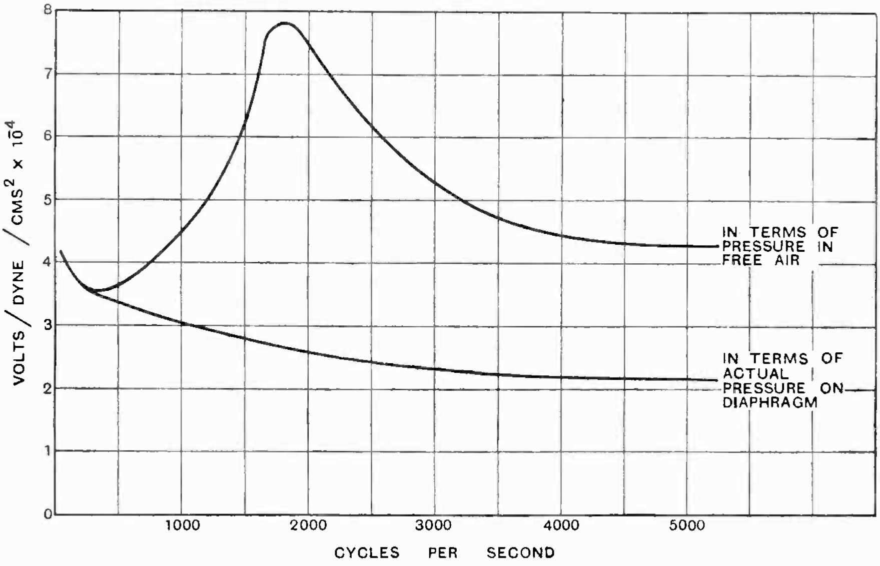

Fig. 5.—*Condenser Microphone Calibration.*

absence. Fig. 5 shows the frequency characteristic of a microphone as used for loud speaker tests. The hump at 1700 cycles per second is caused by the slight cavity in the face of the microphone, and its position and size vary with the dimensions of the cavity, *e.g.*, if the microphone is used without the protecting gauze guard the hump is somewhat flatter and occurs between 2,000 and 3,000 cycles per second, as the cavity is then slightly shallower.

The Microphone Amplifier.

The output from the microphone is amplified before measurement by means of a four-stage amplifier, the circuit of which is shown in Fig. 6. Excessive amplification is not aimed at ; it is only required that with the input available the output shall be of the order of one volt on a 600-ohm load, *i.e.*, somewhat over that at the beginning

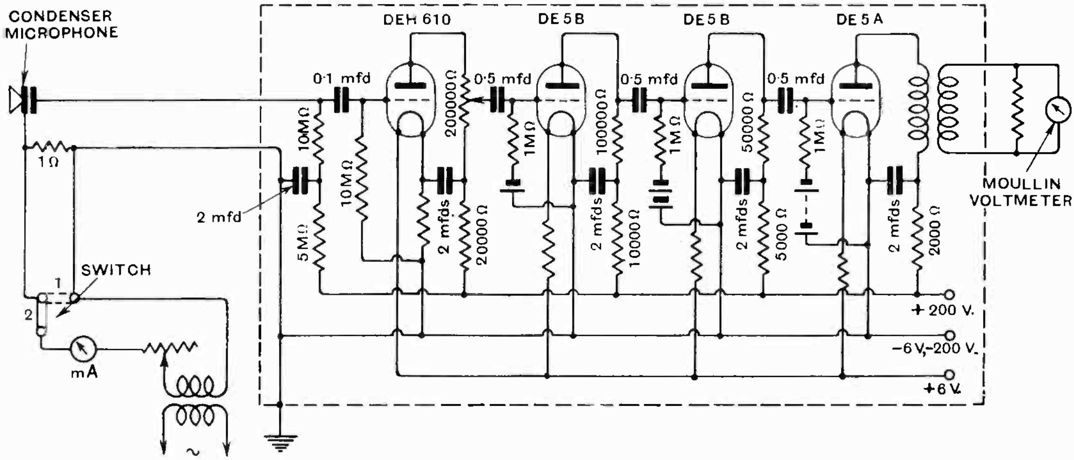

Fig. 6.—*Amplifier for Condenser Microphone.*

Other similar microphones are available with sensitivities several times that shown in Fig. 5, and with a very similar shaped characteristic. The output in terms of the actual pressure on the diaphragm is also shown in the figure. A. J. Aldridge in the *Post Office Electrical Engineers' Journal* for Oct., 1928, has also published similar curves.

It may be mentioned that the Rayleigh disc is the only instrument at present known which will directly measure the sound at a point in the open without introducing any appreciable distortion of the sound field due to the obstruction offered by the instrument. All other sound-measuring devices measure the pressure, and the pressures indicated rise as the wavelength becomes comparable with the dimensions of the instrument, which always occurs within the audio range. The Rayleigh disc forms the only direct means by which they may be calibrated so as to include this and other effects, such as those due to the effect of resonant cavities and that of the load of the mass of air in contact with the moving membrane.

of a long telephone line. The potentiometer in the plate circuit of the first valve enables the output to be adjusted in known steps (each step gives half the output of the previous one). The characteristic is flat except for a fall at the low frequencies when the impedance of the microphone and its lead becomes comparable with that of the two 10 MΩ resistances in parallel. This could be improved by using higher resistances or by increasing the capacity of the condenser, but as the amplification of the amplifier is taken at each calibration point this fall is not of very serious consequence.

When the switch is put over to position 2 the output of the oscillator passes through the 1-ohm resistance placed close to the microphone. A known voltage is thus inserted into the circuit. By calibrating in this way the whole of the amplifier and lead to the microphone is made to act as a voltmeter, measuring the microphone output directly at its terminals.

(To be concluded.)

Electrical Wave Filters.

By M. Reed, M.Sc., A.C.G.I., D.I.C.

(*Continued from page* 196 *of April issue.*)

(2) Band Pass Filter.

The general formulæ will now be applied to the case of a band pass filter.

The band pass filter to be considered is shown in Fig. 26.

This filter can be regarded as being derived from the simple filter of Fig. 27.

Comparison with Figs. 15(a) and 15(b) will show that the two filters of Figs. 26 and 27 are related by the following equations :—

$$L_1 = mL_0 \quad \ldots \quad (32)$$

$$C_1 = C_0/m \quad \ldots \quad (33)$$

$$L_2 = \frac{1 - m^2}{4m} L_0 \quad \ldots \quad (34)$$

If we regard C_2 as consisting of two capacities C_A and C_B in series, then :—

$$C_A = \frac{4m}{1 - m^2} C_0$$

$$C_B = mC$$

$$\therefore \frac{1}{C_2} = \frac{1}{C_A} + \frac{1}{C_B} = \frac{1}{m}\left[\frac{1 - m^2}{4C_0} + \frac{1}{C}\right] \quad \ldots \quad (35)$$

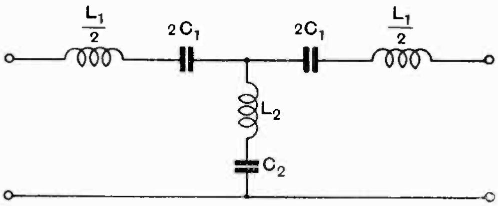

Fig. 26.

From (32) and (33) :—

$$m = \frac{L_1}{L_0} = \frac{C_0}{C_1} \quad \therefore C_0 = mC_1 = C_1 \times \frac{L_0}{L_1} \quad (35a)$$

Substituting the value of $m = L_1/L_0$ in (34), we have :—

$$L_2 = \frac{1 - (L_1/L_0)^2}{4L_1/L_0} \cdot L_0 = \frac{L_0^2 - L_1^2}{4L_1}$$

$$\therefore \quad L_0^2 = L_1(L_1 + 4L_2) \quad \ldots \quad (36)$$

From (35)

$$\frac{4C_0 + C}{C_0 C} = 4m/C_2 + m^2/C_0^2 = m(4/C_2 + m/C_0)$$

but

$$m = C_0/C_1 = L_1/L_0 \quad \therefore \frac{4C_0 + C}{C_0 C} = m\left[\frac{4C_1 + C_2}{C_1 C_2}\right]$$

$$\therefore \quad \frac{4C_0 + C}{C_0 C} = L_1/L_0\left[\frac{4C_1 + C_2}{C_1 C_2}\right] \quad \ldots \quad (37)$$

From Fig. 27 we have that :—

$$Z_1/Z_2 = \frac{\omega L_0 - 1/\omega C_0}{-1/\omega C} = -\omega C[\omega L_0 - 1/\omega C_0]$$

$$= -[\omega^2 L_0 C_0 - 1]C/C_0 \quad \ldots \quad (38)$$

(*a*) *Cut-off Frequencies.*

The cut-off frequencies f_1 and f_2 will be given by solving the equations

$$Z_1/Z_2 = 0 \text{ and } Z_1/Z_2 = -4.$$

When $Z_1/Z_2 = 0$ we have from (38) that

$$\omega_1^2 L_0 C_0 = 1$$

$\therefore$ the lower cut-off frequency is given by :—

$$f_1 = \frac{1}{2\pi\sqrt{L_0 C_0}} \quad \ldots \quad (39)$$

Which is the resonant frequency for the series arm.

When $Z_1/Z_2 = -4$, we have from (38) that

$$(\omega_2^2 L_0 C_0 - 1)C/C_0 = 4$$

$$\therefore \quad \omega_2^2 L_0 C_0 = \frac{4C_0 + C}{C}$$

$$\therefore \quad \omega_2^2 = \frac{1}{L_0}\left[\frac{4C_0 + C}{CC_0}\right]$$

The upper cut-off frequency is therefore given by

$$f_2 = \frac{1}{2\pi}\sqrt{\frac{1}{L_0}\left(\frac{4C_0 + C}{CC_0}\right)} \quad \ldots \quad (40)$$

(*b*) *Terminal Impedances.*

In the case of the low pass filter it was indicated (see page 195) that it was desirable to terminate the filter in an impedance equal to its nominal characteristic impedance. In the general case, the impedance at the mid-frequency is used as the basis for design. The mid-frequency is defined as the geometric mean of the two cut-off frequencies, i.e., $f_m = \sqrt{f_1 f_2}$. In the case of the low pass filter one of the cut-off frequencies is zero, hence

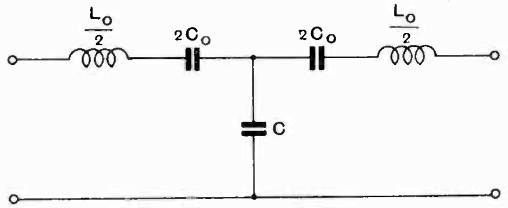

Fig. 27.

$f_m = 0$, and therefore the nominal characteristic impedance should be calculated at zero frequency (see page 193).

The series characteristic impedance of the band-pass filter of Fig. 27, at the mid-frequency, can be obtained as follows :—

From equation (1) we have that for any symmetrical structure, the series characteristic impedance is given by :—

$$Z_K = \sqrt{Z_1 Z_2(1 + Z_1/4Z_2)} \quad \ldots \quad (40a)$$

Therefore, for the filter under consideration, we have by substituting the values of Z_1 and Z_2, that :—

$$Z_1 Z_2 = \frac{1}{\omega C}\left(\frac{\omega^2 L_0 C_0 - 1}{\omega C_0}\right) \quad \ldots \quad (40b)$$

From equation (38) we have that

$$1 + \frac{Z_1}{4Z_2} = 1 - \left(\frac{\omega^2 L_0 C_0 - 1}{4C_0}\right)C$$
$$= \frac{4C_0 - (\omega^2 L_0 C_0 - 1)C}{4C_0} \quad \ldots \quad (40c)$$

$\therefore$ from equations (40a), (40b) and (40c), we have :—

$$Z_K^2 = \frac{\omega^2 L_0 C_0 - 1}{4\omega^2 C_0^2}\left[\frac{4C_0 + C}{C} - \omega^2 L_0 C_0\right] \ldots \quad (40d)$$

Now the mean frequency f_m has been defined as being given by $f_m^2 = f_1 f_2$, where f_1 and f_2 are the values of the cut-off frequencies.

$$\therefore \quad \omega_m^2 = 4\pi^2 f_1 f_2 = \frac{1}{L_0 C_0}\sqrt{\frac{4C_0 + C}{C}} \quad (40e)$$

From equations (39) and (40).

$\therefore$ from (40e) we have :—

$$\frac{4C_0 + C}{C} = \omega_m^4 L_0 C_0 \quad \ldots \quad (40f)$$

Hence from equations (40d) and (40f), we have that the impedance Z_0, at mid-frequency, is given by :—

$$Z_0^2 = \frac{\omega_m^2 L_0 C_0 - 1}{4\omega_m^2 C_0^2}\left[\omega_m^2 L_0 C_0(\omega_m^2 L_0 C_0 - 1)\right]$$
$$= \frac{L_0}{4C_0}(\omega_m^2 L_0 C_0 - 1)^2$$

Substituting for ω_m^2 from equation (40f), it is seen that :—

$$Z_0 = \tfrac{1}{2}\sqrt{\frac{L_0}{C_0}}\left[\sqrt{\frac{4C_0 + C}{C}} - 1\right] \quad \ldots \quad (41)$$

It should be noted that equation (40d) gives the value of the series characteristic impedance of the filter of Fig. 27 at any frequency given by $\omega = 2\pi f$. The expression for this impedance can be reduced to a more convenient form in the following way. We have from equation (40) that :—

$$\omega_2^2 = 4\pi^2 f_2^2 = \frac{1}{L_0 C_0} \times \frac{4C_0 + C}{C}$$
$$= \left(\frac{4C_0 + C}{C}\right)\omega_1^2$$

$$\therefore \quad \frac{4C_0 + C}{C} = \left(\frac{\omega_2}{\omega_1}\right)^2 \quad \ldots \quad (41a)$$

From equations (39) and (41a), equation (40d) reduces to the form :—

$$Z_K^2 = \frac{\omega^2 L_0 C_0 - 1}{4\omega^2 C_0^2}\left[\left(\frac{\omega_2}{\omega_1}\right)^2 - \left(\frac{\omega}{\omega_1}\right)^2\right]$$
$$= \frac{(\omega^2 L_0 C_0 - 1)(\omega_2^2 - \omega^2)}{4\omega^2 \omega_1^2 C_0^2}$$

From equation (39) we have that :—

$$\frac{1}{\omega_1^2 C_0} = L_0 \qquad \therefore \qquad \frac{1}{\omega_1^2 C_0^2} = \omega_1^2 L_0^2$$

$$\therefore Z_K^2 = \frac{\omega_1^2 L_0^2}{4\omega^2}(\omega_2^2 - \omega^2)(\omega^2 L_0 C_0 - 1) \quad (41b)$$

Now from equations (41), (39) and (41a), we have that :—

$$Z_0 = \frac{L_0}{2}(\omega_2 - \omega_1) \quad \ldots \quad (41c)$$

$$\therefore \qquad \frac{L_0^2}{4} = \frac{Z_0^2}{(\omega_2 - \omega_1)^2} \quad \ldots \quad (41d)$$

From equations (41b), (41d) and (39) we obtain :—

$$Z_K^2 = Z_0^2\left[\frac{\omega_2^2-\omega^2}{(\omega_2-\omega_1)^2}\left\{1-\left(\frac{\omega_1}{\omega}\right)^2\right\}\right]$$

$$= \frac{Z_0^2}{(\omega_2-\omega_1)^2}\left[\omega_2^2+\omega_1^2-2\omega_1\omega_2 - \left\{\frac{\omega^4+\omega_1^2\omega_2^2-2\omega^2\omega_1\omega_2}{\omega^2}\right\}\right]$$

Now $\omega_m^4 = \omega_1^2\omega_2^2$

$$\therefore\ Z_K^2 = \frac{Z_0^2}{(\omega_2-\omega_1)^2}\left[(\omega_2-\omega_1)^2-\frac{\omega^2-\omega_m^2}{\omega^2}\right]$$

$$= Z_0^2\left[1-\left\{\frac{\omega^2-\omega_m^2}{\omega(\omega_2-\omega_1)}\right\}^2\right]$$

$$= Z_0^2\left[1-\left\{\frac{(\omega/\omega_m)-(\omega_m/\omega)}{(\omega_2/\omega_m)-(\omega_1/\omega_m)}\right\}^2\right]$$

$$\therefore\quad Z_K = Z_0\sqrt{1-\left\{\frac{(f/f_m)-(f_m/f)}{(f_2/f_m)-(f_1/f_m)}\right\}^2} \quad (42)$$

By exactly similar methods, expressions for the mid-shunt impedance at the mid-frequency and at any frequency may be obtained.

The Derived Band Pass Filter.

As already indicated, the formulæ for the derived filter of Fig. 26 can be easily obained from the equations for the simple filter of Fig. 27.

From (32), (33) and (39) the lower cut-off frequency is given by :—

$$f_1 = \frac{1}{2\pi\sqrt{L_1C_1}} \quad \ldots \quad \ldots \quad (43)$$

From (36), (37) and (40) the upper cut-off frequency is given by :—

$$f_2 = \frac{1}{2\pi}\sqrt{\frac{C_2+4C_1}{C_1C_2(L_1+4L_2)}} \quad \ldots \quad (44)$$

The value of the mid-series characteristic is the same as for the simple filter, and is given by equation (42) where the value of Z_0 can be obtained by substitution for L_0, C_0 and C in (41).

Frequency of Infinite Attenuation.

Referring to Fig. 26, it is seen that the impedance of the shunt arm will be zero at a frequency given by :—

$$f_\infty = \frac{1}{2\pi\sqrt{L_2C_2}} \quad \ldots \quad \ldots \quad (45)$$

Therefore at this frequency the value of Z_1/Z_2 will be infinity, and hence it follows from what has been said on page 194 that the attenuation will be infinite. The frequency given by equation (45) will therefore be the frequency of infinite attenuation.

For the derived filter it is seen that :—

$$Z_1/2 = \frac{j}{2}\left(\omega L_1-\frac{1}{\omega C_1}\right)$$

$$Z_2 = j\left(\omega L_2-\frac{1}{\omega C_2}\right)$$

$$\therefore\quad Z_1/4Z_2 = \frac{C_2(\omega^2L_1C_1-1)}{4C_1(\omega^2L_2C_2-1)} \quad \ldots \quad (46)$$

Substituting for L_1C_1 and L_2C_2 from equations (43) and (45) respectively, we have :—

$$Z_1/4Z_2 = \frac{C_2}{4C_1}\cdot\left(\frac{f_\infty}{f_1}\right)^2\cdot\left(\frac{f^2-f_1^2}{f^2-f_\infty^2}\right) \quad (46a)$$

From equation (44) we have that :—

$$\omega_2^2 = 4\pi^2f_2^2 = \frac{C_2+4C_1}{C_1C_2(L_1+4L_2)}$$

$$= \frac{C_2+4C_1}{C_2/\omega_1^2+4C_1/\omega_\infty^2}$$

$$\therefore\quad (f_2/f_1)^2C_2+4(f_2/f_\infty)^2C_1 = C_2+4C_1$$

$$\therefore\quad C_2/4C_1 = \left[\frac{f_\infty^2-f_2^2}{f_2^2-f_1^2}\right]\frac{f_1^2}{f_\infty^2} \quad \ldots \quad (46b)$$

Substituting this value of $C_2/4C_1$ in equation (46a), we have that :—

$$Z_1/4Z_2 = \left(\frac{f^2-f_1^2}{f^2-f_\infty^2}\right)\left(\frac{f_\infty^2-f_2^2}{f_2^2-f_1^2}\right)$$

$$= \frac{\left[1-\left(\frac{f_\infty}{f_2}\right)^2\right]\left[1-\left(\frac{f_1}{f}\right)^2\right]}{\left[1-\left(\frac{f_1}{f_2}\right)^2\right]\left[\left(\frac{f_\infty}{f}\right)^2-1\right]} \quad \ldots \quad (47)$$

Values of the Elements for a Band Pass Filter.

From the preceding formulæ, expressions may be derived for the values of L_1, C_1, L_2 and C_2, respectively.

From equation (41d) we have that :—

$$L_0 = \frac{Z_0}{\pi(f_2-f_1)} \quad \ldots \quad \ldots \quad (48)$$

and from equations (48) and (32) we have that :—

$$L_1 = \frac{Z_0m}{\pi(f_2-f_1)} \quad \ldots \quad \ldots \quad (49)$$

From equations (35a) and (39) we have

$$C_1 = \frac{L_0 C_0}{L_1} = 1/\omega_1{}^2 L_1$$

substituting for L_1 from (49) we obtain :—

$$C_1 = \frac{f_2 - f_1}{4\pi f_1{}^2 Z_0 m} \quad \ldots \quad \ldots \quad (50)$$

From (34) and (49) we have that :—

$$L_2 = \frac{Z_0}{\pi(f_2 - f_1)} \times \frac{1 - m^2}{4m} \quad \ldots \quad (51)$$

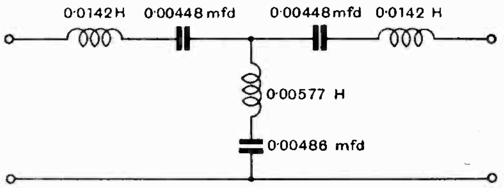

Fig. 28.

From (44) we have that :—

$$\omega_2{}^2 = \frac{C_2 + 4C_1}{C_1 C_2 (L_1 + 4L_2)}$$

$$\therefore\ C_2(\omega_2{}^2 L_1 C_1 + 4\omega_2{}^2 L_2 C_1 - 1) = 4C_1 \quad (52)$$

Substituting for L_1C_1 from equation (43), and for L_2C_1 from equations (51) and (50), equation (52) becomes :—

$$C_2 \frac{(f_2{}^2 - m^2 f_1{}^2)}{m^2 f_1{}^2} = 4C_1$$

$$\therefore \quad C_2 = \frac{(f_2 - f_1)m}{(f_2{}^2 - m^2 f_1{}^2)\,\pi Z_0} \quad \ldots \quad (53)$$

After substituting the value for C_1 given in equation (50).

From equations (51) and (53) we have by multiplication :—

$$L_2 C_2 = \frac{1 - m^2}{4\pi^2(f_2{}^2 - m^2 f_1{}^2)} \quad \ldots \quad (54)$$

$\therefore$ from equations (45) and (54) we have that :—

$$m^2 = \frac{f_\infty{}^2 - f_2{}^2}{f_\infty{}^2 - f_1{}^2} = \frac{(f_\infty{}^2 - f_1{}^2) - (f_2{}^2 - f_1{}^2)}{f_\infty{}^2 - f_1{}^2}$$

$$= 1 - \frac{f_2{}^2 - f_1{}^2}{f_\infty{}^2 - f_1{}^2}$$

$$\therefore\ m = \sqrt{1 - \frac{(f_2/f_1)^2 - 1}{(f_\infty/f_1)^2 - 1}} \quad \ldots \quad \ldots \quad (55)$$

From equations (49), (50), (51), (53) and (55), the values of the filter elements, in any particular case, can be determined.

Example.

A numerical example will illustrate the use of the formulæ given above.

Assume that it is required to design a filter to have a lower cut-off frequency of 20,000 cycles per second; an upper cut-off frequency of 25,000 cycles per second, and that the frequency of infinite attenuation is 30,000 cycles per second. Assume, also, that the value of the terminating impedances at mid-frequency is 600 ohms.

We have therefore

$$f_1 = 20{,}000$$
$$f_2 = 25{,}000$$
$$f_\infty = 30{,}000$$
$$Z_0 = 600$$

Then from equation (55) $m = 0.742$

From (49) $L_1 = 0.0284$ henrys

,, (50) $C_1 = 0.00224$ mfd.

,, (51) $L_2 = 0.00577$ henrys

,, (53) $C_2 = 0.00486$ mfd.

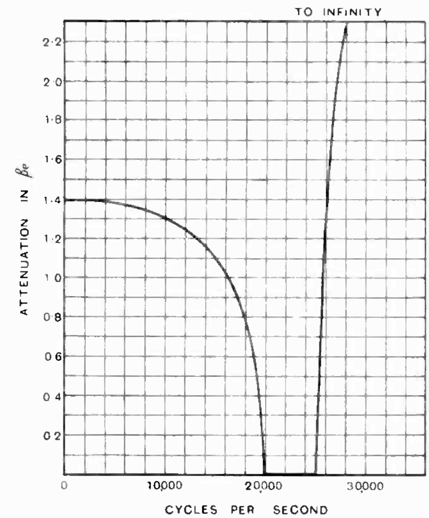

Fig. 29.—*Attenuation characteristic of band pass filter.*

The filter required is therefore as shown in Fig. 28.

The attenuation and phase constant characteristics for this filter can be obtained in exactly the same manner as the corresponding characteristics were obtained in the case of the low pass filter. The value of Z_1/Z_2 at any frequency can be calculated from equation (47) and the corresponding attenuation and phase constant can be read off from the curves of Figs. 6 and 7, respectively. Figs. 29* and 30 show the attenuation and the phase constant characteristics, respectively, for this filter.

The Effect of Resistance in Filter Circuits.

So far it has been assumed that the series and shunt arms are pure reactances and hence the ratio Z_1/Z_2 is either a positive or negative number. In any actual filter there is, however, a certain amount of resistance associated with the inductances and condensers. At frequencies below 3,000 cycles the resistance of paper and mica condensers is usually negligible. At higher frequencies, where only mica condensers are generally used, the dissipation in the condensers can also be neglected. The resistance of the inductances in a filter, is, however, seldom negligible and must generally be taken into consideration.

Where the resistance cannot be neglected, then the value of Z_1/Z_2 will in general be a vector quantity, and the attenuation and phase constant must therefore be read off from the curve corresponding to the angle of Z_1/Z_2 in Figs. 6 and 7 respectively.

The effect of resistance on the value of attenuation constant is most important in the transmission band, where the attenuation constant would be zero if there were no dissipation. Its effect is most pronounced in the neighbourhood of the cut-off frequencies where the transmission bands merge into attenuation bands. In the attenuation bands, the general effect of resistance is negligible. It effects, however, the value of the attenuation constant at those frequencies at which infinite attenuation would occur if there were no dissipation. Speaking generally, the difference between the value of the attenuation for the ideal filter and for the filter with resistance becomes greater as the value of "a" is reduced.

From Fig. 7 it is seen that resistance has the effect of rounding off the abrupt changes in phase that occur in the neighbourhood of the cut-off frequencies, i.e., when $|Z_1/Z_2|$ becomes greater than 4.

It is convenient to express the dissipation in any reactance by the ratio of its effective resistance to its reactance. This ratio is denoted by "d" and in the case of a coil given by $d = R/\omega L$. The value of "d" will not, in general, be constant over a wide frequency range, but if its value is known at an important frequency in the transmitting range, it may usually be regarded to hold for the rest of the transmitting range.

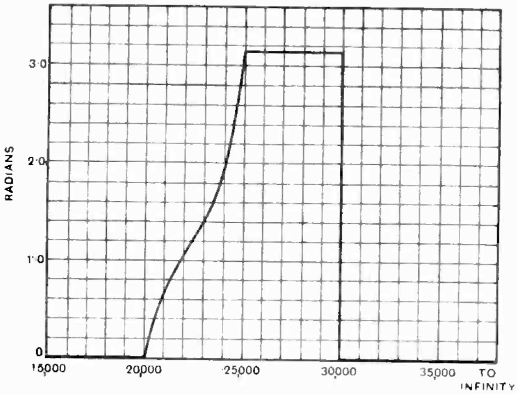

Fig. 30.—*Phase constant characteristic of band pass filter.*

In the cases we have already considered, the effect of dissipation can be seen from the following. Consider first the filter of Fig. 21. If R_1 and R_2 are the effective resistances of the inductances in the series and shunt arms, respectively, then :

$$Z_1 = R_1 + j\omega h_1 = \frac{\omega L_1}{Q} + j\omega L_1$$

where $Q = 1/d$

$$Z_2 = R_2 + j\left(\omega L_2 - \frac{1}{\omega C_2}\right)$$

$$= \frac{\omega L_2}{Q} + j\frac{\omega^2 L_2 C_2 - 1}{\omega C_2}$$

$$\therefore \quad Z_1/Z_2 = \frac{(1 + jQ)\,\omega^2 L_1 C_1}{\omega^2 L_2 C_2 + jQ(\omega^2 L_2 C_2 - 1)}$$

Substituting the values of L_1, L_2 and C_2 as given by equations (29), (30) and (31), we have :—

$$Z_1/Z_2 = U + jV = \frac{4(1 + jQ)(f_\infty^2/f_c^2 - 1)}{1 + jQ(1 - f_\infty^2/f^2)} \quad \text{.. .. (56)}$$

* This curve is plotted only up to 28,000 cycles/sec. After 30,000 cycles/sec., the attenuation decreases until at infinite frequency it is $1.94\beta c$.

Hence, knowing the value of Q, the attenuation and phase constant at any frequency can be determined from the corresponding curves of Figs. 6 and 7.

In the case of the filter of Fig. 26, if R_1 and R_2 are the effective resistance of the series and shunt arm inductances, respectively, then :—

$$Z_1/Z_2 = L_1/L_2\left[\frac{1 - jd - 1/\omega^2 L_1 C_1}{1 - jd - 1/\omega^2 L_2 C_2}\right]$$

An analysis similar to that given on page 258, can be expressed as :—

$$\frac{Z_1}{Z_2} = \left(\frac{f_1}{f_\infty}\right)^2 \frac{[(f_\infty/f_2)^2 - 1][(1 - jd)(f/f_1)^2 - 1]}{[1 - (f_1/f_2)^2][(1 - jd)(f/f_\infty)^2 - 1]} \quad \ldots \quad (57)$$

Thus giving the means of obtaining the attenuation and phase constant at any frequency.

It should be noted that for frequencies outside the transmitting range the formulæ Z_1/Z_2 for the non-dissipative structure can be employed without undue error.

(To be continued.)

Books Received.

THE NATIONAL PHYSICAL LABORATORY, COLLECTED RESEARCHES, Vol. XXI, 1929.

Containing 21 papers on recent research in matters connected with wireless, by Dr. D. W. Dye, R. M. Wilmotte, L. Hartshorn, C. E. Webb, Dr. R. L. Smith-Rose, R. H. Barfield, F. Adcock and J. Hollingworth. Pp. 448, with numerous illustrations and diagrams. Published by H.M. Stationery Office. Price 22s. 6d. net.

TELEVISION, TO-DAY AND TO-MORROW. By Sydney A. Moseley and H. J. Barton Chapple, with a Foreword by J. L. Baird.

An account of the history and development of the Baird system, with descriptions of the apparatus and chapters on Synchronism, Photo-electric Cells, Noctovision, Colour and Stereoscopic Television, Tele-Cinema and kindred subjects. Pp. 130+XXIII, with 38 diagrams and 48 half-tone plates. published by Sir Isaac Pitman & Sons, Ltd. Price 7s. 6d. net.

REPORT OF THE RADIO RESEARCH BOARD, for the period ended 31st March, 1929.

Including the General Report and Review of Investigation in the Propagation of Waves, Directional Wireless, Atmospherics, Standards and Measurements, Aerials, Amplifiers, Interference, Short Waves, and other subjects. Pp. 166, with Frontispiece. Published by H.M. Stationery Office. Price 3s. 6d. net.

CANTOR LECTURES ON WIND INSTRUMENTS FROM MUSICAL AND SCIENTIFIC ASPECTS.

A series of three lectures delivered before the Royal Society of Arts by E. G. Richardson, B.A., Ph.D., D.Sc., explaining the production of sound waves by wind eddies in various instruments including the orchestral wood-wind and brass; organ flue pipes and reeds; and the Aeolian harp, with brief descriptions of the nature and mechanism of different wind instruments. Pp. 38, with 18 illustrations. Issued by the Royal Society of Arts, London. Price 2s. 6d.

RADIO DATA CHARTS.

In the design of wireless receivers and associated apparatus a large number of calculations are involved, some of which are by no means simple and would ordinarily take up a great deal of time, even when tackled by those accustomed to working out such problems. By devising charts in the form of abacs it is possible to reduce to comparative simplicity the task of arriving at any required result.

The purpose of the book of Radio Data Charts just issued by the publishers of *The Wireless World* is to place in the hands of the designer of wireless apparatus a ready means of solving his problems without recourse to complicated formulæ and mathematics. By the use of the charts it is possible to tackle all the more familiar problems in radio receiver design, from such simple requirements as finding the relationship between inductance, capacity and frequency, right up to the design of high frequency transformers and the estimation of stage gain with various types of couplings.

This book of Radio Data Charts is based on a series of charts designed by R. T. Beatty, M.A., B.E., D.Sc., originally published in *The Wireless World* and now revised and amplified by the author for publication in book form. The pages of the book are approximately the same size as the pages of *The Wireless World*, and the published price is 4s. 6d., or 4s. 10d. post free from the publishers.

Recent Developments in Direction-finding Apparatus.

Paper by Mr. R. H. Barfield, M.Sc., A.M.I.E.E., read before the Wireless Section, I.E.E., on 2nd April, 1930.

ABSTRACT.

Part I.—Medium Waves (300 to 600 m).

THIS part of the paper deals with the development of direction-finding work with the Adcock aerial system. Preliminary work on the subject was described by the present author and Dr. R. L. Smith-Rose a few years ago (see *E.W. & W.E.*, June, 1926), when the Adcock aerial was in the form of vertical dipoles, with the

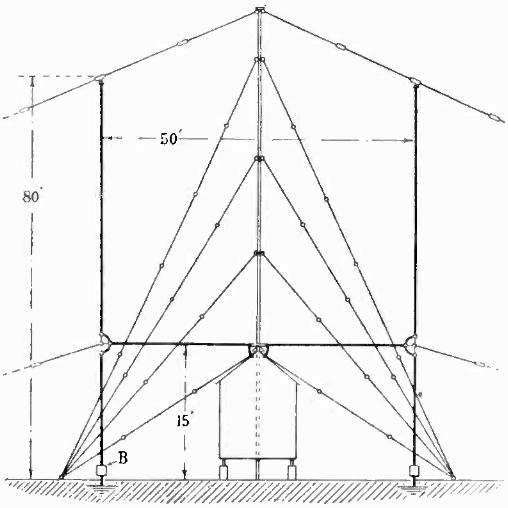

Fig. 1.—*Aerial system. B = box containing balancing condenser.*

working hut and apparatus suspended at the centre of the system. The present paper describes developments of the system working at ground level. The Adcock system is, of course, particularly intended to eliminate the "night-error" effect which arises when waves are returned from the Heaviside layer.

In the arrangement now described, the hut containing the apparatus is on the ground and balancing condensers are inserted in the earth leads to compensate for its lowering. The aerial system is supported by a single central mast, as shown in Fig. 1*. The four aerials 80 ft. high are suspended from radial stays, anchored at points 400 ft. out from the mast, and broken by insulators into 20 ft. lengths. Each aerial is broken 15 ft. above ground and twin horizontal leads spaced 6 in. apart in a horizontal plane are led into the hut. The diagram of aerial connections is shown in Fig. 2. Balancing condensers, variable up to 0.0003 μF. max. are inserted as at *B* in Fig. 1. These have a value of about 60 $\mu\mu$F. when the aerial is balanced. Methods of balancing the system are described in the paper, the object of the balancing system being to make the impedance of the lower half of the aerial equal to that of the upper part with respect to e.m.f.'s. generated in the horizontal members of the aerial system by the horizontal electric component of the received waves.

The goniometer and receiving apparatus do not differ in any important way from the installation of a standard Bellini-Tosi system.

The following tests are described :—

(*a*) Calibration for direct waves and range tests.

(*b*) Tests during "night effect" (i) comparison with closed-loop direction-finder, (ii) Effect of balancing condensers.

(*c*) Calibration by means of downcoming waves from a local transmitter elevated by a kite.

The calibration curve compares favourably with those obtained with other d.f. systems in like conditions. No difficulty was expressed in obtaining sharp minima and the range appeared to be not noticeably different from the Bellini-Tosi or other system.

As regards night effect, result curves and tables are given showing the undoubted superiority of the Adcock system. The presentation tends to underestimate the magnitude of the disturbance on the loop, since tables of standard deviation,

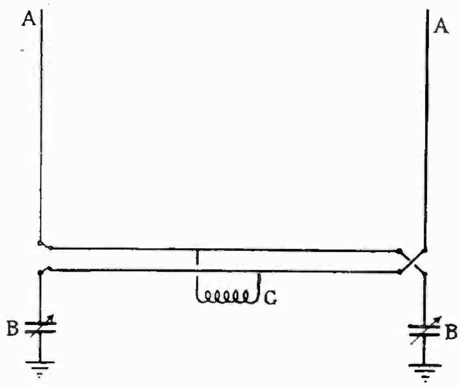

Fig. 2.—*Diagram of aerial connections. G = field coil of goniometer, B = balancing condensers, A = aerial.*

etc., do not include the cases when no minimum was possible on the loop. Such conditions are extremely rare with the Adcock aerial. On longer waves or over sea conditions would be even better.

As an example of the comparison, an extended table of observations shows standard deviations

* The author's original figure numbers are adhered to throughout this abstract.

for the loop varying from 2 to 10 times those simultaneously obtained for the Adcock system.

A table and curve also show the effect of the balancing condenser in minimising variation of bearing.

The experiments with the kite transmitter were intended to investigate residual errors in the Adcock system shown still to exist by the previous results. A small transmitter was raised several hundred feet

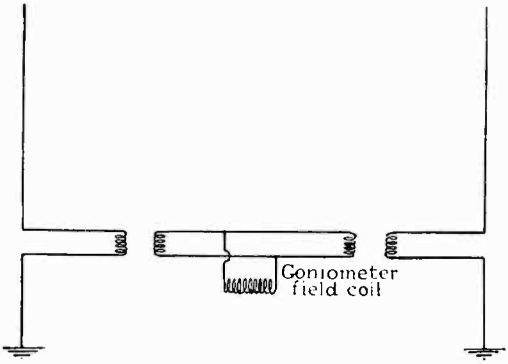

Fig. 13.—*Simplest arrangement of chain coupling.*

above the receiver by means of a kite to provide a source of artificially produced downcoming waves with a known and suitable degree of horizontal polarisation. Result curves are given showing the superiority of the Adcock system. To take an example a wave arriving 15° to the horizontal and with its electric force at 60° to the vertical, gave an error of 24° on the loop and only 7° on the Adcock.

This residual error is attributed to instrumental effects, and the latter section of this part of the paper discusses the theory of the balanced Adcock system and possible methods of improvement. The error is particularly attributed to the continuous horizontal leads, and various systems of chain coupling are suggested, the simplest form being that shown in Fig. 13.

Part II.—Short Waves (12 to 60 m.).

The first section deals with a closed-loop direction finder, shown in Fig. 14. The loop is a single turn of 3 ft. square, completely screened in a 1 in. square brass tube. The receiver is a 6-valve supersonic one of commercial pattern. The single tuning condenser, externally controlled, tunes the inductance of the first oscillator-detector, to which the loop is coupled.

The advantages of the instrument for short-wave working lie mainly in the form of the screening used, and are

(1) Complete absence of antenna effect.

(2) Robustness of loop.

(3) Loop may be approached and, on the higher wavelengths, may even be touched without appreciably altering the bearing or weakening signals.

The next section describes a rotating Adcock direction-finder for a similar wave-range. The system consists of two spaced vertical aerials fixed at the ends of a rotating horizontal arm, the aerials being connected in opposition as shown in Fig. 16(*a*). Each aerial is made up of two 5 ft. lengths of ¾ in. aluminium tube. The horizontal arm is in two 5 ft. lengths of 1½ in. brass tube, joined at the centre by a brass union. The twin horizontal leads are stretched tight in the brass tube ¾ in. apart, and at the centre are brought out to two terminals for connecting to the primary of the transformer, as shown in Fig. 16 (*a*). The primary and secondary windings are separated by an "electrostatic" screen *E*, which also serves as a mechanical support for the former. The screen consists of a cylindrical cage 8 in. high and 4 in. diameter, of fine vertical wires spaced ⅛ in. apart. The construction is shown in greater detail in Fig. 16 (*b*).

Both types of direction-finder have been subjected to the following tests :—

(*a*) Tests with local transmitter, (i) On ground, (ii) transmitter elevated 40 ft. above ground.

(*b*) Effect of immediate surroundings.

(*c*) Tests up to the limit of ground-ray range.

(*d*) Long-range tests.

The local transmitter elevated above the ground could give a downcoming wave of controllable horizontal polarisation, and result curves, which are given, again show the marked superiority of the Adcock system in the very small error produced in these circumstances compared to the loop receiver.

With either instrument direction finding is possible on 24 metres up to 70 miles in day time,

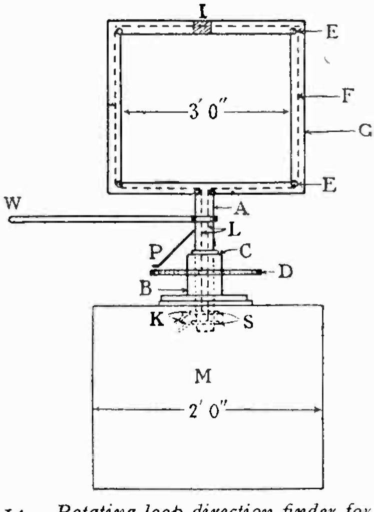

Fig. 14.—*Rotating-loop direction-finder for short waves. A = brass vertical axis 1½in. diam., B = brass bearing 3in. internal diam., C = brass collar, D = aluminium scale, E = ebonite spacing pieces, F = direction-finding loop, G = outer brass pipe, I = insulated gap, K = brushes, L = leads, M = metal-lined box with amplifiers, tuner, etc., P = pointer, S = slip-rings, W = wooden handle.*

and 30 miles at night (these results applying to summer season only). The site should be 100 yards clear of obstacles in all directions. Over 20 miles, minima become flatter until they become too flat to read on either type. At about 500 miles the

Adcock gives fair indications of bearing, while the loop is practically useless on account of flatness of minima and extent of bearing variation.

The variable errors and flatness of minima observed at distances exceeding 20 miles and under, say, 800, are due to downcoming waves. The fact that at such ranges these effects were of equal extent on both systems, shows that these downcoming waves were scattered or laterally deviated, as suggested by Eckersley. Otherwise, the Adcock would have shown less error, as revealed by the tests with artificially produced downcoming waves.

The work described was conducted under the auspices of the Radio Research Board.

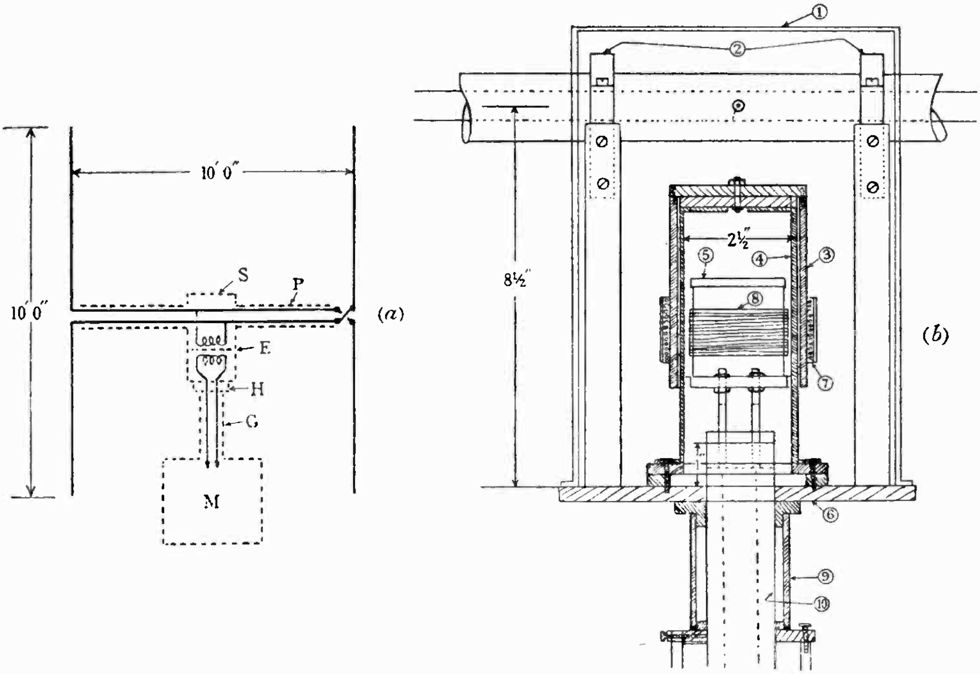

Fig. 16.—(a) *Rotating Adcock pair—circuit and screening arrangements ;* (b) *Rotating Adcock direction-finder. Scale : 3in. = 1ft. F = electrostatic screen, G = brass tube with down leads, H = bearing, M = metal-lined box with amplifiers, etc., P = metal pipe, S = screen,* (4) *electrostatic screen,* (5) *ebonite former for secondary,* (6) *brass baseplate,* (7) *primary winding,* (8) *secondary winding,* (9) *outer rotating tube,* (10) *inner fixed tube.*

Discussion.

AIR-COMMODORE A. W. WARRINGTON-MORRIS, who opened the discussion, expressed interest in the subject from the viewpoints of both service and civil aviation. Three companies were about to run night services between Croydon and the Continent, and d.f. was an important matter. Was it necessary to rebalance the aerial system on change of wavelength ? The author's results on short waves were not promising for the use of these waves at moderate distances, and he would be glad to know if there was any hope of success on slightly longer waves.

MR. T. L. ECKERSLEY expressed his main interest in short waves. The author's results gave interesting confirmation of his own. The error that remained in the short-wave Adcock was no doubt due to asymmetry of the lower part of the aerial. Had the author made any observations on very long distances ? On signals from New York he had observed swings of 2 or 3 degrees and very perfect balance was needed. He had little hope of reliable d.f. in the skip distance.

MR. N. E. DAVIES described work on the same problem by the Research Dept. of the Marconi Co. The Adcock principle depended on a non-radiating link between the vertical aerials and the goniometer. The problem was to transfer from the aerial to the receiver, so that only the normally polarised component gave directional indications. The Marconi Co. relied first on screening the horizontal leads and on nullifying the re-radiation from screen to aerials. The leads were single conductors completely shielded and led to a shielded goniometer. Observations showed the possibility of an accuracy of 2 or 3 degrees in the worst conditions of night effect on 1,000 m., and they hoped for a like accuracy on 400–500 m. Slides were shown illustrating the Marconi installation at Chelmsford.

MR. F. B. SMITH asked the author's opinion as to the suitable wavelength range for his apparatus. Recent developments of beacon transmissions showed the necessity for Adcock systems at distances of over 100 miles. On the equi-signal beacon system errors might still be got even on Adcock.

MR. C. E. HORTON said the author's main results agreed with his own experiences. Discussing Adcock aerials and loops, he pointed out that the impedance of the aerial caused the Adcock to compare badly at longer waves. On an Adcock aerial of the size of an ordinary frame it was difficult to get good signal strengths. He suggested burying long horizontal leads as a satisfactory way of applying the Adcock principle, but referred to the great difficulties of erecting such aerials on ships, especially battleships.

MR. J. F. HERD described a demonstration of the loop and Adcock receivers (on short waves) working on the elevated local transmitter, and showing the stability of Adcock minimum as abnormal polarisation was artificially introduced by tilting the transmitter. He also asked for comparison of the previous medium-wave system (when the hut was suspended in the air) and the present system at ground level.

DR. R. L. SMITH-ROSE referred to the technical difficulties of getting the system down to ground level. He thought that Mr. Adcock was to be congratulated on his original suggestion of such an aerial scheme, which was purely British in its use as a direction finder. He suggested the existence of an error in one of the author's calculations on the theory of the balanced Adcock system.

The author replied briefly to the discussion, and the meeting terminated in a vote of thanks, moved by the Chairman, Capt. C. E. Kennedy Purves, R.N.

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.

"Threshold Howl."

To the Editor, E.W. & W.E.

SIR,—Referring to Mr. Alder's article on "Threshold Howl" in the April issue of *E.W. & W.E.*, this is of much interest because the literature on the subject is very small indeed and the effect dealt with is extremely troublesome.

I disagree, however, with Mr. Alder's statement that it is immaterial whether the detector valve is preceded by high frequency stages or not, as I think that in fact a particular variety of threshold howl is caused entirely by the existence of one or more stages of high frequency amplification. The effect is identical with that described and explained in the article in question, but occurs even when the conditions described do not exist, and is only present when the aerial or input circuit of the high frequency amplifier is in tune with the circuit between the high frequency valve and the detector. The cycle of events appears to be somewhat as follows.

When reaction is increased to the point of oscillation these oscillations are radiated from the detector valve circuits, assuming them to be not perfectly screened and a proportion is picked up by the input to the high frequency valve; oscillations therefore build up in the input circuit and are amplified through the high frequency valve and thereby communicated to the detector valve circuit, and the phase relations may be such as to cause a momentary cessation of oscillation. The process then commences all over again and continues to take place at an audible frequency.

If reaction is increased so as to be further removed from the threshold of oscillation, it is no longer possible for the stray high frequency coupling, amplified by the high frequency valve, to interrupt the detector valve oscillations.

The above explanation is confirmed by the fact that this variety of threshold howl does not appear to take place when the screening is very complete, and when it is present it can usually be removed by altering the relative positions of the input and output high frequency circuits.

Another common cause is imperfect filtering of the output of the detector valve, permitting high frequency currents to stray through the low frequency amplifier, whence they may be communicated to the aerial circuit. It would be interesting to know whether this other variety threshold howl has been generally observed.

M. G. SCROGGIE.

Effect of a Screen on Electromagnetic Waves.

To the Editor, E.W. & W.E.

SIR,—In the February Editorial an attempt is made to discriminate between the electric field of an electromagnetic wave and the electric field which must be associated with the alternating magnetic field in the absence of the electric field of the wave itself, but it is not easy to see how these can be differentiated, and one may be forgiven for criticising such statements as "a space may be screened from the electric field but not from the magnetic field of a wave." It seems more correct to say that a wave may be modified by the screen; but it is certain that if the electric vector is modified, then so is the magnetic vector. These points can be illustrated by taking the simple cases of plane waves usually considered in wireless theory.

If a plane wave is travelling in the direction of the axis of x with its electric vector Z parallel to the axis of z, then the equations of electromagnetic theory require that the magnetic vector β should be parallel to the y axis and connected with Z by the relation $C\frac{d\beta}{dt} = \frac{dZ}{dx}$ (C being a constant whose value is here immaterial). Now if the same magnetic field β exists inside the screened space, the electric field associated with it must still be given by the above equation, and cannot therefore differ essentially from the electric field of the wave outside. This argument suggests that the electric and magnetic fields of the wave must be considered as coexistent and inseparable and the blocking of either involves the blocking of the wave.

Maxwell's equations also show that in the case of a plane wave tilted forward in the direction of propagation (the type of wave which can travel over an imperfectly conducting plane earth), it is not possible to destroy the vertical component of the electric vector without destroying the whole wave; for the components X and Z of electric force must satisfy the relation $\frac{dX}{dx} + \frac{dZ}{dz} = 0$ so that, if Z is zero everywhere inside a given space, X must be independent of x in that space and cannot therefore be associated with a wave travelling in the direction of the axis of x; there is no alternating electric field—and therefore no wave—in the screened space.

The type of screen described in the Editorial recalls the optical grating; and the effect of a plane grating of equally-spaced parallel wires on electromagnetic waves travelling at right angles to it has been investigated by J. J. Thomson in his *Recent Researches in Electricity and Magnetism*; his results are briefly that waves in which the electric vector is perpendicular to the wires are almost entirely transmitted, while, if the electric vector is parallel to the wires, the waves are almost entirely reflected so that the grating acts as a perfect screen, as it does in the now well-known case of directive transmission by a double line of aerials. Close to the screen, of course, the field is complicated, but Thomson gives four to five times the distance between the wires as a maximum distance at which the complicating terms are appreciable. A complex incident wave can be supposed split up into constituent waves with electric vectors parallel and perpendicular to the wires of the grating; the first of these constituents is reflected and the second transmitted and so the effect of the screen is to polarise the wave.

I am not acquainted with any experimental work with screens such as are mentioned in the Editorial, so do not know if the distance of the observing station from the screen is sufficiently great to avoid the complications noted above; and the shape of the screen introduces further complications, so that unusual types of fields are to be expected. It seems desirable to draw attention to these possible explanations of any unusual features found, as they do not take liberties with the fundamental conceptions of electromagnetic theory. It may be remarked that isolated points or lines may exist where one of the electric and magnetic forces vanishes but not the other (nodal points or lines), although this cannot happen *throughout a given space*.

D. BURNETT.

"A Hoary old Fallacy."

To the Editor E.W. & W.E.

SIR,—I have just noticed a recent issue of *E.W. & W.E.* in which your leader writer calls attention (and, if I do not mistake the author of the leader, for the second time) to the fact that I publicly perpetuated "a hoary old fallacy." I acknowledge my sin and my shame, but still feel that the blame should be properly apportioned.

We engineers in our novitiate sit at the feet of wisdom and learn the gospel from the priests of science, the professors. Is it to be blamed on us, that, when we rise to fame, we still believe in the wisdom of our early mentors and repeat as gospel what we have been taught? Of course, we have to interpret much of theory in its bearing upon practice, but, in matters which have little bearing on practicalities—such as the supposed physical forms of æther waves—we can be forgiven for not examining too closely what is, to an engineer, of chiefly academic interest.

But I think your leader writer is right to point out a glaring example of error so that it may make teachers more careful in the future. In fact, an engineer might counsel the new generation of his fellow workers to be very wary of what he learns in school or university, and avoid the errors into which I, for instance, fell in my innocence.

Dare he, for instance, accept the dictum of a very learned professor that there are no sidebands, or that television has, or will have, by a slight technological adjustment of quantities, public service value? Perhaps the two dicta are mutually dependent.

Or again, will he not suffer a rude shock, after he has read an elementary book on wireless and finds it stated that the maximum efficiency of a "thermionic triode oscillation generator" is 50 per cent., to find that any engineer can prove 70 per cent. or even 80 per cent. efficiency? Or that reaction—I beg your pardon—retroaction in receiver circuits does no more than lower resistance? Or that it is necessary in commercial design of ordinary telephone transmitters to dissipate as much power in the low-frequency control system as the high-frequency generator?

If this letter is not too long or the list too formidable, might I remind you that it is whispered that another of our teachers said on the eve of the greatest revolution in wireless technique that there could be no more developments of a fundamental nature? And even our research laboratories give us the uncompromising statement that trees alone determine the attenuation of the ground wave in wireless broadcasting.

The sins of the fathers shall indeed be visited . . . An engineer nevertheless owes all his ground knowledge to the teachings of professors and, while we must all realise the great debt we owe to those who foreswear the rewards of commercialism in their desire to perpetuate knowledge, it is, I think, timely to point out that even they are at times fallible. When *they* perpetuate fallacies, however, they incur the greater responsibility inasmuch as they inculcate the expectation of unswerving loyalty among their followers, a loyalty commonly tested in a "final exam."

P. P. ECKERSLEY.

Abstracts and References.

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PROPAGATION OF WAVES.

RESEARCHES ON THE DIELECTRIC PROPERTIES OF IONISED GASES, AND HIGH FREQUENCY DISCHARGE.—H. Gutton. (*Ann. de Physique*, Jan., 1930, Vol. 13, pp. 62–129.)

Erratum. In last month's abstract, pp. 207–208, the 14th line on p. 208 should read " *above* 200 m. the potential increases with the frequency . . ."

MEHRFACHWEGE UND DOPPLEREFFEKT BEI DER AUSBREITUNG DER KURZEN WELLEN (Multiple Paths and Doppler Effect in the Propagation of Short Waves).—O. Böhm. (*Telefunken-Zeit.*, Dec., 1929, Vol. 10, No. 53, pp. 9–22.)

The writer first defines four types of multiple signals due to :—I.—Several paths, close to each other, forming a " bundle of paths " and causing intervals of the order of 0.001 sec. II.—Reflections between earth and Heaviside layer—intervals 0.01 sec. III.—Backward and multiple transits round the earth—intervals 0.1 sec. IV.—Reflections outside the earth's atmosphere—intervals over 1 sec. Neglecting Type IV as unimportant in practice, he deals first with Type III, illustrating them by oscillograms of the 15.3 m. Buenos Aires to Geltow tests. No means have yet been found for guarding against the forward, multiple transit signals, but luckily these are rarer—and generally weaker—than the backward signals. The latter can be guarded against by reflector systems : these, when fed by radiation only, give only a certain amount of protection, which is rendered almost complete (1 : 50) by feeding the reflector by coupling. In fact, with the latter arrangement at the receiver (reversed in direction) the strong forward signals can be cut out and the weak backward ones received perfectly. This thorough screening is very necessary in practice, since the backward signals are sometimes appreciably stronger than the forward.

Type II (" near " echoes—short-time echoes) are illustrated by results over 40 km. Their rapid and frequent fluctuations are attributed to quick movements in the layer. Four horizontal dipoles, one above the other, used as a receiving system, gave rise to these echoes, whereas the simultaneous use of three vertical dipoles gave no trace of them, owing to the vertical aerials taking no notice of nearly vertical radiation. It is probable that such echoes may occur over long distances, especially when the good reflecting surface of a sea lies between sender and receiver.

Type I, with intervals of the order of 0.001 sec., are only noticed in the high-speed working of picture telegraphy. Thus between Buenos Aires and Geltow, facsimile telegrams sent at the rate of 1 sq. decimetre per 4 minutes were perfect, while those four times quicker were completely illegible : this was in no way due to defects in the apparatus, for on many occasions while spoiled records were being received on the forward signals, perfect ones could be received on the backward signals. The constant alterations of the multiple paths was also confirmed by transmitting a straight line perpendicular to the direction of scanning : at high speeds the greatly broadened record was built up of many separate parts, whose varying disposition showed that the whole " bundle of paths " was in a constant state of change.

Doppler Effect : the writer next gives an illustration, and explanation, of the peculiar (slanting) distortion of a record due to the Doppler effect produced by these fluctuations in path-length. Such manifestations are noticeably liable to occur at the same time as fading, and he considers it probable that many cases of fading may be explained simply by the Doppler effect (which may amount to 20,000 cycles per sec.) throwing the receiver out of resonance. He then deals with the whole question of Fading, both " general " and " selective " — the former he attributes to a number of causes, some not yet understood : ionisation changes (variations in damping and refractive index) and variations in the plane of polarisation. Selective fading is attributed to pure interference phenomena, due to multiple paths and path-variations. Tests (Telefunken with Siemens and Halske) on the selective fading of side-bands are described. This fading sometimes seriously affects intelligibility of speech. Moreover, since the carrier wave itself is subject to selective fading which affects the total strength of speech [square law demodulator], this class of fading has a secondary result resembling " general " fading. No cure has yet been found for selective fading.

General fading, on the other hand, can be combated in several ways : suppression and replacement of carrier wave, amplifying devices [automatic control], limiting, aerial combinations, modulation or " wobbling " of the transmitted wave. The first of these is more difficult on short than on long waves, but very good results have been obtained between Berlin and Buenos Aires—though trouble with the Doppler effect was occasionally encountered. The second method is very effective for general fading, but not completely satisfactory for selective fading of the carrier—at least, when the amplification control is applied *before* rectification : but even this type of fading seems to be counteracted by l.f. control depending on the final output of a constant control note, and Telefunken are adopting this system " everywhere." It may with advantage be combined with r.f. regulation dependent on the intensity of the combined bands.

For picture telegraphy, Telefunken has evolved a successful special control system in which during each in-coming impulse the amplification is brought quite quickly to the right value and remains almost unchanged during the pauses. For black-and-white reproduction this is combined with a form of limiting, in which any signal *above* a certain threshold value records itself.

Amplitude- or frequency-modulation. The

former is largely employed to reduce selective fading of the carrier, but is not completely effective: it is better to send out several wavelengths close together, of equal amplitude—a plan which Telefunken are now trying. Frequency modulation (" wobble ") seems to have advantages over amplitude modulation: the strength never falls nearly to zero (as it does in the latter system) because at every instant the amplitude of the signal passes through a series of values, in time with the wobbled frequencies (but *see* Roder, these Abstracts, under " Transmission "). This improvement is clearly shown in oscillograms.

By a combined use of these remedies most of the difficulties of fading in picture telegraphy have been overcome. The broadening of lines, which still limits the speed of transmission, is still being fought against; but a description of the methods now being tried would be premature.

FADING EFFECTS IN THE RECEPTION OF SHORT WAVES.—Gothe and Schmidt. (*See* under " Reception.")

" WOBBLE " FOR PREVENTION OF FADING.—Roder. (*See* abstract under " Transmission.")

LES ONDES TRÈS COURTES (Ultra-short Waves).—R. Jouaust. (*L'Onde Élec.*, Jan., 1930, Vol. 9, pp. 5–17.)

A general survey, with particular attention to the work of Ferrié, Gutton and Touly, Mesny, David, Beauvais and other French investigators (*see* various past Abstracts). The depression of the optical horizon due to atmospheric refraction (involving an atmospheric coefficient which, as Koss showed, is clearly influenced by the condition of humidity) probably applies also to ultra-short waves and explains the ranges beyond the " straight-line path " which have been obtained—*e.g.*, France to Corsica. Weakening of signals at the close of day is also explained by refraction.

LOW RESISTANCE OF EARTH MATERIALS.—W. I. Rooney. (*Sci. News-Letter*, 22nd Feb., 1930, Vol. 17, pp. 120–121.)

" Certain solid substances, such as clay impregnated with magnesium salts, are better conductors of earth currents than sea water, formerly considered one of the best conductors. The resistance of earth materials may vary from 100 ohms to 5,000,000 ohms per cubic centimetre within the same square mile."

WAVE PROPAGATION OVER CONTINUOUSLY LOADED FINE WIRES.—M. K. Zinn. (*Bell Tech. Journ.*, Jan., 1930, Vol. 9, No. 1, pp. 189–206.)

An investigation of the character of wave transmission along a pair of wires each of which is loaded with a continuous sheath of magnetic material. Expressions for the propagation constants are developed from the general theory of such a system. Simple approximate formulæ are given for the size of wires that are generally used in paper-insulated cables.

DIAGRAMME DES CHAMPS ÉLECTRIQUES MESURÉS À MEUDON (Diagram of Electric Fields Measured at Meudon). (*L'Onde Élec.*, Nov., Dec., 1929, Vol. 8, pp. 496–501.)

One of a long series provided by the URSI.

JAPANESE RESULTS ON SHORT WAVES.—Nakagami, Ono and Anazawa. (Summary in *Rev. Gén. de l'Élec.*, 1st Feb., 1930, Vol. 27, pp. 40D–41D.)

Results of tests up to 1928. Wavelengths varied from 25 m. to 100 m. Between Japan and Nauen, 26 m. waves on 2 kw. gave better results than 42 m. on 7 kw. On 100 watts, Japan had very good results with a 79 m. wave, with N. Zealand, Hawaï and the Philippines.

LONG-WAVE RADIO RECEIVING MEASUREMENTS AT THE BUREAU OF STANDARDS IN 1928.—L. W. Austin. (*Proc. Inst. Rad. Eng.*, January, 1930, Vol. 18, pp. 101–105.)

Cf. 1928 Abstracts, p. 683. The annual averages of both European and nearby American stations were slightly lower than those of 1927, while atmospheric disturbances were about the same.

L'ONDOSCOPE, APPAREIL DE PROJECTION POUR LA DÉMONSTRATION DES PROPRIÉTÉS GÉNÉRALES DES ONDES (The Ondoscope, an Apparatus for the Demonstration of the General Properties of Waves). —. Charron. (*Génie Civil*, 25th January, 1930, Vol. 96, pp. 89–90.)

SULLA PROPAGAZIONE DELLE ONDE NEI MEZZI CON ASSORBIMENTO SELETTIVO (The Propagation of Waves in Media with Selective Absorption).—G. Giorgi. (Summary in *Nuovo Cim.*, Jan., 1930, Vol. 7, pp. xxxii–xxxiii.)

UNE EXPÉRIENCE DÉCISIVE RELATIVE À LA LOI DE LA PROPAGATION DE LA LUMIÈRE (A Decisive Experiment as to the Law of Propagation of Light).—B. Zanella. (*Rev. Gén. de l'Élec.*, 12th October, 1929, Vol. 26, pp. 569–574.)

Translated from a paper in *L'Elettricista*. The tests proposed both use the Kerr cell in place of the Fizeau disc (*cf.* Mittelstaedt, 1929 Abstracts, p. 567).

LA PROPAGATION DES ONDES SUR LES SURFACES ÉLASTIQUES À SIX PARAMÈTRES (The Propagation of Waves on Elastic Surfaces with Six Parameters).—L. Roy. (*Comptes Rendus*, 10th Feb., 1930, Vol. 190, pp. 341–343.)

THE THEORY OF THE ZONE PLATE DERIVED FROM VOIGT'S INTEGRAL.—C. T. Lane. (*Canad. Journ. of Res.*, January, 1930, Vol. 2, pp. 26–30.)

The writer has found that hardly any text-books in English treat diffraction theory satisfactorily. In the present paper he works out the properties of the zone plate, in the case where it is illuminated by monochromatic plane waves at normal incidence.

Optique des Surfaces Diffusantes (The Optics of Diffusing Surfaces).—J. Dourgnon and P. Waguet. (*Bull. d. l. Soc. Franç. d. Élec.*, Sept., 1929, Vol. 9, pp. 939–960.)

ATMOSPHERICS AND ATMOSPHERIC ELECTRICITY.

Fenomeni Radioatmosferici (Radioatmospheric Phenomena).—P. Ilardi. (*La Meteorologia Practica*, 1929, Vol. 10, No. 2.)

The paper begins with a historical survey and critical comparison of the work hitherto done on the subject of radioatmospherics. Special attention is drawn to Paoloni's auricular scale, which classified radioatmospherics into eight grades of true atmospherics and six grades of intense local phenomena. Mention is also made of the work of Watson Watt on percentage of directivity, of Pickard and de Groot on the relation between atmospherics and insulation in the upper atmosphere, and of Kincaid on atmospherics and barometric pressure. A short account is given of Lugeon's work on the orographical effect and his explanation of the phenomena as due to the emission of highly damped Hertzian waves by centres of vapour condensation. The work of Watson Watt on the relation between atmospherics and rain gave rise to an explanation of rain as due to separation of electric charges, followed by a neutralisation phase when discharge occurs. De Groot and the 1924 International Congress at Madrid found, however, that there was no well-defined connection between atmospherics and rainfall zones. The connection between atmospherics and astrophysical phenomena, *e.g.*, magnetism, is discussed.

The work of Bureau indicated that atmospherics are produced in the neighbourhood of the place of observation and are caused by meteorological disturbances in general. Strong signals are usually only disturbed by near atmospherics and, with more sensitive receivers, more distant signals come in. The investigations of Bellescize on resonance and secondary atmospherics are mentioned.

The experiments of the Royal Meteorological Society made use of a synchronising system based on the use of the syllables of a specially transmitted discourse. The method was essentially auricular and the result obtained was that only a minimal percentage of the atmospherics disturbing broadcasting come from a short distance. The atmospherics disturbing signals of medium wavelength have relatively distant sources. Cases were noted in which "cold fronts" were the sources of atmospherics.

The writer criticises these results as follows :—

(1) They were essentially preliminary and the synchronising method used was unsuitable.

(2) No mention was made of the intensity or scale of intensity.

(3) Large personal errors were bound to be involved.

(4) Most of the observations were made in England, a region free from strong, numerous atmospherics.

(5) The results disagree completely with those of Bureau.

Bureau has made more experiments which give very short ranges for the atmospherics, but his explanation that the transmitted wave is locally modulated by the atmospheric does not seem feasible. He gives graphs to show correspondence between groups of atmospherics and passage of different masses of air and says that atmospherics are due to instability of the atmosphere ; but this does not disprove the arguments of the supporters of the "cold fronts—long range" hypothesis.

Ilardi then proceeds to describe the work of the Italian Radioatmospheric Service. This is based on the radioatmospheric scale and auricular system of Paoloni, as this is thought to give greatest simplicity and fidelity of results. Great importance is attached to ensuring that the different observing stations are concerned with the same atmospheric discharges and observations are made during the sending of rhythmic signals on Wednesdays and Saturdays 18.35–18.40. A network of stations is to be formed and foreign co-operation is promised.

An analysis is now given of data recorded in 1927 at the Geophysical Station at Monte Cassino. The wavelength used was 2,600 m. and the hours of observation were 9, 15 and 21. Atmospherics recorded were classified according to the Paoloni scale of eight grades, four distinct and four confused. An annual graph was drawn for every type of atmospheric considered, in order to study their distribution at various seasons and their relation to general and local meteorological disturbances. In the first group of graphs the daily mean over periods of 10 days is plotted for the 36 periods composing a year ; this gives the density of each type of atmospheric during the year. The second group of graphs gives the total number of atmospherics at the hours 9, 15 and 21 and so the hourly variation. The results are compared with meteorological observations. Typical graphs of group 1 are given but without scales of reference. The hourly variation gives a morning minimum and evening maximum.

The connection between atmospherics and atmospheric pressure seems to be that high pressure corresponds to low density, low pressure to high density and frequency of atmospherics. The influence is most marked in the first and last months of the year when atmospherics are fewer in number. An oscillographic study of the various types is necessary.

The observations which have been made in tropical regions show that the general effects are exactly similar to those observed in temperate regions.

The indications of the automatic static recorder are thought to be suitable only for a global study of density and direction of atmospherics and not for a detailed investigation of the different types. Ilardi states that all serious experiments have used the auricular method and hence are all based on the selective faculty of the human ear.

Finally a programme is given of the experiments to be undertaken in Italy ; these comprise a study of the effect on various wavelengths at different hours of the day. The question of range of atmospherics is not yet solved.

Investigations on Heavy Ions in the Atmosphere.—H. Israël. (*Gerlands Beitr.*, No. 2, Vol. 23, 1929, pp. 144–166.)

NUOVE RICERCHE SULL'ELETTRICITÀ ATMOSFERICA (New Researches on Atmospheric Electricity).—Idrac. (*Nuovo Cim.*, Aug.–Sept., 1929, Vol. 6, pp. cxli–cxlii.)

Extracts from a paper by Eredia in *Notiziario Tec. di Aeronautica* (July and Oct.). Idrac describes an electrified stratum very frequently occurring between 6000 and 7000 m., generally of little thickness but fairly stable. A second recrudescence of a high potential field seems to occur between 12,000 and 13,000 m.

METEORIC SHOWERS AND RADIO TRANSMISSION.—H. Nagaoka. (*Proc. Imp. Acad.*, Tokyo, June, 1929, Vol. 5, pp. 233–236.)

Denning arrived at a mean height of about 100 km. for the arrival of meteors: the writer suggests that the dust thus dispersed, and the passage of the meteors through the ionised layer, may have some effect on radio transmission.

ÜBER KUGELBLITZE (Globular Lightning).—A. Meissner. (*Met. Zeit.*, 1930, No. 1, pp. 17–20.)

A general explanation of globular lightning is found by assuming that the phenomenon is the electrical analogy of a waterspout; it may be regarded as formed by lightning discharges passing very near to one another in opposite directions which set the ionised gas between them into rotation. It thus develops the properties of a gyrostat and its stability depends on the equilibrium between the pressure of the external air and the centrifugal force of the rotating gas composing it.

On this assumption it is also possible to explain the formation of globular lightning inside a closed space (*cf.* Marchant, April Abstracts) and the phenomena which are sometimes observed in connection with electrostatic influence machines. The velocity of the rotating air is estimated to be of the order of 645 metres per second.

L'INFLUENCE DE LA NATURE DU TERRAIN ET DES LIGNES ÉLECTRIQUES SUR LES POINTS DE CHUTE DE LA FOUDRE (The Influence of the Nature of the Ground and of Electric Lines on the Striking Points of Lightning).—A. Boutaric: C. Dauzère. (*Génie Civil*, 15th Feb., 1930, Vol. 96, pp. 158–160.)

A summary of Dauzère's work, dealt with in these Abstracts (1928, p. 517; 1929, 568).

PROTECTIVE VALUE OF CHOKING COILS.—S. M. Jones and R. A. Hudson. (*Elec. World*, 12th Oct., 1929, Vol. 94, pp. 729–733.)

A choking coil alone cannot appreciably decrease the voltage or the steepness of the front of the wave transmitted, unless the inductance is many times greater than the usual value. To decrease the voltage of the transmitted wave to two-thirds of that of an incoming 7-microsecond-front wave, an inductance of 8000 microhenries would be required instead of the usual value of about 36.5 mhy. There would be serious objections to the use of so high an inductance.

THYRITE FOR LIGHTNING ARRESTERS.—K. B. McEachron. (*Sci. News-Letter*, 8th Feb., 1930, Vol. 17, p. 87.)

Thyrite is a moulded compound including silicon carbide or carborundum. "Each time the voltage across a piece of thyrite is doubled, the current increases 12.6 times . . . Samples have a resistance of 50,000 ohms at 100 v. and less than half an ohm at 10,000 v. They will carry lightning discharges as high as 30,000 A. without any signs of distress." The contact surfaces are coated with metal by the Schoop metal-spraying process (1929 Abstracts, p. 112). *Cf.* Slepian, Tanberg and Krause, April Abstracts, p. 209.

PROPERTIES OF CIRCUITS.

ELEKTROMAGNETISCHE AUSGLEICHSVORGÄNGE IN GESCHICHTETEM ERDREICH (Transient Oscillations in Stratified Earth).—F. Ollendorff. (*Archiv für Elektrot.*, 18th Jan., 1930, Vol. 23, No. 3, pp. 261–278.)

Extracts from author's summary:—Transient oscillations in laminated conductors are investigated mathematically; in particular, an expression is found for the transient electromagnetic field of the return circuit in a non-homogeneous earth with greater conductivity at the surface. . . . In the neighbourhood of the conductor (near zone) the greatest values of the field strength occur immediately after the current is switched on, whereas at greater distances the maximum disturbance is not reached until a certain time has elapsed. Thus a macroscopic velocity of the transmission process may be defined; this proves to be a constant depending on the electromagnetic constants of the lamina. . . .

In the case of the transient oscillations caused by exponential increase of a direct current, the transient field in the earth reaches a maximum and subsequently decreases very slowly, the rate being inversely proportional to the time. Estimation of the maximum shows that it is considerably smaller than the highest voltage reached when the current is suddenly increased. . . . For transient oscillations due to alternating current, a similar estimation shows that the steady voltage has exactly the same value as the maximum transient voltage, so that the highest voltage reached has a value double that of the steady voltage.

When an impulsive voltage is put directly into the closed circuit, a short circuit current arises . . . which initially increases very rapidly and, later, rises more slowly but never becomes stationary. The impossibility of defining a steady state is a characteristic property of the transient oscillation phenomena investigated here.

SOBSTVENNIE NEZATUHAIUTSHIE KOLEBANIA TELEGRAFNOTELEFONNOI LINII (Sustained Free Oscillations in a Transmission Line).—M. I. Mantrov. (*T.i T.b.p., Leningrad*, December, 1929, Vol. 10, pp. 608–622.)

In Russian. A report on investigations carried out at the Moscow Institute of Physics with the object of (*a*) ascertaining whether the fundamental transmission line equations are applicable to an artificial line made up of a number of elementary low frequency filter sections, and (*b*) studying free oscillations in such a line. Oscillations were induced in an artificial line from a low frequency oscillator transformer coupled to it and the line characteristics measured, using a Wheatstone bridge and a thermocouple and mirror galvanometer. The results so obtained show that an artificial line of this kind can be regarded from the point of view of its electrical properties as being practically equivalent to the theoretical line defined by the fundamental equations. By including the artificial line in the oscillating circuit of the valve the study of free oscillations in the line is made possible. Two different oscillating circuits were used and their frequencies measured for different lengths of the artificial line. Theoretical expressions for the determination of these frequencies are given. Curves showing the distribution of the square of the current are also shown.

THE USE OF CONTINUED FRACTIONS IN THE DESIGN OF ELECTRICAL NETWORKS.—T. C. Fry. (*Bell Tech. Journ.*, January, 1930, Vol. 9, No. 1, p. 229.)

Abstract only of paper in the *Am. Math. Soc. Bull.*, July–August, 1929. In U.S. Patent No. 1570215 and several technical papers by Bartlett and Cauer it has been shown that continued fractions can often be used in designing networks with preassigned impedances. The chief difficulty of the method has been that it frequently required the structures to contain negative resistances, inductances or capacities, and therefore the results, though correct in theory, were often worthless in practice because the networks could not be constructed.

The present paper removes this difficulty in virtually all cases where the analytic character of the desired impedance is known, that is, where it can be represented by a formula and not merely by a graph. In such cases the choice of a type of structure, as well as the assignment of values to the elements, becomes almost a matter of routine with the definite assurance in advance that no negative elements will be required.

THEORIE NEUTRALISIERTER VERSTÄRKERKETTEN (The Theory of Neutralised Amplifier Chains).—R. Feldtkeller. (*Zeitschr. f. Hochf. Tech.*, Feb., 1930, Vol. 35, pp. 45–55.)

The well-known principle of neutralisation, for suppressing the reaction of the oscillating power in the anode circuit on the preceding grid circuit, is usually carried out by employing as neutralising impedance a condenser connecting the secondary winding of a coupling transformer to the grid circuit of the preceding valve. The present paper shows that the same principle can be applied to amplifier chains with broad zones of distortionless amplification, by using as each neutralising impedance a series connection of condenser, inductance and resistance connected between the grids of two successive valves. The neutralisation thus obtained covers the entire frequency zone, and the form of the neutralisation conditions (as derived by the writer's theoretical analysis) shows that it is independent of the impedances between which the chain is connected.

The writer investigates the distortion at the lower and upper limits of the frequency range, and the dependence of amplification on this upper limit. Rules for the calculation of the components are evolved : both l.f. and r.f. amplifiers are considered.

ELECTRICAL WAVE FILTERS.—M. Reed. (*E.W. & W.E.*, March and April, 1930, Vol. 7, pp. 122–128, and 190–196.)

First two instalments of an article on the theory and calculation of wave filters based chiefly on the work in America of Campbell, Zobel, Carson, and Johnson and Shea. The sections at present dealt with are as follows :—(*A*) The fundamental formulæ for a symmetrical structure are derived, and it is shown how these formulæ may be applied to wave filters. (*B*) It is shown that any complicated filter may be reduced to a simple filter from which it is said to be " derived," and all the formulæ for the complicated filter may be calculated by considering the simple filter only. (*C*) The above analysis is applied to the design of wave filters in general. As illustrative examples, the designs of a low-pass and of a band-pass filter are worked out in full.

THE EQUIVALENT GENERATOR THEOREM.—V. D. Landon. (*Proc. Inst. Rad. Eng.*, Feb., 1930, Vol. 18, pp. 294–297.)

Author's summary :—It is proved that any electrical network with two output terminals may be replaced by a generator and a series impedance without changing the current in an externally connected load. The voltage of the generator is the no-load voltage of the output terminals. The value of the series impedance is the impedance of the unloaded network looking into the output terminals. The use of the theorem is illustrated, and it is pointed out that it is valid for transient as well as steady state conditions.

SELECTIVITY OF COUPLED COILS.—A. L. M. Sowerby. (*Wireless World*, February 26th, Vol. 26, pp. 214–219.)

A discussion of the means available for securing flat-topped resonance curves " of the right width to be a neat fit on the transmitter's frequency band," taking into account the effect of coil resistance.

THE BALANCE OF POWER IN AERIAL TUNING CIRCUITS.—F. M. Colebrook. (*E.W. & W.E.*, March, 1930, Vol. 7, pp. 129–140.)

The problem of coupling an aerial to a receiving circuit involves two factors, sensitivity and selectivity. The two factors must for various reasons be considered separately, and the present paper is devoted almost exclusively to sensitivity.

Considering the receiver as an input impedance made up of a resistance R_s in parallel with a capacity C_s, the writer shows that the " balance of power " is obtained (*i.e.*, equal power is consumed in aerial circuit and receiver circuit) when the tuning and coupling arrangements are such that the reactance of the equivalent aerial circuit is reduced to zero, while at the same time its effective resistance is doubled by suitable control of the load effect of R_s (this is assuming that the coupling and tuning arrangements are of negligible resistance). Thus the optimum condition for sensitivity is given by the equation $\frac{E^2}{4R_a} = \frac{V^2}{R_s}$, where R_a is the resistance component of the aerial effective impedance and E and V are the r.m.s. values of the potential differences maintained across the aerial and across the receiver respectively. "One interesting deduction follows immediately. The maximum voltage magnification obtainable under the given conditions is $V/E = \frac{1}{2}\sqrt{R_s/R_a}$. For instance, taking R_a as 10 and R_s as 5×10^4, the upper limit of V/E is 35.4, and by no means can this figure be exceeded. On the other hand, it is easy to fall considerably below this figure, even with a resistanceless tuning system, if the coupling conditions are ill suited to the given aerial and receiving set." The general proposition is illustrated and confirmed by reference to particular tuning and coupling systems. Reference is here made to a paper by Medlam and Oschwald (*ibid.*, 1925) of which the present paper is in effect a generalisation.

A NEW TRANSFORMATION IN ALTERNATING-CURRENT THEORY, WITH AN APPLICATION TO THE THEORY OF AUDITION.—B. van der Pol. (*Proc. Inst. Rad. Eng.*, Feb., 1930, Vol. 18, pp. 221–230.)

See 1929 Abstracts, p. 268.

EIN BEITRAG ZUR DARSTELLUNG DER FREQUENZABHÄNGIGKEIT VON TRANSFORMATORSCHALTUNGEN FÜR NIEDERFREQUENZVERSTÄRKUNG (Contribution to the Representation of the Frequency Dependence of Transformer Connections for Low Frequency Amplification).—H. Kafka. (*Zeitschr. f. Hochf. Tech.*, Feb. 1930, Vol. 35, pp. 56–60.)

In the equation for the ratio of the grid potential vectors of two successive valves, transformer-coupled, namely

$$\frac{\mathfrak{E}_{g1}}{\mathfrak{E}_{g2}} = \frac{1}{Vu}\left[1 - \eta^2\sigma + j\left\{\eta\,(D_1 + d_2) - \frac{D_1}{\eta}\right\}\right],$$

where V = amplification factor, u = turns ratio, $\eta = \frac{f}{f_0}$ (f_0 being the natural frequency of the secondary circuit), σ = total leakage factor, and D_1 and d_2 are the primary and secondary dampings, the quantity within the square brackets is a measure of the frequency dependence of the ratio in question, and is denoted by the vector $\mathfrak{F}$.

By giving different values to the frequency ratio η, the end point of $\mathfrak{F}$ describes a curve which gives a very useful picture of the dependence on frequency of the circuit investigated. The writer illustrates the practical construction of this locus by taking as an example the new Philips' transformer and an A. 415 valve, tabulating the various values of the terms composing $\mathfrak{F}$, for values of f ranging from 50 to 10,000, thus arriving at $|\mathfrak{F}|$ for those frequencies and finally plotting the curve. He then discusses in detail the shape of this curve and its implications, ending by considering the influence on it of the output impedance across the terminals of the transformer.

THEORIE DER ZWEIELEKTRODENRÖHREN UND ERZEUGUNG ELEKTRISCHER SCHWINGUNGEN VON EXTRA NIEDRIGER FREQUENZ (The Theory of the Two Electrode Valve and the Generation of Extra Low Frequencies).—Y. Ito. (*Zeitschr. f. Hochf. Tech.*, Jan., 1930, Vol. 35, pp. 12–20.)

In addition to the usual electrostatic control of the thermionic current of a valve by the action of the grid, there is the possibility of controlling it by changes in the heating current, or rather by the changes in the filament temperature thus produced. As is well known, very small changes of filament temperature will produce large alterations in the saturation current; it must, therefore, be possible by such means to obtain amplifying effects, and consequently—by the use of reaction—to obtain self-sustained oscillations. The writer makes a theoretical investigation of these possibilities: the present paper deals only with amplification; the generation of oscillations will be considered in Part II.

The theoretical maximum obtainable amplification factor ($W = \sqrt{\frac{N_v}{N_u}}$, where N_v and N_u are the output and input powers respectively) is found to be given by $W = \frac{1}{2} \cdot \frac{1}{\sqrt{r}} \sqrt{G}$; here r is the resistance of the filament and G is the "merit" of the valve, measured by four times its maximum a.c. output in watts for an application of an a.c. of 1 A. to the filament. For a particular valve taken as an example, W = 9.6 for a frequency of 1 p.p.s. and 3.5 for a frequency of 20 p.p.s. Experimental confirmation of these values was obtained, the necessary extra-low frequencies being generated by the diode circuit described in Part II. Quite good agreement was found between calculated and observed values.

PHASENVERHÄLTNISSE UND SCHWINGUNGSEINSATZ BEI EINEM ZWEIRÖHRENSYSTEM NACH ART DER LEITHÄUSER-HEEGNER-SCHALTUNG (Phase Relations and Oscillation Threshold in a Two-Valve Leithäuser-Heegner Circuit).—M. v. Ardenne and K. Schlesinger. (*Zeitschr. f. Hochf. Tech.*, Feb., 1930, Vol. 35, pp. 60–67.)

The two-valve Leithäuser-Heegner capacitive reaction circuit was investigated both theoretically and experimentally by its originators in 1921, but the changed conditions now existing (*e.g.*, the increased amplification factors and reduced internal capacities of modern valves, which enable the circuit to be used for wavelengths down to about 200 m.) make a re-examination desirable; in particular, the use of the circuit for broadcast reception calls for an investigation of the phase relations in the anode circuit and the reaction branch circuit.

To avoid certain difficulties in working with the frequency-range in question ($0.5 - 1 \times 10^6$ p.p.s.), the test circuit was designed on an electrically proportionate scale of 50 to 1, *i.e.*, for a wavelength of 15,000 m., so that the internal capacities were negligible in comparison with the concentrated, adjustable and calibrated external capacities. This circuit was used to confirm the theoretical results arrived at from a discussion of the vector equation for the circuit connected to an oscillatory circuit: *e.g.*, the conditions for self-excitation, from which emerge the existence of an optimum phase-displacement, the necessity for a capacitive phase rotation in the anode circuit, and the gain-producing action of a non-reactive resistance connected in the reaction branch circuit.

An expression is derived for the amplification due to reaction: this gives a criterion for a setting-up of oscillation. Expressed in words, the condition for smooth adjustment of reaction to oscillating point, with avoidance of back-lash and "jump" ("ziehen" and "springen") is that at the threshold either the input resistance or the total amplification, or both simultaneously, must decrease, or else one of these factors must decrease so sharply that its decrease swamps any increase of the other factor. The practical implications of this are indicated: the avoidance of these two defects by making use of grid- or anode-rectifying action. Thus in a particular case taken, a harsh oscillation adjustment with a large back-lash loop was completely cured by a positive grid bias of 2 v. "It should be even easier to apply grid-current damping in the *second* circuit, since greater potential amplitudes are present there." In regard to the use of anode rectification, the writer refers to his and Schlesinger's paper on the necessity for ohmic resistance of a proper value inserted in the anode circuit (Jan. Abstracts, p. 37).

O SOBSTVENNIH KOLEBANIAH V FOTOELEMENTAH (The Self-oscillation of Photo-electric Cells).—B. L. Rosing. (*T.i T.b.p.*, Leningrad, December, 1929, Vol. 10, pp. 590–598.)

In Russian. A theoretical discussion of the subject based on the author's experiments is presented. The nature of the oscillations and the conditions necessary for their production are established. The dependence of the frequency of the oscillations on (*a*) the constants of the oscillating circuit, and (*b*) the intensity of illumination of the cell is discussed. The possible use for signalling purposes of oscillations controlled by the variable illumination of a cell is indicated. Some oscillograms obtained by means of a cathode ray oscillograph are shown.

CONVERSIONE STATICA ED ARMONICA DI FREQUENZA (Static and Harmonic Conversion of Frequency).—F. Vecchiacchi. (*Elettrotec.*, 5th Jan., 1930, Vol. 17, pp. 2–10.)

A long paper, copiously illustrated with oscillograms, on frequency multiplication and de-multiplication by circuits containing triodes.

THE DYNATRON: A REVIEW OF A FORGOTTEN DEVICE, WITH SOME SUGGESTIONS FOR A REVIVAL OF IT.—W. H. Newbold. (*QST*, Feb., 1930, Vol. 14, pp. 33–36.)

The writer considers that this circuit had its usefulness curtailed by lack of suitable valves, and that the valves of to-day open up fresh possibilities. Apart from its special properties as an oscillator, its power of supplying negative resistance to a circuit should be useful for increasing selectivity, and in connection with super-regenerative methods of receiving short waves. He refers to A. W. Hull's two papers (*Proc. I.R.E.*, Feb., 1918 and March, 1922), the second of which deals with the use of the pliodynatron (dynatron with second grid) as a detector.

THE GENERATION OF POLYPHASE HIGH FREQUENCY CURRENTS.—Tank and Ackermann. (*See* under "Transmission.")

THE FLYWHEEL CIRCUIT OF AN ANTENNA.—Lüthy. (*See* under "Aerials.")

TRANSMISSION.

DIE ERZEUGUNG KÜRZESTER ELEKTRISCHER WELLEN MIT ELEKTRONENRÖHREN (The Generation of Ultra-Short Waves by Thermionic Valves).—H. E. Hollmann. (*Zeitschr. f. Hochf. Tech.*, Jan., 1930, Vol. 35, pp. 21–27.)

First part of a comprehensive survey bringing up to date the same writer's survey dealt with in 1929 Abstracts, pp. 207, 268/9, and 326; also his I.R.E. paper on the mechanism of electron oscillations in a triode (p. 274). He begins by commenting on the great amount of work which has been done recently on the subject: his paper goes on by referring first to his own theory of "frequency reaction" (1929 Abstracts, p. 571) and its confirmation by analogous phenomena in relaxation oscillations and in mechanical models; "negative" frequency reaction (as shown in the Multivibrator). It then refers to the variable capacity of valve electrodes—Kohl's idea of the effect of the "electron gas" as dielectric (1929 Abstracts, p. 269); the writer's own results with "grid-diodes" (Feb. Abstracts, p. 98), obtaining electronic oscillations disobeying the B.-K. relation, and increasing in wavelength for increase of grid voltage—their behaviour being explained by the retarding field effect of the negative space-charge; Hornung's investigations of Kohl's results (1929 Abstracts, p. 269) and his explanation, alternative to Kohl's, based on the parallel connection of the inductance of the cathode, and its leads, to the effective inductance of the oscillatory circuit.

The paper then deals with electron oscillations between the grid wires: Pierret and his TMC valve and ultra-B.-K. oscillations (12–18 cm.) suggested as due to electron swings from one part of the grid to another (1929 Abstracts, p. 149); Beauvais, confirming Pierret's results in that the frequency altered with the spacing of the grid wires; the writer's results with the same type of valve (*ibid.*, p. 389) and his disbelief in Pierret's theory. A long section is devoted to Knipping's work (*ibid.*, pp. 571–572) and another long one to Möller's (March Abstracts, p. 157): in connection with the above, reference is made to Tonks's earlier work on the "virtual cathode" (surface of zero potential occurring with large emission currents) and its effects.

Part I ends by considering Kalinin's results with a Russian transmitting valve (wavelengths down to 8 cm.—*see* Jan. Abstracts, pp. 41–42) and those of Potapenko (March Abstracts, pp. 157–158).

SCHWINGUNGEN IN DREIELEKTRODENRÖHREN MIT POSITIVEM GITTER (Oscillations in Triodes with Positive Grid Voltage).—M. J. O. Strutt. (*Ann. der Physik*, Jan., 1930, Series 5, Vol. 4, No. 1, pp. 17–32.)

Author's summary :—(1) The normal Philips emitter valve TAO 810 is very suitable for the production of high frequency oscillations with positive grid voltage. (2) If the filament voltage is kept constant and the grid voltage increased, a series of oscillation regions appear at voltages which form a geometric series. (3) In each of these oscillation regions the wavelength is constant, regarded as a function of the grid voltage. Examples of wavelengths measured were 120 cm. ; 45 cm. ; 17 cm. and [again] 17 cm. (4) On increase of the filament voltage, the oscillation regions move towards higher grid voltages, the condition stated under (2) being always fulfilled. (5) Increase of filament voltage with constant grid voltage results in decrease of the wavelength.

(6) Variation of the length of the Lecher wire system coupled to the triode, the grid voltage remaining constant, causes all known phenomena of the theory of coupled oscillating circuits to arise. (*a*) Small variations of intensity ; no alteration in the wavelength. (*b*) Large variations of intensity ; discontinuous variations in the wavelength. (*c*) Large variations of intensity ; "Ziehen" loop.

(7) These phenomena occur in the first and second oscillation regions, but in the third and fourth only (*a*) are observed. (8) The maximum intensity for a wavelength of 120 cm., was more than 100 mA., for a wavelength of 17 cm. more than 10 mA., with a heavy load which the triode supports for several hours.

GENERATION OF MULTIPHASE HIGH FREQUENCY CURRENTS. (German Pats. 484463 and 484845, Wired Radio Inc., pub. 17th and 23rd Oct., 1929.)

(1) Each of two coils at right angles is connected to an oscillatory circuit, these two circuits being loosely coupled together and one of them being excited by a h.f. generator. The currents in the two coils are 90° out of phase, so that a rotating field exists in the interior. Three coils are disposed at an angle of 60° with each other in this field, and in them are induced three-phase currents which can be used to control the grid circuits of three power valves.

(2) A similar arrangement using a rotating electrostatic field instead of an electromagnetic one.

ÜBER DIE ERZEUGUNG VON *n*-PHASEN-HOCHFREQUENZSTRÖMEN (The Generation of Polyphase High Frequency Currents).—F. Tank and L. Ackermann. (*Helvet. Phys. Acta*, No. 7, Vol. 2, 1929, pp. 512–521.)

Multi-phase high frequency currents find their application in the production of high frequency rotating fields, in special arrangements for directed wireless, and in the test room. The authors investigate mathematically the processes involved in the production of such currents, summing up as follows :—" A system of n similar, symmetrically coupled valve generators is so excited that between the corresponding currents of successive generators a phase difference of $2\pi/n$ or a whole multiple of this exists." If the various circuits are far out of tune with each other, the mutual reaction is small and each one keeps nearly to its own separate wavelength. As resonance is reached, a point is arrived at where the multiple oscillations break up, leaving only a single frequency—a phenomenon closely related to Möller's so-called " mitnahme " effect (*Jahrbuch d. drahtl. Tel.*, 1921, Vol. 17, p. 256). The equations for a triple system show that for a mutual coupling coefficient of positive sign a three-phase generation is possible, whereas with a negative coefficient the system oscillates without phase differences. A large number of different methods of connection for three-phase currents exist : one of the best is that of Mesny (*Proc. I.R.E.*, 1925, Vol. 13, p. 471). *See* also Takagishi and Iso, Jan. Abstracts, pp. 46–47.

ULTRA-SHORT WAVE DIRECTIVE TRANSMITTER.—L. S. Palmer and L. K. Honeyball. (*Journ. Scient. Instr.*, Feb., 1930, Vol. 7, pp. 50 and 67.)

Description, with diagram, of the Palmer-Honeyball 6.04 to 8.65 m. transmitter exhibited at the Physical and Optical Societies' Exhibition. The transmitting loop is of copper tubing of about one inch diameter, giving small inductance and large radiating surface ; it is electrically divided about its vertical axis so that one-half forms the anode inductance and the other half the grid inductance, the two halves being coupled by a condenser providing the tuning control. The filament leads pass inside the tubular grid inductance and are thus screened from induction by stray fields.

INSULATING TROUBLES IN ULTRA-SHORT WAVE GENERATORS.—Esau and Busse. (*See* under " Subsidiary App. and Materials.")

SUPPRESSION OF UNWANTED FREQUENCIES IN H.F. GENERATOR CIRCUITS.—(German Pat. 484372, Lorenz, pub. 14th Oct., 1929.)

The use of special absorbing circuits, tuned also to act as rejector circuits for the working frequency.

SHORT WAVE GENERATING CIRCUITS.—(German Patents 486009 and 484373, Telefunken, pub. 8th Nov. and 14th Oct., 1929.)

For frequency multiplication by an anode circuit tuned to a higher frequency than that impressed on the grid, the efficiency is increased by providing reaction—for the higher frequency—between grid and anode circuits. The second patent deals with push-pull circuits, externally driven : the need of a neutralising condenser, for abolishing reaction between grid and anode circuits, is avoided by connecting the input circuit to the mutually insulated cathodes instead of to the grids. *See* *Z. f. Hochf. Tech.*, Jan., 1930, p. 28.

DIE KRISTALLSTEUERUNG DER KURZWELLEN-SENDER (Crystal Frequency Control of Short Wave Emitters).—A. Meissner. (*Telefunken-Zeit.*, Vol. 10, No. 53, pp. 5–8.)

An account of the method of frequency control of short wave emitters by means of the natural vibrations of quartz plates. The chief difficulty is the existence of several natural frequencies of vibration of the plate in the neighbourhood of the frequency required. These may be explained as due to the presence of coupling between the natural length-wise and cross-wise vibrations of a rectangular plate. Small alterations in the length often reduce the number of the natural frequencies to unity: a table of experimental results is given. Variations in temperature also have the same effect. By careful grinding it is possible to produce with certainty quartz plates with one and only one frequency of vibration for any desired wavelength.

"WOBBLED" TRANSMISSION FOR ELIMINATION OF FADING: PIEZOELECTRIC METHODS.—(German Pat. 484767, Telefunken, pub. 21st October, 1929.)

Various circuits are covered, in which one or more piezo-crystals, in conjunction with one or more valves, are used: the piezoelectric circuit has its resistance modulated at the "wobble" frequency required.

PREVENTION OF FADING.—(N. Zealand Pat. 64018, Telefunken, pub. 4th December, 1929.)

The possibility of interference between the waves travelling by different paths is prevented by dividing the signals into a number of wave-trains (each lasting say 1/1,000 sec.) following each other in rapid succession.

MODULATION SYSTEM FOR MULTIPHASE HIGH FREQUENCIES.—(German Pat. 484341, Wired Radio Inc., pub. 26th Oct., 1929.)

In an example given, three valves, whose grids are controlled by a three-phase h.f. supply, have three output circuits coupled to three windings in series with a common aerial. In *one* grid-control circuit only a modulating system is introduced. "Calculation shows that with the superposition of the three phases the carrier component is suppressed and only the two side-bands are radiated."

FREQUENTIE-MODULATIE (Frequency Modulation). —B. van der Pol. (*Tijdschr. Ned. Radiogen.*, Dec., 1929, Vol. 4, pp. 57–70.)

Author's summary:—The differential equation of a frequency-modulated transmitter is considered, and the expression of the current as a function of time is derived. Frequency analysis of this function is made for two specific cases: (*a*) sinusoidal frequency modulation (telephony); (*b*) right angle frequency modulation (telegraphy with "marking" and "spacing" wave). The distribution and amplitudes of the frequencies present are seen to depend upon the value of an absolute parameter, the "frequency modulation index," equal to the ratio of the maximum frequency deviation to the imposed audio frequency. The overall width of the band occupied is found to be in general equal to the highest of these two frequencies. In the case of high-speed frequency-modulated telegraphy, however, side frequencies of noticeable amplitude may occur outside this band.

ÜBER FREQUENZMODULATION (Frequency Modulation).—H. Roder. (*Telefunken-Zeit.*, Dec., 1929, Vol. 10, No. 53, pp. 48–54.)

The use of frequency modulation has been suggested on the grounds that it reduces the frequency bands necessary for telephony (*cf.* Westinghouse patent, *E.W. & W.E.*, March, 1929). The writer shows by a theoretical investigation that this is not the case: on both sides of the carrier a large number of side-bands are produced, spaced among themselves by the modulating low frequency μ. To the resulting l.f. distortion there is added also amplitude distortion, and the system is unsuited to telephony (*cf.* 1929 Abstracts, pp. 509,572). The above is based largely on Carson's 1922 paper. The writer ends by considering, on the lines of what has gone before, the "wobble" method of counteracting fading. "It was hoped, by this, to send out a uniform and completely filled frequency band $2b\nu$ (twice the frequency displacement), but the expected success was not obtained: not a continuous spectrum, but only isolated lines of the spectrum were produced—in agreement with the above theory. . . . The amplitudes of the side-bands have very varied values, whereas for the prevention of fading what is wanted is a number of side-bands as equal as possible in amplitude. Thus here again Frequency modulation fails, *while by means of Amplitude modulation the desired result can be attained.*" But *cf.* and contrast Böhm, in same journal (see these Abstracts, under "P. of Waves") who shows successful "wobble" records and prefers this method to amplitude modulation—at any rate for picture telegraphy.

THE "WAVE-BAND" THEORY OF WIRELESS TRANSMISSION.—G.W.O.H. (*E.W. & W.E.*, March, 1930, Vol. 7, pp. 119–121.)

An editorial on Fleming's article (April Abstracts, p. 212). The real question is not what change of amplitude, but what *rate of change* of amplitude is admissible. "The depth or degree of modulation is important in that it effects the amplitude of the side-bands and therefore also the disturbance they cause, but this is included in the statement that the disturbing effect of a transmission depends on the rate of change of the amplitude of the carrier, which is only another way of saying that it depends on the spread and strength of the wave band."

THE "WAVE-BAND" THEORY OF WIRELESS TRANSMISSION.—C. L. Fortescue, L. H. Bedford, J. A. Fleming, O. Lodge, R. T. Glazebrook, J. A. Ratcliffe, G. B. Brown. (*Nature*, 8th and 22nd Feb., 1930, Vol. 125, pp. 198–199 and 271–273.)

A discussion arising from the article with the above title by J. A. Fleming in *Nature*, Jan. 18th, 1930 (*cf.* April Abstracts, p. 212). C. L. Fortescue describes the experimental demonstration of the existence of "side-bands" by taking the resonance curve of a selective receiver with an unmodulated, and then with a modulated, valve oscillator. In the latter case, resonant "humps" can be shown to exist at the frequencies $(p \pm q)/2\pi$, $(p \pm 2q)/2\pi$, etc., ($p/2\pi$ frequency of unmodulated wave, $q/2\pi$ frequency of modulation). L. H. Bedford points out that the question at issue is not how much the amplitude may vary, but at what frequency. J. A. Fleming replies to the points raised.

In the issue of 22nd Feb., O. Lodge gives reasons for the view that a mathematical alternative invariably corresponds with some physical reality and that therefore a sinuous wave of fluctuating amplitude may be rightly and exactly represented as if it were a band of neighbouring frequencies. R. T. Glazebrook evaluates the current set up in a receiver of frequency $r/2\pi$ when receiving a wave of frequency $p/2\pi$ modulated to $q/2\pi$ and finds that in any event there will be the two side-band waves which under favourable conditions will produce large effects.

C. L. Fortescue emphasises the fact that an unduly selective receiver *does* fail to reproduce high notes in their proper proportion. J. A. Ratcliffe enumerates three experimental results which show that "side-bands" have a definite physical existence. G. B. Brown shows that there is sufficient experimental evidence for the existence of the Fourier components of a modulated carrier wave.

FREQUENCY FLUCTUATION INDICATOR.—(German Pat. 484344, Int. West. El. Co., pub. 24th Oct., 1929.)

The heterodyned, modulated and amplified energy is divided between two artificial lines; the damping of one of these is independent, of the other dependent, on frequency. Thus only at one particular frequency can the two output voltages cancel, so that any deviation from this frequency can be shown by a differentially connected meter combined with two rectifiers.

QUARTZ GLOW-RESONATORS FOR CONTROL OF SHORT-WAVE TRANSMITTER.—Mögel. (*See* last par. of abstract under "M. and Standards.")

THE EQUIVALENT GENERATOR THEOREM.—Landon. (*See* under "Properties of Circuits.")

THE GENERATION OF OSCILLATIONS OF EXTRA LOW FREQUENCY.—Y. Ito. (*See* under "Properties of Circuits.")

RECEPTION.

ÜBER SCHWUNDERSCHEINUNGEN BEIM EMPFANG KURZER WELLEN (Fading Effects in the Reception of Short Waves).—A. Gothe and O. Schmidt. (*Telefunken-Zeit.*, Dec., 1929, Vol. 10, No. 53, pp. 39–43.)

It is shown, by means of oscillograms, that the effect of short-wave fading (15–17 m.) is quite different in two aerials if these are about 500 m. apart (in which case they can be similar) or if they are at right angles to each other (in which case they can be close together). A combination of three similar aerials, at the corners of a triangle of 500 m. sides, gives a reduction of fading which is good enough for all practical purposes. In the course of the paper the writers refer to Eckersley's results from the Lisbon station PQW (1928 Abstracts, p. 397), and point out that he lays stress on the phase-opposition of the quick fadings recorded. "Nowhere," they continue "does he mention having observed phase-agreement; but rather deduces, from the opposition, that the quick fading is due to rotation of the plane of polarisation."

Their own records from the same station show phase-agreement as often as opposition, so that they conclude the cause to be interference of two waves rather than polarisation changes. Slow fadings (30 secs.), on the other hand, may well be due to the rotation of plane of polarisation, since they are almost always opposed in the two aerials.

LOCATING RADIO INTERFERENCE WITH THE OSCILLOGRAPH.—J. K. McNeely and P. J. Konkle. (*Science*, 7th Feb., 1930, Vol. 71, p. 163.)

Mention of a paper read before the Am. Assoc. for the Advancement of Science. Slides were exhibited showing that different types of interference give characteristic patterns on the oscillogram.

QUARTZ CONTROL FOR FREQUENCY STABILISATION IN SHORT-WAVE RECEIVERS.—P. v. Handel, K. Krüger and H. Plendl. (*Proc. Inst. Rad. Eng.*, Feb., 1930, Vol. 18, pp. 307–320.)

English version of the paper dealt with in 1929 Abstracts, p. 573.

A BROADCAST RECEIVER FOR USE IN AUTOMOBILES.—P. O. Farnham. (*Proc. Inst. Rad. Eng.*, February, 1930, Vol. 18, pp. 321–326.)

(1) A capacity antenna is preferred to a loop because of the directional effects and the size of the latter; though the small effective height of the capacity antenna (about 1 m.) makes a receiver sensitivity of at least 100 μV. necessary—this implies a rather high degree of ignition shielding. (2) Ignition shielding—methods and results. (3) Receiver characteristics: a low audio-frequency amplification, to keep down microphonic noise: high r.f. gain by use of shielded tetrodes, so that by supplying the detector with a rather high input voltage, the detector may operate directly into the output valve (*cf.* Ballantine: "Detection at High Signal Voltages," 1929 Abstracts, p. 570). The r.f. amplification from grid of first valve to grid of fourth (detector) is about 45,000 at 1,000 kc. (4) Physical structure: a model weighed 10 lb. 2 oz. with valves, cable and volume control (this last is very necessary, and an automatic control is recommended). (5) Power supply: heater current from 6 v. automobile batteries, plate and screen voltages from 180 v. cells. (6) Results of Road Tests: strong reception up to 50–100 miles from broadcasting stations.

QUALITY IN RADIO RECEIVERS.—K. W. Jarvis. (*Rad. Engineering*, Dec., 1929, Vol. 9, pp. 33–37.)

"So little has been accomplished in view of the factors still to be subjugated." Frequency distortion: harmonic distortion: amplitude distortion: time distortion (time lag in rising to maximum amplitude and decreasing again to minimum): binaural reception, etc.

RECENT INFLUENCES IN RECEIVER DESIGN.—A. G. Warren. (*Wireless World*, 12th February, 1930, Vol. 26, pp. 168–171.)

A résumé of the salient points in the design of the modern quality receiver. The author treats in succession the r.f. stage, the detector and the l.f. amplifier, emphasising the importance of a correct choice of component values.

THE A.C. HIGH-FREQUENCY RECEIVER.—B. Dudley. (*QST*, Jan., 1930, Vol. 14, pp. 9–14 and 78.)

Full description and specification of a three-valve receiver, with reaction, for waves down to about 20 m., worked off a.c. mains. Only grid-bias is supplied by battery.

AN ELEVEN-VALVE SUPER-HETERODYNE RECEIVER.—S. Kawazoe. (*Res. Electrot. Lab., Tokyo*, No. 263, 1929, 64 pp.)

Constructional design, performance of this set, which covers a band of Broadcast wavelengths.

REVOLUTIONIZING HIGH-FREQUENCY TUNER DESIGN: A HIGHLY SELECTIVE RECEIVER WHICH COVERS 13,000 KC. WITHOUT PLUG-IN COILS.—W. H. Hoffmann and D. H. Mix. (*QST*, Feb., 1930, Vol. 14, pp. 9–14.)

A six-valve receiver covering the range 19 to 100 metres without the use of plug-in coils or the necessity for any other alteration inside the receiver. Special points are the return to the use of a variometer and the special design of the variable condenser: the "stator" plates can be rotated on an auxiliary shaft, and are so shaped that the rotor plates, when turned, interleave with progressively smaller or larger portions of the stator plate areas, according to the position of the stator.

FILAMENT CURRENT FROM D.C. MAINS.—H. B. Dent. (*Wireless World*, 19th February, 1930, Vol. 26, pp. 183–187.)

A survey of the most economical methods with examples of current practice in commercial receivers.

SIX TYPICAL A.C. MAINS RECEIVERS. (*Wireless World*, 19th February, 1930, Vol. 26, pp. 196–201.)

Illustrated descriptions, with circuit diagrams of representative instruments. Those dealt with are:—Ediswan Three-Valve All-Electric, Columbia Five-Valve All-Electric, McMichael Mains Screened Dimic Three, Amplion combined radio-gramophone, Philips All-Mains type 2511, and R.I. All-Electric type AY3.

HUNTING TROUBLE ON 28 MEGACYCLES.—A. L. Blais. (*QST*, Jan., 1930, Vol. 14, pp. 21–23 and 30.)

The writer considers that the amateur use of the 28 mc. band has been hindered by troubles at the receiving end. He examines these difficulties and also gives a number of *QST* references in connection with transmitters and receivers for this band.

NEUTRO-NETZANSCHLUSSEMPFÄNGER (The "Neutro" Mains-driven Receivers).—Siemens and Halske. (*E.T.Z.*, 26th December, 1929, Vol. 50, pp. 1883–1884.)

Illustrated description of two (4- and 5-valve) receivers.

GENERATOR INTERFERENCE WITH WIRELESS.—U. Dickes. (*Electrician*, 7th March, 1930, Vol. 104, p. 306.)

Interference, not amenable to cure by condensers, was caused by a Diesel engine driving a d.c. dynamo; traced to an irregular interruption of a steady current, between dynamo and Diesel, by the oil film of the sliding bearings.

PHASE RELATIONS AND OSCILLATION THRESHOLD IN A TWO-VALVE LEITHÄUSER-HEEGNER CIRCUIT.—v. Ardenne and Schlesinger. (*See* under "Properties of Circuits.")

CROSS MODULATION IN R-F AMPLIFIERS.—Sylvan Harris. (*Proc. Inst. Rad. Eng.*, February, 1930, Vol. 18, pp. 350–354.)

The first type of cross modulation discussed is that occurring when the screen-grid valve amplifier is coupled to the aerial by a resistance or closely coupled transformer (*e.g.*, an auto-transformer). Since this stage is non-selective, all signals in the neighbourhood of the aerial will be impressed on the input valve in a degree depending on the frequency characteristic of the coupling device. The first valve then acts as a modulator, and the selective system following it may be tuned to the beat frequency produced between any two signals, provided this beat frequency lies within the tuning range of the system. Thus the intermingled programmes of the two stations would be heard.

This trouble can be cured by making the aerial stage selective, or—since this type of modulation is a function of even-order derivatives of the valve characteristic—it can be cancelled out by using a push-pull arrangement with two aerial coils wound in opposite directions, so as to give the two grids opposite polarities.

The above form of cross modulation is entirely a matter of plate-circuit rectification, since the grid is sufficiently negative to prevent the flow of electrons to the grid. If the bias is made low enough, however, a further complication appears—grid circuit rectification and consequent cross modulation. Here the selective system of the amplifier is not tuned to a beat frequency (as in the first type) but to one or other of the interfering signals. It is liable to occur, even when the aerial is selectively coupled, when working at reduced voltages and low volumes. Such conditions often occur in volume-control arrangements using a variation of screen- or control-grid voltages, or both. The obvious way to avoid it is to keep a minimum control-grid bias; this, however, may lead to poor quality owing to the r.f. valves operating near or at the cut-off of plate current. The writer has had to resort to the expedient of controlling the input to the amplifier, and the valve voltages, simultaneously by means of two volume controls operated by a single shaft.

TELEPHONY AND MULTIPLEX TELEGRAPHY ON SHORT WAVES.—Küpfmüller. (*See* under "Stations, Design and Operation.")

AERIALS AND AERIAL SYSTEMS.

STRAHLUNG VON ANTENNEN UNTER DEM EINFLUSS DER ERDBODENEIGENSCHAFTEN: (C) RECHNUNG IN ZWEITER NÄHERUNG (Radiation from Antennæ under the Influence of the Properties of the Ground: (C) Calculation of the Second Approximation).—M. J. O. Strutt. (*Ann. der Physik*, January, 1930, Series 5, Vol. 4, No. 1, pp. 1–16.)

Author's summary:—The formulæ given in two former papers (*cf.* 1929 Abstracts, p. 329) for the radiation from vertical and horizontal electric and magnetic antennæ only contain terms of the order R^{-1}, where R denotes the distance of the emitter from the receiver. The present paper gives another derivation of these formulæ by Laplace's asymptotic method of integration and extends them as far as terms of the order R^{-2} inclusive. The magnitude of these correction terms enables the exactness of the former approximation to be estimated; this is essential in the discussion of measurements. Further, these correction terms are important in connection with the construction of broadcasting antennæ, for they alone do not vanish at points on the earth's surface (the radiation there is zero, to a first approximation). A numerical discussion of the field at a distance of ten wavelengths from the emitter gives the result that the first approximation holds most exactly for radiation which makes a large angle with the earth, and is most inexact for very small angles above the earth.

DIE WIRKUNGSWEISE VON DRAHTREFLEKTOREN (The Method of Action of Wire Reflectors).—F. Sammer. (*Telefunken-Zeit.*, Dec., 1929, Vol. 10, No. 53, pp. 61–71.)

Author's summary:—It is shown that even in the simple case of a single-wire arrangement both the amplitude and phase differences, as well as the near, transitional and distant fields, must be taken into consideration by the use of the proper Hertz equations.

For single-wire systems, for rapid calculation a vector diagram is given (derived from one of these equations) which gives the amplitude and phase of the induced reflector-current, for resonance, as a function of the distance. By the application of a correction factor the graphical solution is extended to multi-wire systems such as occur generally in practice.

For a given spacing and a given number of wires there is in general only one optimum tuning. The value of the optimum depends on the number of wires and their spacing. For single-wire systems the optimum distance $d = \lambda/8$, for two- or multiple-wire systems $d = \lambda/4$ or $\lambda/5$; [" the optimum is very flat. As a rough and ready rule for all arrangements it may be taken that the reflector should stand where near, transitional and distant fields have the same amplitude—namely, at a distance $d = \lambda/2\pi$ "]. Screening is absolutely better with multi-wire systems than with single-wire.

Finally, the reaction of the reflector on the antenna is calculated. This in general has the effect of altering the radiation resistance and natural wavelength. If $d = \lambda/4$, at optimum tuning the radiation resistance will be increased by 12 per cent and the natural wavelength lengthened.

DIE SCHWUNGRADSCHALTUNG DER ANTENNE (The Flywheel Circuit of an Antenna).—W. P. Lüthy. (*Helvet. Phys. Acta*, No. 1, Vol. 3, 1930, pp. 39–82.)

An elaborate experimental and theoretical investigation of the well-known flywheel circuit, and its various derivatives, connected in series with the aerial. It is shown that the two-wave property of such an arrangement is a coupling effect. Coupling equations are derived, giving calculated values of the wavelengths which agree well with the observed values, except on the shortest wavelengths (below, say, 90 m.) where the high damping for the short wave probably caused the discrepancy. The paper ends by a discussion of the use of the flywheel circuit for "split-wave" diplex transmission and for reception.

BERECHNUNG DER STRAHLUNGSDIAGRAMME VON ANTENNENKOMBINATIONEN (The Calculation of the Radiation Diagrams of Antenna Combinations).—R. Bechmann. (*Telefunken-Zeit.*, Dec., 1929, Vol. 10, No. 53, pp. 54–60.)

PRACTICAL DESIGN DATA FOR THE SINGLE-WIRE-FED HERTZ ANTENNA.—L. G. Windom. (*QST*, Sept., 1929, Vol. 13, pp. 19–22 and 84.)

VALVES AND THERMIONICS.

THERMIONIC EMISSION AND ELECTRICAL CONDUCTIVITY OF OXIDE CATHODES.—A. L. Reimann and R. Murgoci. (*Phil. Mag.*, March, 1930, Vol. 9, No. 57, pp. 440–464.)

Authors' abstract:—The following observations were made:—

(1) The electrical conductivity c of a "formed" alkaline earth oxide varies with the temperature T, according to a law of the form $c = ae^{-\frac{\beta}{T}}$, where a and β are constants. (2) During the process of forming, both the thermionic emission and the conductivity grow similarly, and after its completion both are "poisoned" similarly by exposure of the oxide to (*a*) oxygen, (*b*) a discharge in carbon monoxide, and (*c*) a discharge in hydrogen. Complete recovery of the formed condition by re-forming is possible only a few times in succession after poisonings by (*a*) and (*b*), but any number of times after poisoning by (*c*). (3) At current densities comparable with those in the coatings of oxide cathodes from which saturated thermionic space current is being taken, the current conducted through an oxide powder between two electrodes, embedded therein, also saturates.

On the basis of these observations, together with the results of related work by other investigators, we have formulated the following theory of the action of oxide cathodes:—

(1) The coating conducts the space current, which,

of necessity, passes through it, electrolytically. Practically only the metallic ions are mobile, the oxygen ions playing no active part in the electrolysis.

(2) The whole surface of each crystal of oxide of a formed cathode is covered with a mobile monatomic layer of alkaline earth metal. The passage of space current is accompanied by a continual circulation of this metal, which diffuses outwards along the surfaces of the crystals and inwards through the crystals in the form of electrolytic ions.

(3) At the usual operating temperatures of oxide cathodes, the average life of alkaline earth metal particles on the emitting surface is of the order of 10^{-3} second, and the rate of flow of this metal over the surface of an idealized independent unit of barium circulation in the form of a cube of side l would be of the order of 300 l per second.

(4) The coating is probably in very imperfect contact with the core metal, so that the space current passes from core metal to coating mainly in the form of thermionically emitted electrons. Sufficiently copious electron emission of the core metal at the low temperatures of operation of these cathodes would be made possible by a contamination of its surface with adsorbed barium or with barium and oxygen.

Explanations are suggested for :—

(1) the eventual "life-failure" of oxide cathodes,

(2) the observed phenomena relating to poisoning,

(3) the considerable variation in the published values of the thermionic constants of oxide cathodes.

Tantalum in Vacuum Tubes.—F. L. Hunter. (*Rad. Engineering*, Dec., 1929, Vol. 9, pp. 29–31.)

A discussion of the uses and advantages of tantalum. As a plate material it fills requirements more completely than any other metal—workable in all directions to the grain, even permitting drawing operations; when annealed takes a permanent set during stamping, no tendency to spring back: melting point in vacuum 2,850° C.: vapour pressure far less than molybdenum, negligible deposit on the walls (most important for very high frequency valves): very rapid out-gassing when heated quickly to 700° C., decreasing rapidly —nearly all total gas will leave it at 800° C. in a few seconds. Equal advantages are described for its use as grid material, in gas-filled discharge tubes, etc., etc.

Über die Elektronen- und positive Ionenemission von Wolfram-, Molybdän- und Tantalglühfäden in Kaliumdampf (On the Emission of Electrons and Positive Ions from Tungsten Molybdenum and Tantalum Filaments in Potassium Vapour).—Edith Meyer. (*Ann. der Physik*, Series 5, 1930, Vol. 4, No. 3, pp. 357–386.)

Author's summary :—The emission of electrons and positive ions by tungsten, molybdenum and tantalum filaments in potassium vapour is investigated. The emission of electrons and positive ions is given as a function of the filament temperature for various values of the potassium vapour pressure. The shape of the curves is essentially the same as that found by Langmuir and Kingdon, Killian and J. A. Becker for tungsten in potassium, rubidium and cæsium vapour. The electron emission attains a maximum, which occurs at the same filament temperature for different potassium vapour pressures; this result is in contrast to the results obtained by the writers mentioned. The electron emission from layers of potassium on different metals varies very markedly with the nature of the foundation material. The influence of this is not, as Langmuir assumes, determined by the difference of the ionisation voltage of the alkali metal and the work function of the foundation material. It is possible that this phenomenon depends on the surface properties of the material used.

The potassium vapour pressures obtained from the measurements of emission of ions differ from those calculated from the temperature of the discharge tube. Not every potassium atom which meets the surface is ionised; this is probably due to peculiarities in the nature of the wire surface. From the measurements it appears probable that the thickness of the adsorbed layer is of the order of several atomic layers.

De Electronenemissie van Metaalopppervlakken (The Electron Emission of Metal Surfaces).—C. Zwikker. (*Physica*, No. 9, Vol. 9, 1929, pp. 321–330.)

A paper on the writer's theoretical and experimental treatment of Richardson's discovery of the interdependence of the thermionic constants A and b. The Millikan formula for the "field current," $i_F = BF^2e^{-a/F}$, is compared with the Richardson formula $i_T = AT^2e^{-b/T}$, and the quantum mechanical theory of the Millikan current is briefly discussed on the lines set out by Nordheim.

Anode Spots and their Relations to the Absorption and Emission of Gases by the Electrodes of a Geissler Discharge. —C. H. Thomas and O. S. Duffendack. (*Phys. Review*, Jan. 1st, 1930, Series 2, Vol. 35, No. 1, pp. 72–91.)

The Temperature Dependence of Field Currents.—N. A. de Bruyne. (*Phys. Review*, 15th Jan., 1930, Series 2, Vol. 35, No. 2, pp. 172–176.)

A Study of Noise in Vacuum Tubes and Attached Circuits.—F. B. Llewellyn. (*Proc. Inst. Rad. Eng.*, Feb., 1930, Vol. 18, pp. 243–265.)

(1) Shot effect in presence of a space charge. Previous theory of shot effect was based on absence of space charge. Johnson showed that as the filament current is increased from zero the noise at first increases rapidly in accordance with Fry's formula; next, however, it goes through a maximum as the space charge comes into play, and then decreases to a value which is nearly independent of filament current. It is in the last-named region that valves are usually operated.

The writer reviews the two assumptions underlying Fry's formula and examines how they are affected by the presence of a space charge. One is unaffected, but the second—that all electrons emitted by the filament are drawn over to the plate, so that variations in filament emission are transferred to the plate without change—no longer holds. *It is to be inferred that the shot effect, as such, is zero in the region of temperature saturation of the filament.* The mathematical formulation for this effect, together with computation formulæ for the shot effect at various degrees of partial saturation, are given in two final Notes. Difficulties inherent in obtaining complete experimental verification are discussed.

(2) Thermal noise (Johnson and Nyquist, 1928 Abstracts, p. 581). After a review of these workers' results, the writer deals with the query, "what is the effective temperature, as regards the production of thermal noise, of the internal plate resistance of a valve?" It is shown that the plate resistance must be taken at the filament, or cathode, temperature. Since this now ranges between 1,000 and 2,000° K., a fairly large portion of the noise may be contributed by the plate resistance.

(3) Experiments showed that the valves tested gave values of total noise considerably above the computed curves, even when shot effect was reduced to zero. This excess was probably due to ions and the emission of secondaries from grid, screen or plate; but these effects have not been successfully isolated either in theory or experiment. It is found, however, that a large negative bias on the grid is harmful in this respect. "Except in valves which have only a poor temperature-saturation of the filament, it is possible to reduce the noise on the plate side to such an extent that the high impedance circuits employed on the grid side of the first tube of a high gain receiving system contribute practically all of the noise by virtue of the thermal agitation phenomenon."

A Study of the Output Power obtained from Vacuum Tubes of Different Types.—H. A. Pidgeon and J. O. McNally. (*Proc. Inst. Rad. Eng.*, Feb., 1930, Vol. 18, pp. 266–293.)

Authors' summary:—"Economical operation of the large number of tubes involved in the Bell System makes necessary the adoption of common supply voltages. This requires that repeater tubes of various types be designed to operate at a fixed plate voltage. For this reason the design of amplifier tubes to give as large a power output as possible at the operating plate voltage is of considerable importance.

"In the case of three-electrode tubes, it is possible from theoretical considerations to compute, approximately, the electrical parameters a tube must have in order to give the maximum output power of a given quality obtainable under fixed operating conditions.

"The electrical characteristics and output of fundamental, second and third harmonics of two of the more common telephone repeater tubes are given.

"It is of considerable interest to determine whether greater power output of comparable quality can be obtained from tubes containing more than one grid. Since no sufficiently exact theoretical analysis of multi-grid tubes is yet available to permit the determination of the parameters of optimum tubes, a comparative experimental investigation of a number of such structures has been undertaken. The electrical characteristics and output of fundamental, second and third harmonics of several such experimental tubes are given. The power output of multi-grid tubes and of three element tubes is compared. The reasons for the comparatively large power output of certain types of multi-grid tubes are discussed."

The "certain types" of multi-grid valves referred to in the last sentence are the so-called "co-planar grid" valves. This design has been found particularly effective in the utilisation of a positive grid to reduce space charge effects; the second grid is placed so that its lateral wires *lie in the same plane as those of the negative control grid, and alternate with them.* The two supports of the one grid lie inside the two supports of the other, so that the former grid is narrower than the latter: the narrower grid is used as the control, since a larger current is collected by the unshielded portion of the positive grid if the arrangement is reversed.

One might expect that with this co-planar grid valve, as with the ordinary two-grid valve with outer positive grid, secondary emission from plate to positive grid would seriously restrict the range of operation. This is not the case: under normal conditions the number of secondaries is kept small by the shielding of the positive grid by the field of the negative control grid. Another advantage of the system is that the necessary spacing between filament and plate is reduced to a distance comparable with that in triodes: the valve resistance is reduced, and at the same time the region between the two grids, affected by space charge or excessive turbulence in the flow of electrons, is eliminated. Apart from these and other advantages leading to increased power output, the design offers the possibility of using both grids as a means of dual control: under suitable conditions the input impedance to the positive grid is high enough to make this feasible. The co-planar grid valve is more difficult to construct than other two-grid valves, but "a method of satisfactory fabrication could doubtless be found."

Production Testing of Vacuum Tubes.—K. S. Weaver and W. J. Jones. (*Proc. Inst. Rad. Eng.*, Feb., 1930, Vol. 18, pp. 336–349.)

(1) Organisation of Test Procedure: Factory test: Engineering department inspection and test: Warehouse inspections: strength and life tests. (2) Test engineering: emission: plate currents under fixed working conditions: gas: leakage currents: amplification constant, plate resistance and mutual conductance.

DIRECTIONAL WIRELESS.

Equi-Signal Radio-Beacon: Simultaneous Weather Service. (*Bur. of Stds. Tech. News Bull.*, Dec., 1929, p. 116.)

At present the radio-beacon (aural type) and radio-telephone weather services are operated on the same wavelength, one service being interrupted for the sake of the other; this avoids the necessity of retuning but prevents the two services from being available simultaneously. It would be advantageous if the pilot could have available his course indication even while listening to the weather broadcast.

The visual type of radio-beacon offers possibilities for the simultaneous transmission of the two services on the same radio frequency. The modulation frequencies are 65, 86.7 and 108.3 p.p.s. respectively, and intelligible speech does not require modulation frequencies below 300 p.p.s. A receiving set tuned to the carrier frequency can be provided with a filter circuit and arranged so that the frequencies above 300 are supplied to the head telephones while those below 300 go to the vibrating-reed course indicator. Preliminary tests on the practicability of this plan have been started.

Fog Landing Developments by the Bureau of Standards.—Note from the U.S. Bureau of Standards. (*Journ. Franklin Inst.*, March, 1930, Vol. 209, No. 3, pp. 409–410.)

The pilot landing in fog must be guided to and along a suitable runway, must know how far along it he has gone, and the height of the landing path above ground must be properly regulated. Of these three requirements, the first is given by a small directive radio beacon, the second by a marker beacon and the third by a landing beam. The method now being tried to provide the third element of the system is a directed beam of 60,000 to 100,000 kilocycles per sec., which is directed at a small angle above the horizontal. A simple receiving arrangement with visual indicator is used on the aeroplane. When the latter is so manœuvred as to keep the deflection of this indicator always at a fixed point, the aeroplane follows a gliding path down to the ground which is quite suitable for the landing operation.

Automatic Recording of Rotating Beacon Bearings. (*Journ. Scient. Instr.*, Feb., 1930, Vol. 7, pp. 49–50.)

One of the N.P.L. exhibits at the Physical and Optical Societies' Exhibition. At the receiving end, the bearing is recorded on a drum rotated synchronously with the transmitter by the aid of the usual phonic motor and tuning fork.

Velocity of Sound in Sea-Water. — Lübcke. (*See* under " Acoustics.")

ACOUSTICS AND AUDIO-FREQUENCIES.

Over Ruimte-Acoustiek (The Acoustics of Spaces). —J. Zenneck. (*Tijdschr. Ned. Radiogen.*, Dec., 1929, Vol. 4, pp. 71–79.)

The writer here covers much the same ground as in his I.R.E. paper dealt with in 1929 Abstracts, p. 214.

Zur Theorie des Tonraumes (The Theory of Sound Vibrations in a Closed Space).—K. Schuster. (*Ann. der Physik*, Series 5, 1930, Vol. 4, No. 4, pp. 513–532.)

A theoretical discussion of the acoustic vibrations in a closed space of the form of an oblate spheroid symmetrically divided into two parts by a partition containing a circular hole. The differential equation for the velocity potential is solved with the appropriate boundary conditions.

Velocity of Sound in Sea-Water.—E. Lübcke. (*Zeitschr. f. tech. Phys.*, No. 9, Vol. 10, 1929, pp. 386–388.)

In echo sounding, the velocity at first diminishes owing to the fall of temperature, and afterwards increases on account of the increase of pressure. Omitting the coldest and warmest seas, an average velocity for all depths is found to be 1,496 m. per sec., and an international average value of 1,500 m./sec. is suggested for ordinary navigational purposes. The value is of importance also in distance measurement by simultaneous use of radio-electric and water-sound signals.

An Artificial Voice for Testing Purposes.—A. Hudson. (*Journ. P.O. Elec. Eng.*, Oct., 1929, Vol. 22, pp. 193–195.)

A moving-coil loud speaker is actuated by a rhythmic oscillator modulated in such a way as to produce a sound possessing the same essentials as speech.

Akusticheskie izmerenia metodom impulsa (Acoustical Measurements by the Impulse Method).—A. I. Belov. (*T.i T.b.p., Leningrad*, December, 1929, Vol. 10, pp. 572–583.)

In Russian. In order to eliminate interference from reflected waves in acoustical measurements, Andreev has devised a method for determining the amplitude of the first impulse only of an incoming sound wave. The method is based on the observation of a light contact piece held with variable pressure against a diaphragm and the determination of the critical pressure under which the contact piece becomes detached from the diaphragm when a sound wave impinges on the latter. The break of contact is indicated by a telephone which is preferably connected in the plate circuit of a valve the grid bias of which is controlled by the contact piece. The theory of the method and an account of experiments carried out at the State Laboratory of Physics are given and polar curves for two loud speakers shown. The possible use of the impulse method for the determination of the absorption of sound by different materials is also indicated.

Reflection of Sound Energy and Thickness of Plate Reflector — Ultrasonic Method.—R. W. Boyle and D. K. Froman. (*Canad. Journ. of Res.*, Nov., 1929, Vol. 1, pp. 405–424.)

The work illustrates the application of the theory of monochromatic interference spectroscopy of optics to sound. By experiments with lead, duralumin and paraffin, at different high frequencies, the effects of both high and low reflecting powers are shown, and also the possible influences of harmonics. It is also shown that in travelling through thin discs the velocity of the waves is given more accurately by the bulk modulus of elasticity than by Young's.

Transmission of Sound Energy and Thickness of Plate Transmitter at Normal Incidence—Ultrasonic Method.—R. W. Boyle and D. O. Sproule. (*Canad. Journ. of Res.*, Jan., 1930, Vol. 2, pp. 3–12.)

Authors' abstract:—Another and more direct experimental method for determining the reflection from and the transmission through parallel-faced partitions of sound energy of short wavelength was studied. Measurements were taken of the energy transmitted through obstructing plates by means of a torsion pendulum placed in the "ultra-sonic shadow," the incidence of the energy being normal. The theoretical and experimental results obtained in previous researches by taking reflection measurements only were confirmed, and again it was shown necessary to employ the bulk modulus of elasticity for computations of velocity instead of Young's.

Schallisolation und Schallabsorption: Verfahren zu ihrer Messung (Sound Insulation and Sound Absorption: Methods of Measurement).—E. Meyer. (*Zeitschr. V.D.I.*, 1st March, 1930, Vol. 74, No. 9, pp. 273–279.)

Sulle Correnti unidirezionali d'Aria prodotte da Membrane vibranti (On the Unidirectional Current of Air produced by Vibrating Membranes).—A. Stefanini. (*Nuovo Cim.*, Jan., 1930, Vol. 7, pp. 1–12.)

On the Wave-Form of a Sound produced by a Spark.—J. Okubo and E. Matuyama. (*Phys. Review*, 1st Dec., 1929, Vol. 34, pp. 1474–1482.)

The sound produced by a condensed spark was studied by the Michelson interferometer. It was found that the wave consists of a high-frequency oscillation of air of the order of 10^{-4} sec., having two discontinuities, one due to a condensation at the head and the other to a rarefaction at the tail. The variation of the wave-form, as it propagates onwards, was also studied.

Over Monopool- en Dipoolkarakter van eenige Geluidsbronnen (On the Monopole and Dipole Character of Some Loud Speakers).—C. Zwikker and P. J. Bouma. (*Physica*, No. 8, Vol. 9, 1929, pp. 289–294.)

Taking a pulsating sphere as an example of an acoustic monopole and a vibrating diaphragm (producing compression on one side and rarefaction on the other) as that of a dipole, the writers examine the theoretical differences in behaviour of the two classes, and investigate experimentally various forms of sound producers with a view to allotting them to one class or the other.

Über die Eigenfrequenz von einseitig eingespannten Stäben (On the Natural Frequency of a Rod Clamped at One End).—A. Esau and M. Hempel. (*Zeitschr. f. tech. Phys.*, Jan., 1930, Vol. 11, pp. 23–24.)

The writers conclude that the du Bois Reymond formula is not reliable, while that of Kohlrausch is satisfactory.

Balsa Wood Diaphragms for Loud Speakers.—R. W. Paul and B. S. Cohen. (*Journ. Scient. Instr.*, Feb., 1930, Vol. 7, pp. 50–52.)

Balsa wood has extremely low density coupled with high elastic modulus: the diaphragms here described give large output free from noteworthy resonances. The discs are protected against the absorption of moisture by special treatment, and are reinforced with glued-on strips which render them very rigid.

Tests on Cone Units. (*Wireless World*, 5th February, 1930, Vol. 26, pp. 135–140; 12th February, 1930, pp. 162–166; 26th February, 1930, pp. 233–234.)

Constructional details and electrical characteristics, including impedance measurements at various frequencies, are given of a number of representative commercial types of cone loud speakers with reed and balanced armature movements.

Matching the Speaker to the Output Tube: the Design and Operation of the Output Transformer.—J. M. Thomson. (*QST*, Jan., 1930, Vol. 14, pp. 31–34.)

The considerations involved are pointed out, formulæ obtained for turns ratio, etc., and practical data supplied for the design of satisfactory coupling transformers for electromagnetic and moving coil types of loud speaker. Among the practical points mentioned are the following:—the primary reactance at the lowest frequency to be transmitted, usually 50 cycles, should be at least twice as large as the plate impedance of the valve. Ideal results will be obtained if it is five times as large. The resistance of the secondary coil should be:—not more than one-fifth of the loud speaker resistance for the electromagnetic type: less than one-eighth to one-tenth for the m.c. type (though this will operate "satisfactorily" for a value of one-fifth).

Untersuchungen über Grundfragen der Akustik und Tonpsychologie (Investigations into Fundamental Questions of Acoustics and Tonic Psychology).—E. R. Jaensch. (Long Summary in *Physik. Berichte*, 1st Jan., 1930, Vol. 11, p. 8.)

Researches leading to the conclusion that in addition to the resonance processes involved in hearing there are other actions involved which follow a principle deviating from the Fourier analysis: the writer therefore replaces the Helmholtz theory by one attributing to the ear a multiplicity of resonant systems.

Über die Vokale (On the Vowel Sounds).—V. Engelhardt and E. Gehrcke. (*Zeitschr. f. tech. Phys.*, Nov., 1929, Vol. 10, pp. 563–567.)

Tests to determine whether the "absolute" or the "relative" theory of the hearing of vowel-sounds is the correct one. It is found that both are partially correct, the proportion varying with the particular vowel and the particular hearer.

Theory of Vibration of the Larynx.—R. L. Wegel. (*Bell Tech. Journ.*, Jan., 1930, Vol. 9, No. 1, pp. 207–227.)

AUDITORY NERVE IMPULSES.—E. G. Wever and C. W. Bray. (*Science*, 21st Feb., 1930, Vol. 71, p. 215.)

"By placing an electrode on the cat's auditory nerve near the medulla, with a grounded electrode elsewhere on the body, and leading the action currents through an amplifier to a telephone receiver, the writers have found that sound stimuli applied to the ear of the animal are reproduced in the receiver with great fidelity."

THE REISZ HIGH-QUALITY CARBON-GRANULE MICROPHONE.—E. Reisz. (*A.E.G. Mitt.*, No. 9, 1929, pp. 601–604.)

PHOTOTELEGRAPHY AND TELEVISION.

ÜBER EINE NEUE ART VON PHOTOZELLEN (A New Type of Photocell).—B. Lange. (*Physik. Zeitschr.*, Feb. 1st, 1930, Vol. 31, No. 3, pp. 139–140.)

A preliminary account of a new type of photocell, in which the efficiency is increased by using the low contact potential between a metal and a semi-conductor in place of the higher metal-vacuum contact potential used in the ordinary photocell. The photo-sensitive electrode E_1 is in the form of a flat plate in contact with a unipolar layer u of semi-conducting material, the other side of which is in contact with a second electrode E_2. The photoelectrons set free by the light pass through u to E_2 and thus through an external circuit connecting E_1 and E_2. It is found desirable to make u as thin as possible—only a few molecules thick—to reduce the inertia of the cell so that it will respond faithfully to acoustic frequencies. This thinness of dielectric also lowers the resistance of the cell and increases the current output, and no auxiliary voltage is necessary.

The relatively low contact potential [about 10 times smaller] enables considerably smaller energy quanta to produce the photoelectric current than in the ordinary cell, so that the cell is sensitive to infra-red light, the long-wave limit, up to the present, being 6,600 mμ. By suitable choice of the semi-conducting material, a selective efficiency for various spectral regions can be obtained—probably due to resonance effects between photoelectrons of certain frequencies and the atomic oscillations of the molecules of the material. Thus a copper-copper oxide cell has a selective sensitivity for a wavelength of about 800 mμ.

Applying Einstein's quantum-relation $N = Q/h\nu_0$ to the limiting wavelength, it is found that the new cell gives a quantum-gain about 10 times as great as that of an alkali cell (22.5 coul./cal. compared with 2.04). The writer hopes to increase this still further by the use of special unipolar materials, in which case "we arrive at efficiencies at which a direct, practical conversion of light into electrical energy would seem to be possible."

TELEVISION WITH CATHODE-RAY TUBE FOR RECEIVER.—V. Zworykin. (*Rad. Engineering*, Dec., 1929, Vol. 9, pp. 38–41.)

The transmitter described is a modified moving-picture projector. The receiver is the special cathode-ray tube named the Kinescope (April Abstracts, p. 220). An oxide-coated filament is mounted within a controlling cylindrical electrode. The beam passes through a small hole in the front part of this element and then again through a hole in the first anode, which accelerates the electrons to 300–400 v. The second anode (a metallic coating on the inside of the glass) gives a further acceleration up to 3,000–4,000 v., at which the velocity of the electrons is about 1/10 that of light; and also focuses the beam, electrostatically, into a sharp spot on the screen. The target wall of the bulb is about 7 in. in diameter and is covered with a fluorescent material such as willemite, prepared by a special process which makes it slightly conductive (to remove the charges produced by the beam).

The two sets of deflecting elements (plates and coils) are set outside the neck of the tube, between the two anodes, and therefore act on the comparatively slow electrons; the fields required are consequently comparatively small. The mean brightness of the line is controlled by a negative bias on the cylindrical controlling element, on which are superposed the signal variations.

Three sets of signals are thus required—picture signal, horizontal scanning frequency, and impulses for framing. It has been found possible to combine all three into one channel: the photoelectric cell voltage of the transmitter is first amplified to the suitable level; there is then superposed on it a series of high audio-frequency impulses lasting only a few cycles and occurring when the light beam passes the interval between two pictures. The *picture frequencies* together with the *framing frequencies* are then passed through a band-eliminating filter, which removes the picture component of the same frequency as that of the horizontal scanning. Following this, a portion of the voltage which drives the *transmitter vibrator* is impressed on the signals, passed through the filter, and the entire spectrum is used to modulate the r.f. carrier. At the receiving station the amplified signals are divided by a band-pass band-elimination filter into two parts: one the synchronising frequency, the other the picture frequency plus the framing frequency. The synchronising frequency is amplified by a tuned amplifier which supplies current to the deflecting coils of the kinescope. The picture and framing frequencies are applied directly to the control element of the kinescope. The same voltage which modulates the light is impressed upon a band-pass filter tuned to the frequency of the a.c. voltage used for the framing impulses. The output of this filter is amplified, rectified, and used to unbias a discharging triode which is normally biased to zero plate current, and which takes its plate voltage from the condenser which provides the vertical scanning voltage.

SPOSOB GRUPOVOI PEREDACHI TOCHEK KARTINI V PRIMENENII K TELEKINO (Television by the Group Transmission Method).—V. I. Iltchenko. (*T.i T.b.p. Leningrad*, December, 1929, Vol. 10, pp. 640–650.)

In Russian. In order to reduce the number of signals required to reproduce an image the author proposes a system in which each signal represents a group of points instead of one point. Half of the signals transmitted correspond to the average illumination of the separate groups and the remaining half to the average darkness. At the receiving end a "grid" of condensers comprising as many condensers as there are points on the image is connected to the receiver. This grid may consist simply of glass plates with pieces of conducting material on their surfaces. The condensers are so arranged that on the reception of signals the resultant charge on each condenser is proportional to the intensity of illumination of the corresponding point of the image. Each condenser is connected to an electrode placed in a neon-filled vessel. By a simultaneous discharge of the condensers through these electrodes a momentary impression of the image is obtained. When a sufficient number of condensers is used the number of signals required to reproduce a picture is several hundred times less than would be the case if the usual method in which each point is reproduced separately were employed. An alternative system of transmission in which consecutive strips of the image are reproduced in turn is also explained.

ELEKTRISCHES UND OPTISCHES VERHALTEN VON HALBLEITERN (Electrical and Optical Behaviour of Semi-Conductors).—F. Klaiber. (*Ann. der Physik*, 8th Oct., 1929, Series 5, Vol. 3, No. 2, pp. 229–252.)

SYSTÈME ET APPAREILS DE TÉLÉVISION THERMÏONIQUE (System and Apparatus for Thermionic Television).—— —. Bruni. (*Revue d. Tél., Tél. et T.S.F.*, March, 1930, Vol. 8, pp. 218–225.)

An article based on the French patent 672202 (Bruni). The transmitter is a "photoscope" depending on the action of a beam of electrons directed on to a flat anode covered with a layer of selenium (*e.g.*), on which the image is focused. The receiver is similar except that the anode is coated with a fluorescent material.

FORMS OF GAS-FILLED PHOTOELECTRIC CELLS: THEIR PROPERTIES AND CALIBRATION.—J. Kunz and V. E. Shelford. (*Rev. of Scient. Instr.*, Feb., 1930, Vol. 1, pp. 106–117.)

From the point of view of biologists and meteorologists rather than that of Wireless engineers. Large currents at low voltage were desired, so that portable microammeters could be used with sufficient accuracy. The usual concave surface was unsatisfactory, the response varying with the angle of incidence of the rays. A "collapsed-sphere" form, giving a convex sensitive surface, was satisfactory. The use of several metals instead of one is suggested as a means of increasing the range of colour sensitivity. "The maturing, testing, grading and calibrating of cells by the makers is an essential step in further progress."

THE SELF-OSCILLATION OF PHOTOELECTRIC CELLS.—Rosing. (*See* under "Properties of Circuits.")

PICTURE TELEGRAPHY ON SHORT WAVES: FADING ELIMINATION.—Böhm. (*See* under "Propagation of Waves.")

MEASUREMENTS AND STANDARDS.

EXAKTE FREQUENZMESSUNG KURZER WELLEN (The Exact Frequency Measurement of Short Waves).—H. Mögel. (*Telefunken-Zeit.*, Dec., 1929, Vol. 10, No. 53, pp. 44–48.)

A supplement to the paper dealt with in March Abstracts, p. 166. The apparatus and methods have been improved and simplified, and the accuracy increased ten-fold, so that waves in the 12–60 m. zone can be measured with an absolute accuracy of ± 0.001 per cent or a relative accuracy of 0.0003 per cent. The old quartz glow-resonators could not be guaranteed to give an accuracy of more than 0.01 per cent, but Giebe and Scheibe have so improved the design (among other points, the quartz bar is suspended by silk fibres at two nodal points) that a constancy of about 1×10^{-5} is obtained, with a temperature coefficient of 2–4 $\times 10^{-6}$ per degree Centigrade. For the chosen fundamental of 150 kc./sec. ± 1 per cent., the quartz rod would be only about 20 mm. long, and difficult to bind; so a rod about 4 times as long was chosen and excited longitudinally to its 4th harmonic, with very loose coupling so that the effect of the electrode capacities was very small (probably smaller than 1/100,000). The voltage necessary to produce the glow was only about 20 v., so that the coupling to the generating circuit was accomplished by a small coil with a natural frequency in the neighbourhood of the quartz resonance frequency, loosely coupled at a distance of ½ to 1 m.

The simplified new method uses a standard generator which (for the zone 10–60 m.) has a range of only 2,000 m. ± 1 per cent: it can be adjusted to within 2–3 millionths by means of a precision condenser with fine adjustment and vernier scale. This whole range is covered by 8 or 9 of the improved quartz resonators equally spaced over it. The abolition of the separate generator and standard wavemeter with its detector and mirror galvanometer has enormously simplified the procedure and quickened it up about ten times.

The paper ends with a description of the method by which a short-wave transmitter at Nauen has its frequency directly controlled by a number of these quartz glow-resonators with a resulting constancy of about 0.02 per cent.

SOME REMARKS ON THE MULTIVIBRATOR.—Y. Watanabe. (*Proc. Inst. Rad. Eng.*, Feb., 1930, Vol. 18, pp. 327–335.)

"The author believes that it may be useful to publish the results of his consideration of the theory of multivibrators, particularly since the above-mentioned theories [Armagnat and Brillouin, van der Pol, Friedlander, and Heegner] do not seem to him entirely correct."

His treatment of the symmetrical multivibrator circuit and its behaviour leads to a static method for obtaining the characteristics of such a circuit. From this information, he shows, a characteristic curve can be plotted which has a falling portion provided that the coupling resistance R_a in the anode circuit is made sufficiently large. He then examines the manner in which a periodical change in current may be produced by such a characteristic, and obtains a formula for the period of the oscillations $T = 2C_gR_g \log_e \frac{E - e_c}{e_c}$, where E is the change in the voltage-drop across the anode resistance R_a at the "jumping instant" and e_c is the grid voltage corresponding. The falling characteristic is not always a necessary condition, though it is a favourable one. The writer concludes by pointing out that such a multivibrator circuit can, by suitable adjustment of the anode capacity, also produce sinusoidal oscillations.

REZONANSNIE CHASTOTI PIEZOKVARCEVIH PLASTIN (The Resonant Frequencies of Thin Quartz Crystals). — S. I. Hirshhorn. (*T.i T.b.p., Leningrad*, Vol. 10, pp. 584–590.)

In Russian. A preliminary report on investigations on the subject at the Moscow Technical Institute. Thin quartz crystals sprinkled with lycopodium powder were excited in a high frequency oscillating circuit and the Chladni figures formed on them observed. For each crystal three main types of oscillation were found. Mathematical expressions for determining the frequencies of the oscillations from the constants of the crystals and the nature of the Chladni figures are given. *Cf.* Harding and White, 1929 Abstracts, p. 582.

PRESERVING CONSTANCY OF PIEZOELECTRIC OSCILLATORS.—(German Pat. 486008, Lorenz, pub. 11th Nov., 1929.)

The crystal is provided with a silver coating which is placed very close to massive copper blocks: the whole is fixed in a hydrogen-filled container immersed in ice and water.

CRYSTAL CONTROL OF SHORT WAVE TRANSMITTERS. —A. Meissner. (*See* under "Transmission.")

THE EFFECT OF TENSILE OVERSTRAIN ON THE MAGNETOSTRICTION OF STEEL.—J. S. Rankin. (*Journ. Roy. Tech. Coll., Glasgow*, Jan., 1930, Vol. 2, pp. 173–187.)

QUARTZ CRYSTAL FACTS.—J. H. Hollister. (*QST*, Jan., 1930, Vol. 14, pp. 29–30.)

Practical information regarding the preparation of quartz plates, supplementing previous articles (of which a list is given) in earlier volumes of the same journal.

ACCURACY OBTAINABLE WITH PIEZO OSCILLATORS. —Notes from the U.S. Bureau of Standards. (*Journ. Franklin Inst.*, March, 1930, Vol. 209, No. 3, pp. 407–408.)

A note on observations conducted by the Bureau of Standards in recent months on a number of specially designed piezo oscillators. The circuit arrangements are designed to minimise the effects of external influences on the frequency of operation. The construction is such that the standards are portable and of a size which could be used in a radio transmitting station. The essential differences among the piezo oscillators were in the design of the quartz plate holder. The results obtained indicate that it is possible to construct piezo oscillators for use as frequency standards which are capable of maintaining an accuracy of greater than 1 part per 100,000 over a period of several months.

THE ACCURATE TESTING OF AUDIO AMPLIFIERS IN PRODUCTION.—A. E. Thiessen. (*Proc. Inst. Rad. Eng.*, Feb., 1930, Vol. 18, pp. 231–242.)

The apparatus described is not intended actually to measure the gain of audio-frequency amplifiers, but is used to compare the gain/frequency curves of a succession of such amplifiers with that of a known and unvarying standard, and to compare the undistorted power output they can deliver with that which the standard can deliver. Less than two minutes is required for a complete test.

The method avoids the necessity of measuring the very small power at the input to the amplifier. A resistance of proper value is substituted for a loud speaker load, and an attenuation network is inserted between amplifier and oscillator or power source. This network is variable in known steps and has a constant terminal impedance at all values of loss. A valve voltmeter gives the voltages across the attenuator and the output resistance, as desired.

Several frequencies between 50 and 5,000 cycles are selected: the gain of the standard amplifier at each of these is determined. The variable attenuator is ganged with the frequency control, the attenuation values being set at each frequency to correspond with the amplification of the standard at that frequency. All that is necessary is to insert the amplifier to be tested, and to turn the ganging switch. By observing whether or not the output voltmeter deviates from a fixed standard reading, it is seen at once whether the tested amplifier has the same gain/frequency characteristic as the standard.

In testing the undistorted power output, by turning one switch attenuation is removed step by step between generator and amplifier at the same time that an equal attenuation is added between amplifier and output voltmeter. As this switch is turned, no change in voltmeter reading occurs till the overload level is reached: at this point, the amplifier no longer delivers power in proportion to the input power, and the voltmeter reading begins to drop.

The whole apparatus is combined into one instrument, for mains working.

VARIABLE CONDENSER FOR MEASUREMENTS AT 30 MILLION CYCLES PER SECOND.—E. B. Moullin. (*Journ. Scient. Instr.*, Feb., 1930, Vol. 7, p. 64.)

Two circular cylinders have their axes parallel but not concentric, the inner cylinder being rotated on an axle which is eccentric with both outer and inner cylinders. The first 47 degrees of the scale correspond to an increase of capacity of 1 $\mu\mu$F.; the whole range covers a change of 16 $\mu\mu$F. Two mica condensers, each of 16 $\mu\mu$F., are contained within the condenser and can be switched in parallel with the variable portion. Another switch connects the two cylinders together, turning the instrument into a small variable inductance.

SULLA DETERMINAZIONE SPERIMENTALE DELLA CAPACITA DEI CAVI SOTTO PIOMBO A PIU CONDUTTORI (The Experimental Determination of the Capacity of Lead Covered Multicored Cable).—L. Bosone. (*Elettrotec.*, 5th Nov., 1929, Vol. 16, pp. 705–708.)

AN INDUCTION-DYNAMOMETER FOR MEASUREMENT OF INDUCTANCE AND CAPACITY.—A. Täuber-Gretler. (*E.T.Z.*, 5th Dec., 1929, Vol. 50, p. 1782.)

See 1928 Abstracts, p. 644.

RELAISGALVANOMETER (A Relay Galvanometer).—R. Sewig. (*E.T.Z.*, 5th Dec., 1929, Vol. 50, p. 1783.)

Moll's method of magnifying a galvanometer deflection, by letting the beam of light fall on a differential thermo-element, involved the use of a separate second galvanometer. Sewig combines the thermo-element and the second galvanometer into one instrument. With an ordinary 25 c.p. lamp, a magnification of 200 can be obtained.

VOLTMETRI ELETTRONICI (Thermionic Voltmeters).—M. Boella. (*Elettrotec.*, 15th Oct., 1929, Vol. 16, p. 667.)

Three types of circuit are described which have proved very useful in the Naval Laboratories:—(1) Triode with anode rectification: with low anode voltage and without compensation. Usually the valve employed is the tetrode Radiotron UX. 222, connected as a triode (plate and screen grid joined), on account of its small input-capacity (4 $\mu\mu$F.), low dielectric loss and good grid insulation ($>10^9$ ohms). (2) Inverted triode. (3) Maximum voltmeter with diode, condenser and ballistic galvanometer.

NOUVEAU DISPOSITIF DE MESURE EN COURANT ALTERNATIF MUSICAL: LE POTENTIOMÈTRE-PHASEMÈTRE (New Apparatus for the Measurement of Alternating Currents of Musical Frequency: the Potentiometer-Phasemeter).— —. Naudillon. (*Génie Civil*, 22nd Feb., 1930, Vol. 96, p. 195.)

A paragraph on this instrument, which measures the absolute value of the current and its phase in relation to a reference current of the same frequency with an accuracy equal to that of a bridge, but more quickly. It is useful in connection with the measurement of transformer distortion, exploration of the acoustic field of a hall, etc., etc.

THE MICROMETRIC MUDDLE.—Camp: Uhler: Dorsey. (*Science*, 8th Nov., 20th Dec., 1929, and 17th Jan., 1930, pp. 453, 606 and 67–68.)

Camp begins "Use the symbol $\mu\mu$ and it will be variously interpreted depending on the audience." Chemists and biologists on the one hand and physicists on the other have their own interpretations. Dorsey shows that the trouble is largely due to the way of regarding the micron μ as a thousandth part of a millimetre instead of as a millionth part of the fundamental unit, the metre. Regarding it properly in the latter way, it must follow that $\mu\mu$, the micromicron, is the millionth part of the millionth part of a metre; it is 10^{-9} mm. The millimicron (mμ) is naturally 10^{-6} mm. Any other interpretations are violations of the metric system principle.

ON THE DETERMINATION OF THE PARAMETERS IN AN EMPIRICAL FORMULA.—W. E. Deming. (*Proc. Phys. Soc.*, 15th Feb., 1930, Vol. 42, Part 2, pp. 97–107.)

LES SYMBOLES GRAPHIQUES INTERNATIONAUX CONCERNANT L'ÉLECTROTECHNIQUE (The Graphic International Symbols Relating to Electrical Engineering).—(*Rev. Gén. de l'Élec.*, 25th Jan., 1930, Vol. 27, pp. 128–140.)

Of the 200 odd symbols here listed, 48 concern Radio and the rest ordinary telegraphy and telephony.

SUBSIDIARY APPARATUS AND MATERIALS.

FACTORS INFLUENCING THE SPEED OF INTENSIFYING SCREENS [FOR X-RAYS].—F. E. Swindells. (*Journ. Opt. Soc. Am.*, Feb., 1930, Vol. 20, pp. 51–61.)

A paper dealing with the fluorescent calcium tungstate screens used to reduce the exposure in X-ray work. The photographic film (which has emulsion on both sides of the base) is placed between the active layers of two such screens. The "intensification factor" (ratio of time for X-rays alone to time with intensifying screens, to produce the same blackness on the film) varies according to conditions from about 2 to 20. The writer finds that the speed of the screens increases with shortened development time; increases with increase of tube potential; is independent of the tube current from 2 to 35 mA. and of the target/film distance from 9.5 to 2.5 metres; increases as more filtering material is interposed between tube and screens; and varies considerably with the photographic emulsion used.

SULL'AZIONE FOTOGRAFICA DEGLI ELETTRONI LENTI (On the Photographic Action of Slow Electrons).—B. Rossi and G. Bernardini. (*Lincei Rend.*, No. 3/4, Vol. 10, 1929, pp. 182–185.)

The writers have succeeded in going below K. Cole's limit of 25 v. by photographing 17.5 volt electrons (total emission 3–4 × 10^{-6}A., exposure 30–75 secs.). They did this by using a very thick mineral oil (which in ordinary light shows a strong green fluorescence) for sensitising the plate. They consider that still slower electrons can be photographed, by suitable modification of the sensitising process, since even 16 volt electrons have plenty of power to affect the bromo-silver grain.

DIRECT-READING VACUUM GAUGE FOR MERCURY-ARC RECTIFIERS.—E. Kobel. (*Brown Boveri Review*, Oct., 1929, Vol. 16, pp. 281–284.)

An outline is given in *Science Abstracts*, Sec. B., Feb., 1930, p. 97.

ELECTRIC POWER DISTRIBUTION.—(*Wireless World*, 19th February, 1930, Vol. 26, pp. 180–182.)

A survey of the "National Grid" scheme for

England and Wales submitted by the Commissioners under the Electricity Supply Act of 1926, for the gradual adoption of a standard voltage for consumers.

"If all goes on smoothly, the next ten years should see a gradual standardisation of voltage and frequency and a uniform supply of electricity throughout Great Britain which, besides cheapening the cost of electricity to the consumer, will considerably simplify the task of the manufacturer of wireless sets, as it is undoubtedly this lack of uniformity which is holding back the extended use of mains-operated receivers."

PITANIE LAMPOVOGO PEREDATCHIKA VISOKOI CHASTOTI BEZ KENOTRONOV (The Supply of Anode Power to a Radio Transmitter from a High Frequency Alternator without Rectifiers).—L. E. Shtilerman. (*T.i T.b.p., Leningrad*, December, 1929, Vol. 10, pp. 599–607.)

In Russian. A report on investigations on the subject carried out at the Central Radio Laboratory. It has been found that good results can be obtained both on telegraphy and telephony when the push-pull method of anode supply is adopted and when the frequency of the alternating supply lies between 8,000 and 10,000 cycles. The modulation of the carrier wave at the supply frequency and the means by which this may be reduced are discussed. Circuits are given of two experimental transmitters whose outputs under certain conditions are practically free from undesired modulation. Standard modulation systems can be employed for operation on telephony. A special modulation system giving 50 per cent modulation with good quality telephony is also described.

FILAMENT SUPPLY FOR RADIO RECEIVER FROM RECTIFIED 25-KILOCYCLE CURRENT.—H. A. Brown and L. P. Morris. (*Proc. Inst. Rad. Eng.*, Feb., 1930, Vol. 18, pp. 298–306.)

A paper describing the design of a 25-kc. valve generator, together with rectifying and filtering arrangements, for supplying filament current to a group of d.c. amplifier valves in parallel in a radio receiver. The chief advantages claimed over the use of a.c. filament supply are :—(1) the use of an inexpensive, long life d.c. valve for all radio-frequency stages and for the detector ; (2) instant response of the receiver when the current is switched on ; and (3) absence of any hum : "quietness of battery performance obtained without the vexations of battery maintenance." The power supply to the 25-kc. generator is derived from the a.c. mains, using half-wave rectification : the plate-voltage supply for the receiver may be incorporated in this equipment.

SCHEINWIDERSTANDSMESSUNGEN AN KUPFEROXYDULGLEICHRICHTERN (Impedance Measurements on Copper Oxide Rectifiers).—W. Deutschmann and W. Schottky. (*E.N.T.*, November, 1929, Vol. 6, p. 462.)

Summary only. For the determination of the real and imaginary parts of the impedance, two equivalent circuits are derived, one having a capacity with a series and a parallel resistance ; the other a capacity in series with a resistance, in parallel with a resistance. All three quantities possess a high temperature dependence. Apparently the rectifying process depends on the conduction mechanism in the oxide layer.

HOT CATHODE RECTIFIER FOR HIGH VOLTAGES.—R. Strigel. (*Siemens Zeitschr.*, July and Aug., 1929, Vol. 9, pp. 448–452 and 487–493.)

The particular tube described is for 66 kv. and 200 mA., full-wave rectification.

DER WELLENSTRAHL-OSZILLOGRAPH (The Jet-Wave Oscillograph).—J. Hartmann. (*E.T.Z.*, 19th Dec., 1929, Vol. 50, p. 1853.)

Summary of that part of Hartmann's paper, dealt with in 1928 Abstracts, p. 646, which refers to the use of his mercury jet-wave as an oscillograph.

THE JET-WAVE RECTIFIER.—J. Hartmann. (*Engineer*, 21st Feb., 1930, Vol. 149, pp. 221–223.)

Very full, illustrated abstract of the inventor's recent I.E.E. paper on his rectifier (1928 Abstracts, p. 646).

THE GAS CONTENT OF SPUTTERED FILMS.—L. R. Ingersoll. (*Phys. Review*, No. 6, 1929, Vol. 33, p. 1094.)

Among other conclusions from these researches, it seems probable that the abnormal magnetic and other properties of sputtered films is primarily due to the large gas content : most of this is given up at 300–400°C., which is just the range of temperature where the films become magnetic and much more conductive. *See* also Ingersoll and Hanawalt, *ibid.*, No. 6, 1929, Vol. 34, pp. 972–977.

ELEKTRISCHE LEITFÄHIGKEIT KATHODENZERSTÄUBTER METALLISCHER SCHICHTEN (Electrical Conductivity of Cathode-Sprayed Metallic Films).—E. Perucca (*Ann. der Physik*, Series 5, 1930, Vol. 4, No. 2, pp. 252–272.)

An experimental investigation of the electrical properties of cathode-sprayed gold and platinum films. Unpolarisable constant resistances of the order 10^{10}—10^{12} ohms have been obtained with a temperature coefficient which is practically zero. *Cf.* same writer, March Abstracts, p. 170 : also p. 168.

ÜBER DIE ERWÄRMUNG VON FESTEN UND FLÜSSIGEN ISOLATOREN IN WECHSELFELDERN SEHR HOHER FREQUENZ (On the Heating of Solid and Liquid Insulators in Alternating Fields of Very High Frequency).—A. Esau and E. Busse. (*Zeitschr. f. Hochf. Tech.*, January, 1930, Vol. 35, pp. 9–11.)

During development work on ultra-short wave valve generators (3–4 m.) great trouble was given by the condenser dielectric heating up and losing its dielectric strength. An investigation was therefore made, and the present paper is a preliminary report of the results. The generator used in the investigation had a maximum power of 800 w. (*see* Wechsung, 1928 Abstracts, p. 518). A rectangular secondary circuit with a two-plate air condenser was variably coupled to the primary circuit, and the material under investigation (about 10 c.c. in volume) was introduced into the field of this condenser. Great difficulty was found in keeping the secondary circuit together, since its supporting insulators bent or shattered after more than 10 minutes test. Finally, high-tension porcelain insulators and special fixing cement were used.

A mercury thermometer was inserted in the substance under investigation: as a rule this warmed up only slightly compared with the material —such warming as occurred being due to the glass tube: but if the mercury column was a long one it was liable to produce resonance effects, with fatal results for the thermometer. This is an example of the care that must be taken to avoid resonance effects in any components—*e.g.*, measuring instruments.

The heating of the various substances progressed, at first, linearly with time: the amount of heat developed in unit time was apparently proportional to the square of the current in the secondary circuit. A fall of maximum (resonance) current, for constant coupling and primary energy, was observed on bringing into the condenser field a substance which heated up more than its predecessor: probably the heating is proportional to i^2R, where R is a loss-resistance of the dielectric and i is the displacement current. Quartz glass in a solid piece was little heated, whereas when finely powdered it became extraordinarily hot: solid metal showed little loss, but the same metal in fine powder was raised to incandescence. This dependence on particle size is now being investigated.

After a time, as the temperature rose high above the room temperature, the heating no longer progressed linearly with time and finally a state of equilibrium was reached. At these high temperatures the tests were complicated by the resultant changes in the value of dielectric constant, which not only upset resonance, but also altered the field density and the value of the current through the dielectric under test.

Curves are given showing the results on various liquids. The least heating was displayed by distilled water, paraffin oil showing only little more and being adopted as a standard on account of its constancy. Vegetable oils and fats showed enormously greater effects, all very much the same; resin oil showed by far the greatest of all. Commercial transformer and condenser oils and glycerin showed a good deal more heating than water or paraffin. Impurities caused irregularity in the curves and a general increase in heating.

The colour-change of cobalt chloride, mercury iodide, etc., can be used as an indicator of the heating effects.

Durchschlag von flüssigen Isolatoren (Breakdown of Liquid Insulators).—Lydia Inge and A. Walther. (*Archiv für Elektrot.*, 18th Jan., 1930, Vol. 23, No. 3, pp. 279–304.)

For various carefully purified liquids the dependence of the breakdown voltage on the length of time under test, the distance between the electrodes, the pressure and the temperature is determined for direct, alternating and impulsive voltages.

Three Mechanisms of Breakdown obtained on Glass by Elimination of Edge Effect.—P. H. Moon and A. S. Norcross. (*Journ. Franklin Inst.*, Dec., 1929, Vol. 208, pp. 705–729.)

Tests leading to the conclusion that there are three distinct mechanisms, in the range of temperature and thickness generally used. Which one will be encountered in a given case depends on temperature, thickness, and constants of the material. In the disruptive range, breakdown gradient is independent of thickness, temperature, and resistivity. It is a constant of the material and is 3,100 kv./cm. for G.1 glass. In the intermediate range, the breakdown voltage varies approximately as the $\frac{2}{3}$rd power of the thickness and is an exponential function of the reciprocal of the absolute temperature. In the thermal range, the breakdown voltage varies as the half or lesser power of the thickness and is also an exponential function of the reciprocal of the absolute temperature.

Effect of Occluded Gases and Moisture on the Resistance of Air Condensers at Radio Frequencies.—H. M. Fletcher. (*Phil. Mag.*, March, 1930, Vol. 9, No. 57, pp. 464–473.)

Experimental results indicate that radio-frequency currents do not pull out an appreciable amount of adsorbed gas from the metal plates of condensers. The resistance of condensers varies with the amount of moisture present. The dielectric losses and the metallic resistance vary with wavelength and the ratio of these resistances is not the same in all condensers. The dielectric losses of the three condensers tested were greater than the metallic resistance.

A New Type of Glow Discharge Tube.—H. J. Reich. (*Phys. Review*, No. 6, Vol. 34, 1929, pp. 997–998.)

The tube has a grid as glow discharge cathode, an ordinary anode, and an electron source, electrically independent of both, at a distance of a few millimetres from the [glow] cathode, so that an electron stream can pass through this grid to the anode.

This electron source consists of a tungsten spiral filament and two perforated disc anodes; the inner of these protects the filament from ionic bombardment and also serves for regulating the glow discharge, while the outer anode is used for accelerating the electrons; the usual accelerating potential is 350 v. Such a tube has five parameters: glow potential, filament current, potentials of the inner and outer anodes, and gas pressure.

Konstanthaltung der Drehzahl von Maschinen für Signalzwecke (Governing the Speed of Machines for Signalling Purposes).—W. Dornig. (*E.T.Z.*, 3rd Oct., 1929, Vol. 50, pp. 1443–1446.)

The governor described in a former paper (1929

Abstracts, pp. 111–112) functions equally well for a vertical machine; its action, therefore, cannot depend in any way on gravity.

STATIONS, DESIGN AND OPERATION.

TELEPHONIE UND MEHRFACHTELEGRAPHIE AUF KURZEN WELLEN (Telephony and Multiplex Telegraphy on Short Waves).—K. Küpfmüller. (*Telefunken-Zeit.*, Dec., 1929, Vol. 10, No. 53, pp. 22–39.)

A paper on the special problems presented by the use of short waves, with special reference to the linking-up to land-line telephone networks. The writer discusses first the syllable-intelligibility criterion of a service (65–70 per cent is necessary and sufficient, for smooth working; 30 per cent will work in an emergency) and its connection with the received frequency band (300–2400 p.p.s. is sufficient): the testing of this property of a circuit by measurement of the overall transmission loss (nett attenuation) on the various frequencies (Siemens and Halske level-meter—an absolutely calibrated valve voltmeter of high input resistance).

He then deals with phase- and non-linear distortion: the former only becomes important on very long lines (when time-differences amount to more than 0.01—0.015 sec.): the latter, much more general, luckily has comparatively little effect on speech transmission—curves are given showing the variation of syllable-intelligibility with "klirr" factor (ratio of effective values of overtones to fundamental) from which it is seen that the intelligibility only begins to fall seriously when the factor reaches 20–30 per cent. But for multiplex and for simultaneous telegraphy and telephony, non-linear distortion is of serious importance.

The question of background noise and its ratio to signal is then discussed: on line telephony the level difference should be at least 5 nepers, but on a wireless link it may often be only 3 nepers (intelligibility 65 per cent). Regarding actual strength of received speech, curves are given showing the relation between nett attenuation (microphone to telephone) and intelligibility: the latter, as might be expected, reaches a maximum for an attenuation of about 1 neper (about the strength of direct speech between two speakers at close quarters). At about 7.5 nepers, intelligibility practically vanishes. The CCI limit is 3.3.

The troubles caused by echo-effects are then dealt with, quantitatively, together with their prevention by echo-suppressors. The writer then passes on to consider the wireless link, with its complications of fading; these are dealt with more quantitatively than is usual. Berlin-Hamburg results on 30–40 m. waves suggest that the reflecting layer approaches or recedes from the earth by some 200 m. in a minute. The differing effects of fading on different note-modulated waves are discussed, and the occurrence of damping distortion. There is also a subsidiary non-linear distortion, due to interference and involving the second harmonic:—only for the case where the path-difference is smaller than about 6 km. do the amplitudes of the overtones vary about in proportion to the fundamental. In this case the "klirr" factor is $k = \frac{c}{4}$, where c is the degree of modulation; by choosing c suitably the non-linear distortion can be sufficiently reduced. But if the path-difference $>$ 6 km., there will be moments when the fundamental vanishes but the second harmonic remains, and serious distortion will result.

The only remedy for these interference troubles lies in the choice of a suitable wavelength and the concentration into beams. The troubles due to the slower variations of attenuation are combated by reaction-suppressors (*cf.* Hahn and Warncke, 1929 Abstracts, pp. 164–165) and automatic damping regulators, which are discussed. Secrecy in the wireless link is then considered, including the Western Electric method and that of Siemens and Halske. In the final section on multiplex telegraphy the author, while recognising the many advantages of such a system, admits that its use on short waves presents special difficulties which have not yet been completely overcome; non-linear distortion and damping fluctuations are here more troublesome than in telephony. The paper ends with a brief reference to simultaneous telegraphy and telephony.

BEAM TELEPHONY TO JAPAN.—(*Electrician*, 14th Feb., 1930, Vol. 104, p. 191.)

An account of the successful transmission, from the Imperial and International Communications' Marconi beam station at Dorchester, of the speech of the chief Japanese delegate to the Naval Conference. A wavelength of 26.269 m. was used; the speech was relayed throughout Japan by means of the Japanese broadcasting stations.

SHIP-AND-SHORE RADIO TELEPHONY: DETAILS OF THE "MAJESTIC'S" INSTALLATION.—(*Electrician*, 7th March, 1930, Vol. 104, p. 304.)

TELEPHONE COMMUNICATION BETWEEN SHIPS AND SHORE.—(*Engineer*, 21st Feb., 1930, Vol. 149, p. 203.)

A paragraph on the inauguration of the experimental public service of radio-telephony between the "Majestic" and Great Britain (the P.O. stations Rugby—transmitting—and Baldock—receiving).

RADIO BROADCASTING TRANSMITTERS AND RELATED TRANSMISSION PHENOMENA.—E. L. Nelson. (*Bell Tech. Journ.*, Jan., 1930, Vol. 9, No. 1, pp. 121–140.)

A brief discussion of recent developments in American practice concerning radio broadcasting transmitters. Descriptive material and photographs pertaining to several new commercial transmitting equipments are included. Reference is also made to the more important aspects of the related transmission problem. A short bibliography is attached as an appendix.

WIRE LINE SYSTEMS FOR NATIONAL BROADCASTING.—A. B. Clark. (*Bell Tech. Journ.*, Jan., 1930, Vol. 9, No. 1, pp. 141–149.)

SWISS "REGIONAL" BROADCASTING PLAN.—(*Electrician*, 14th March, 1930, Vol. 104, p. 345.)

A paragraph on the broadcasting stations which are to be supplied by the Marconi Company.

O RADIUSE DEISTVIA RADIOVETSHATELNIH STANCII (On the Range of Radio Broadcasting Stations).—P. G. Panov. (*T.i T.b.p. Leningrad*, December, 1929, Vol. 10, pp. 623–625.)

In Russian. The author suggests that in order to determine the economical range of a proposed broadcasting station the following two curves should be plotted : (*a*) the expense of the station against the range and (*b*) the estimated income from listeners against the range. The intersection of these two curves gives the economical range.

BUILDING RADIO TRANSMITTERS FOR THE CHINESE GOVERNMENT.—P. C. Rawls. (*Science*, 7th Feb., 1930, Vol. 71, p. 163.)

Mention of a paper read before the Am. Assoc. for the Advancement of Science. Difficulties due to white ants and humid atmosphere were largely overcome by the use of glass and teak-wood. Eight hundred Chinese characters were built into a code system to deal with the many different Chinese dialects.

GENERAL PHYSICAL ARTICLES.

HET KORTGOLVIGE EINDE VAN DE REEKS DER ELECTROMAGNETISCHE TRILLINGEN (The Short-Wave End of the Electromagnetic Wave Spectrum).—J. Clay. (*Physica*, No. 10, Vol. 9, 1929, pp. 353–366.)

General survey of the work of the last ten years, especially that of Millikan, Bothe and Kolhörster, and Aston. The writer stresses the importance, for future research, of more accurate methods of wavelength measurement.

ETHER STRUCTURE : THE " DIPOLE ETHER HYPOTHESIS."—A. P. Carman. (*Science*, 21st Feb., 1930, Vol. 71, pp. 214–215.)

" Studies in recent years of the dielectric properties of gases and electrolytes show that electrical forces and inductions in such media depend upon the polarized ions or ' dipoles ' of the medium. Why not extend the same concepts to electrical forces and inductions across a vacuum, that is, through the ether ? "

OVER KATODESTRALEN (Cathode Rays).—G. van Wageningen. (*Physica*, No. 9, Vol. 9, 1929, pp. 337–350.)

The transmission of electrically charged particles through matter is discussed. It is shown that the loss of velocity and the range of the particles may be deduced from the general law that the loss of energy per second is constant. Absorption is discussed and shown to be related to range in a general way. The secondary emission of electrons along the range is shown to be related to the loss of energy. Tables are given for dv/dx, range, absorption coefficient, and total number of secondary electrons liberated per cm. of the range, for all velocities.

ÜBER TEMPERATURMESSUNGEN IN QUECKSILBERDAMPFENTLADUNGEN (Temperature Measurements in Mercury Vapour Discharges).—E. Lübcke. (*Zeitschr. f. tech. Phys.*, Dec., 1929, Vol. 10, pp. 598–603.)

NACHWEIS LANGSAMER ELEKTRONEN MIT HILFE DES GEIGERSCHEN ZÄHLERS, UND UNTERSUCHUNG DER AUS DÜNNEN SCHICHTEN AUSGELÖSTEN PHOTOELEKTRONEN (Registration of Slow Electrons with the help of the Geiger Ion Counter, and the Investigation of the Photoelectrons liberated from Thin Layers).—H. Kallmann. (*Physik. Zeitschr.*, No. 17, Vol. 30, 1929, pp. 526–527.)

LE MÉCANISME DE L'ÉMISSION ET L'EXPÉRIENCE DE MELDE (The Mechanism of Emission [of Radiation] and Melde's Tuning-fork and String Experiment).—L. Décombe. (*Comptes Rendus*, 28th October and 30th December, 1929, Vol. 189, pp. 684–686 and 1251–1253.)

The writer's theory of " pulsating elastic spheres " (protons and electrons—*see* 1929 Abstracts, p. 402) applied to the analogy of Melde's experiment, indicates that the emission of radiant energy is a consequence of oscillations, more or less rapidly damped, made by the stable orbits round their normal positions, when a disturbing cause has displaced them from these.

CLASSICAL AND MODERN ELECTROMAGNETIC THEORIES.—A. Press. (*Phil. Mag.*, November, 1929, Vol. 8, No. 52, pp. 637–658.)

Reconciliation between the classical theories and the latest theories and results is obtained by the theory of Atomic Atmospheres outlined by the writer in 1925, which takes into account the two Fresnelian types of ætheric media, the one condensed after the manner of Stokes near atomic nuclei and forming the atomic diameters, the other being the normal æther between atoms.

RECHERCHES EXPÉRIMENTALES SUR L'ÉLECTROAFFINITÉ DES GAZ (Experimental Researches on the Electronic Affinity of Gases).—M. A. da Silva. (*Ann. de Physique*, Sept., 1929, Vol. 12, pp. 99–168.)

As a result of these researches it is concluded that the electronic affinity of argon is nil, while those of pure hydrogen and of nitrogen appear to have a certain small value (though in the case of hydrogen the results could be explained by the presence of very mobile positive ions—mobility greater than 11 cm./sec.). As regards the mechanism of the formation of negative gaseous ions, the hypotheses of J. J. Thomson and of Wellisch are examined in the light of these researches : that of Wellisch is found to be untenable, whereas the results agree well with that of Thomson.

THE WORK OF SIR JOSEPH LARMOR.—Oliver Lodge. (*Phil. Mag.*, October, 1929, Vol. 8, No. 51, pp. 576–584.)

IONISATION POTENTIAL AND CONDUCTIVITIES OF METALS.—B. B. Ray and D. P. R. Chaudhuri. (*Nature*, 5th Oct., 1929, Vol. 124, pp. 512–513.)

Mukherjee and Ray suggest that the " valency shells " of the neighbouring atoms touch one another and thus form a large equipotential surface in the metal crystal. Electrons in this surface would travel freely without doing any work, and would thus, in this restricted sense, be "free"—as demanded by the "free electron" explanation of the law that the ratio of thermal to electrical conductivity is the same for all metals and is proportional to the absolute temperature.

The writers now find that, with a few anomalous exceptions, in any group of elements, if the metals possess the same crystal structure the product of electrical conductivity and ionisation potential ($K \times I$) varies inversely as the atomic number (N). This fits in with the idea that the "free electrons" as defined above are really responsible for electrical and thermal conductivity.

THE THERMAL CONDUCTIVITY OF A SINGLE CRYSTAL OF BISMUTH IN A TRANSVERSE MAGNETIC FIELD.—G. W. C. Kaye and W. F. Higgins. (*Phil. Mag.*, December, 1929, Vol. 8, No. 54, pp. 1056–1059.)

A LANTERN SLIDE MODEL OF THE WAVE ELECTRON. —S. R. Milner. (*Nature*, 7th Dec., 1929, Vol. 124, p. 876.)

SUR L'EFFET VOLTA. INFLUENCE DE L'OXYDATION DES ÉLECTRODES (On the Volta Effect. Influence of the Oxidation of the Electrodes). —E. Dubois. (*Comptes Rendus*, 30th Dec., 1929, Vol. 189, p. 1260.)

KOLONNENIONISATION IN GASEN BEI ERHÖHTEM DRUCK (Columnar Ionisation in Gases at Increased Pressures).—G. Jaffé. (*Physik. Zeitschr.*, 1st Dec., 1929, Vol. 30, pp. 849–856.)

Further extension of the work referred to in 1929 Abstracts, p. 402.

ELEKTRISCHE MESSUNGEN AN LANGEN GLEICHSTROMLICHTBOGEN IN LUFT (Electrical Measurements on Long D.C. Arcs in Air).—A. v. Engel. (*Zeitschr. f. tech. Phys.*, November, 1929, Vol. 10, pp. 505–508.)

Measurements of mean current density and axial field strength in the positive column, for a range 1–100 A. approx. Also on the influence of the amount of air introduced per minute, and of the tube diameter. The results are discussed.

DIE AUFBAUZEIT VON GLIMMENTLADUNGEN (The Building-up Time of Glow Discharges).—M. Steenbeck. (*Zeitschr. f. tech. Phys.*, Nov., 1929, Vol. 10, No. 11, pp. 480–483.)

A cathode-ray-oscillographic investigation of the processes of a glow discharge. At low pressures Townsend's views are confirmed. Under certain conditions, for the same potential and the same length of gap, the discharge may follow more quickly the higher the gas pressure, in spite of the decreased mobility of the carriers. This result comes near to those of Rogowski. *See* also same author, *Naturwiss.*, 13th Dec., 1929, pp. 981–982, where c.r. oscillograms confirm the Hippel-Franck theory for high gas-pressures.

THE PRODUCTION OF HIGH SPEED ELECTRONS BY INDIRECT MEANS.—E. T. S. Walton. (*Proc. Camb. Phil. Soc.*, Oct., 1929, Vol. 25, Part 4, pp. 469–481.)

An account of an attempt to produce high speed electrons by an indirect method suggested by Rutherford, similar to that employed in experiments on the electrodeless discharge. By an oscillatory spark discharge a rapidly varying magnetic field is produced perpendicular to the plane of a coil wound round a vacuum tube, and thus a circular electric field is generated in the plane of that coil. This electric field should last sufficiently long to enable an electron, placed in it, to acquire a velocity greatly in excess of that produced by allowing the electron to fall through the maximum P.D. used. Results were negative, probably because the stray fields sent the electrons to the walls of the vessel, the accelerating field being only about 100 v. per cm. This was found too, by Wideroe (1929 Abstracts, p. 169) who showed that the electrons struck the walls after going round the tube only 1½ times.

MISCELLANEOUS.

PUBLIC-ADDRESS AND CENTRALIZED RADIO SYSTEMS.—E. W. D'Arcy. (*Rad. Engineering*, October, 1929, Vol. 9, pp. 62–63.)

This first instalment of a series deals with the power amplifier and power supply unit. Subsequent articles will deal with fader controls, line balancing, level-indicating devices, impedance-matching; centralised distributing systems, channel-selecting devices, relay control; laboratory test equipment.

TELEPHONE COMMUNICATION SYSTEM OF THE UNITED STATES.—B. Gherardi and F. B. Jewett. (*Bell Tech. Journ.*, Jan., 1930, Vol. 9, No. 1, pp. 1–100.)

A general description of the telephone communication system of the United States of America; some of the more important engineering problems involved are outlined and the service results obtained are indicated. A bibliography of papers relating to the Bell communication system is given.

ÜBER DEN FLATTEREFFEKT AUF PUPINISIERTEN LEITUNGEN (The "Flutter Effect" in Pupinised Conductors).—W. Deutschmann. (*Zeitschr. f. tech. Phys.*, November, 1929, Vol. 10, pp. 511–515.)

A treatment of this effect as a result of an apparent increase of hysteresis-loss resistance in the coils, due to the presence of the telegraphy currents simultaneously with the telephony currents, leads to an approximate calculation of the phenomenon and of the means to avoid it. Oscillograms agree well with the calculated values.

DIE HOCHFREQUENZTELEPHONIE FÜR ELEKTRIZITÄTSWERKE (High Frequency Telephony for Power Stations).—B. Kleebinder. (*Elektrot. u. Masch:bau*, 8th Sept., 1929, Vol. 47, pp. 798–804.)

Über die periodischen Veränderungen der Form der Sonnencorona (On the Periodic Variations of Form of the Solar Corona).—Ö. Bergstrand. (*Naturwiss.*, 7th Feb., 1930, Vol. 18, pp. 126–130.)

Weather Recurrences and Weather Cycles.—R. Gregory. (*Nature*, 25th January, 1930, Vol. 125, pp. 132–134.)

From the presidential address to the Royal Meteorological Society on January 15th. The existence of the annually recurring spells of cold or warm weather enumerated by Buchan is not supported by scientific evidence. The Brückner cycles, of average length 34.8 years, vary too much among themselves to be useful for the purpose of making long range forecasts of weather; their true value is in connection with the study ot waves of emigration and the movements of peoples, for at the end of the warm half of the cycle an agricultural community will be prosperous, while at the end of the cold half it will be poor. In the rainfall of Great Britain, the Brückner cycle is far less important than one of fifty years; the eleven-year sunspot cycle is also of little importance. More exact information is known about a 5.1-year periodicity in British weather than about any similar phenomenon.

Thyrite for Lightning Arresters.—McEachron. (*See* under "Atmospherics.")

Protection of L.T. Lines against Inductive Effects of H.T. Lines by Special Valves.—A. Tchernycheff. (*Confér. d. Grands Réseaux Élec.*, Paris, 1929.)

Gegeninduktivitätsmessungen an Leitungen mit Erdrückleitung (Mutual Induction in Lines with Ground Return).—H. Klewe. (*E.N.T.*, Dec., 1929, Vol. 6, pp. 467–479.)

Power Line Interference with Telephony.—E. Picault. (*Ann. des P.T.T.*, Oct., 1929, Vol. 18, pp. 885–892.)

A simplification of the CCI formula for the electrostatic effect of an unbalanced power line.

Les Parasites d'Origine Industrielle, en Téléphonie sans Fil. (Wireless Interference from Industrial Sources).— —. Marcotte. (*Industrie Élec.*, 10th May, 1929.)

An examination of the interference due to various causes—telephone lines, luminous signs, power lines, trams, etc.

Apparatus utilizing Photo-Electric Cells for Measuring Colour Temperature and Lumens of Incandescent Electric Lamps.—G. T. Winch. (*Journ. Scient. Instr.*, Dec., 1929, Vol. 6, pp. 374–379.)

Photo-Electric Outfits.—R. C. Walker. (*Journ. Scient. Instr.*, October, 1929, Vol. 6, pp. 322–324.)

The apparatus described here is based on N. R. Campbell's plan (*Phil. Mag.*, May, 1927) of keeping the circuit *current* constant and using the change of voltage across the cell; this plan has the advantages that the cell can be made to operate at the greatest possible voltage and therefore at maximum sensitivity, and that the incidence of light is indicated in a form suitable for amplification by thermionic valves. The G.E.C. incorporate this circuit in two units, which can be used for many purposes—*e.g.*, in the detection of feeble light scattered by smoke, etc. A "bright" emitter is preferable to the more modern type of valve, as its current is more easily saturated—this condition being used to render the glow discharge current of the cell non-persistent.

An Apparatus to Measure Color Temperature of Incandescent Lamp Filaments.—C. H. Sharp. (*Journ. Opt. Soc. Am.*, February, 1930, Vol. 20, pp. 62–70.)

Using the same principle as N. R. Campbell's apparatus, the present arrangement employs only one cæsium cell sensitive over the entire spectrum, the red and blue selection being made by the use of rotating filters.

Photo-Conductivity in Dielectric Liquids.—W. H. Eller. (*Journ. Opt. Soc. Am.*, February, 1930, Vol. 20, pp. 71–80.)

Work undertaken to find whether the increase of conductivity of dielectric liquids when exposed to light has a relation to the characteristic "end absorption" exhibited by most organic liquids. It was found that the ionisation produced by ultra-violet light in the liquids tested had a threshold value corresponding very nearly, if not exactly, with the absorption limit. Another result found was that the mobilities of the ions formed must be very small, thus indicating heavy ions such as would result from breaking up the molecule. "This might throw interesting light upon the toxic effects of violet and ultraviolet light on living organisms."

The Prospect of Direct Conversion of Light into Electrical Energy.—Lange. (*See* under "Phototelegraphy.")

Portable Instrument for Measuring Intensity of Ultra-Violet Rays.—N. C. Rentschler. (*Science*, 21st Feb., 1930, Vol. 71, p. xiv.)

The current from a photo-electric cell with a uranium electrode (sensitive to ultra-violet rays) charges a condenser which, at a certain point, discharges through a glow relay tube. This operates a relay which moves a counter up one number for every discharge. The intensity of the rays is judged by the number of counts in a fixed time.

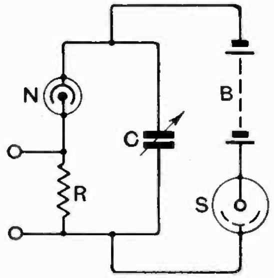
Some Recent Patents.

The following abstracts are prepared with the permission of the Controller of H.M. Stationery Office, from Specifications obtainable at the Patent Office, 25, Southampton Buildings, London, W.C.2, price 1/- each.

LIGHT MODULATING SYSTEMS.

Application date, 1st January, 1929. No. 322667.

Relaxation oscillations are set up in a circuit comprising a Neon tube *N*, a resistance *R*, and a variable condenser *C*, fed in parallel from a battery *B*. A light-sensitive cell is inserted in series with the battery and forms part of the normal resistance controlling the frequency of the oscillations generated by the intermittent conductivity of the tube *N*. Light variations applied to the cell *S* will accordingly modulate the oscillations tapped off across the resistance *R*, giving an output current which can readily be amplified.



No. 322667.

Patent issued to S. G. S. Dicker.

HIGH-FREQUENCY FILAMENT-SUPPLY.

Convention date (U.S.A.), 6th October, 1927. No. 298224.

A.C. current for heating the filaments of a multi-valve set is taken from the mains *via* an oscillator valve, which generates current of a frequency at least double that of the signal currents. This avoids any danger of heterodyning between the filament supply and the signal energy. A sufficiently negative bias is provided to compensate for any excessive grid swing due to the superposition of the H.F. filament supply on the signal voltage. Irregularities in the supply voltage are balanced out by introducing corresponding fluctuations of proper amplitude and phase into the grid circuit of the oscillation generator.

Patent issued to Fansteel Products Co., Inc.

"COMMUNITY" WIRELESS.

Application date, 21st September, 1928. No. 322559.

Relates to broadcast receiving installations designed to serve a number of listeners simultaneously, as, for instance, in hotels, railway trains, etc. In order to maintain constant signal strength in any particular pair of headphones, irrespective of the total number of headphones in use at any time, an ohmic resistance is automatically inserted in series with each headphone circuit when the latter is in use, but is thrown in parallel across the common output transformer from the amplifier when that particular headphone is out of service.

Patent issued to State Railways Radio Co., Ltd., and L. Zoltan.

LIGHT-SENSITIVE DEVICES.

Application date, 19th September, 1928. No. 323041.

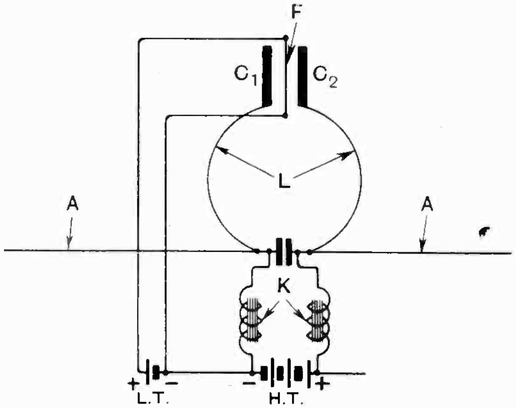
A light-sensitive device comprises a photo-sensitive cell lined with a metal, such as potassium, and containing the usual insulated ring electrode, the cell being located at the upper end of an evacuated vessel which also houses a set of three electrodes forming a thermionic amplifier. The potential difference created by the impact of light on the upper cell is directly applied to the grid and filament of the lower amplifying-set. The whole device is fitted with the standard arrangement of valve pins for plugging into a holder.

Patent issued to F. A. Lindemann.

SHORT-WAVE GENERATORS.

Convention date (Germany), 17th September, 1927. No. 297328.

Oscillations of ultra-high frequency are generated by the emission from a heated filament located between the opposite plates of a condenser. As shown, the filament *F* is energised from a low-tension battery *LT*, and is inserted between the two plates C_1, C_2 of a condenser shunted across a high-tension battery *HT* of 100 volts or more. The main oscillatory circuit comprises the condenser, the supply leads *L*, and a Hertzian half-wave aerial *A*. Chokes *K* confine the generated oscillations to the main circuit. The condenser C_1, C_2 and filament *F* are enclosed inside an evacuated bulb. The condenser may take the form of concentric rings, or inner and outer spirals,



No. 297328.

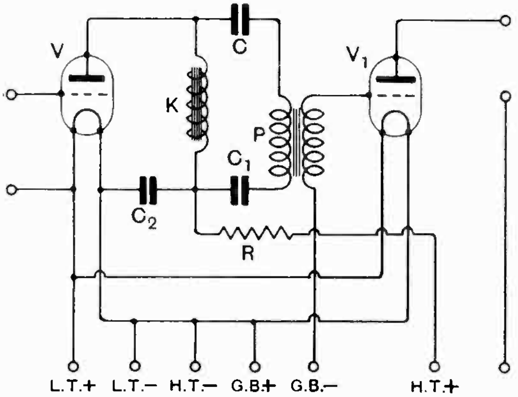
of wire. With such an arrangement oscillations of a wavelength of 30 centimetres have been obtained.

Patent issued to Suddeutsche Telefon Akt.

INTERVALVE COUPLINGS.

Application date, 21st September, 1928. No. 322814.

The primary winding *P* of the coupling-transformer is insulated from the H.T. supply by two condensers *C*, C_1 of sufficient capacity to pass audible-frequency components. The H.T. supply is fed directly to the plate of the valve *V* through a choke *K* in series with a decoupling resistance *R* of 500 ohms. A third condenser C_2 bypasses any



No. 322814.

A.C. components choked back by the resistance *R*. By preventing the passage of direct current through the transformer winding *P*, " osmosis " is avoided and any consequent electrolytic action tending to disintegrate the wire. This permits the use of a very fine gauge wire, of high inductance and comparatively low distributed capacity, giving a constant amplification factor over a frequency band ranging from 30 to 10,000 cycles.

Patent issued to H. Green and Celebritone, Ltd.

ELECTROSTATIC LOUD SPEAKER.

Convention date (U.S.A.), 12th March, 1928. No. 307734.

A rigid back-plate of metal, slightly convex and perforated with a series of concentric holes of graded size, serves as a support for a buffer material such as soft rubber. A flexible diaphragm is stretched over the rubber, and is covered in turn by an outer metallic plate to complete the speaker diaphragm.

Patent issued to Newcombe-Hawley Inc.

VALVE AMPLIFIERS.

Application date, 25th July, 1928. No. 321151.

Relates to electro-mechanical systems, such as electric sound recorders, telephone receivers and transmitters, oscillographs and similar devices for converting electrical into mechanical vibrations, and vice versa, with the minimum distortion of wave form over a wide range of frequencies. The invention consists broadly in connecting the apparatus to a thermionic amplifier comprising a reaction circuit, the character of the reaction effect being controlled so as to enable the velocity, acceleration, or amplitude of a vibrating member to be substantially proportional to a wide range of input voltages, thereby counteracting any distortion of wave form.

Patent issued to P. W. Willans.

SMALL-BULK TRANSFORMERS.

Application date, 7th January, 1929. No. 323124

The fine windings consist of wire having a core made of an alloy containing 90 per cent. copper and 10 per cent. silver, the core in turn being coated with pure silver. This gives the necessary tensile strength, and also affords the necessary protection against corrosion, at a minimum cost.

Patent issued to S. G. S. Dicker.

MAINS TRANSFORMERS.

Application date, 4th February, 1929. No. 322946.

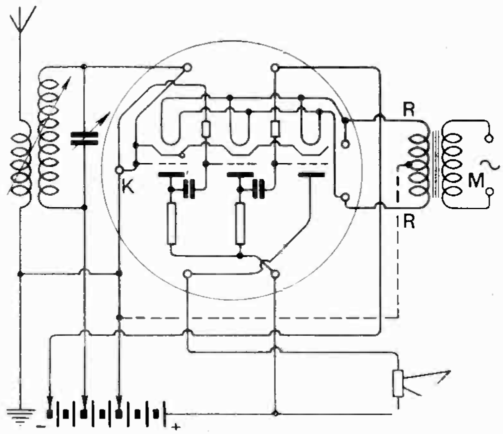
In order to prevent the burning-out or overheating of circuit components due to a short circuit on the secondary side of a mains-unit transformer, one end of the primary winding is connected to a broad metal lip partly surrounding the secondary winding and soldered in turn to a flat spring. If a short-circuit occurs, the metal lip absorbs heat from the secondary winding and fuses the solder, causing the spring to jump back so as to cut off the power supply to the primary winding.

Patent issued to S. G. S. Dicker.

MULTISTAGE VALVES.

Convention date (Germany), 9th August, 1927. No. 295330.

The Figure shows a multistage valve comprising a detector and two stages of resistance-capacity amplification, the filaments being indirectly heated from the mains *M*. In order to eliminate mains " hum," the leads *R* feeding the filaments are kept



No. 295330.

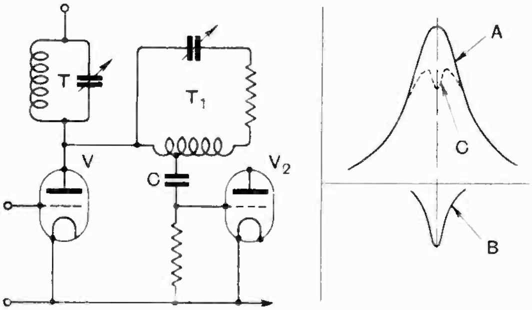
as short as possible, and are thoroughly insulated from the receiving circuit. Only the actual cathodes or electron-emitters are connected to the aerial input, the common point being shown at *K*.

Patent issued to Allgemeine Elektricitäts-Ges.

HIGH-FREQUENCY AMPLIFIERS.

Application date, 27th September, 1928. No. 321771.

In order to compensate for the sharp "cut-off" and consequent loss of the higher side-band frequencies in a highly tuned HF amplifier, a second tuned circuit is inserted between the plate of one



No. 321771.

valve and the grid of the next. As shown, the plate of the amplifier *V* is tuned by the circuit *T*, the second valve V_2 being coupled through a condenser *C*. An intermediate circuit *T*1 is tuned to the incoming carrier wave, but its damping is less than that imposed on the circuit *T* by the valve *V*. The effect of the two circuits is shown separately, the curve *A* representing that due to the circuit *T*, and *B* that due to the circuit *T*1. The flat-topped curve *C* shows the combined effect on the output.

Patent issued to C. E. G. Bailey and the Gramophone Co., Ltd.

PIEZO-ELECTRIC MOUNTINGS.

Convention date (Germany), 17th December, 1927. No. 302584.

A piezo-electric crystal is mounted at the base of an amplifier valve, the whole assembly being constructed as a single compact unit. This ensures a more effective amplification of the piezo voltages than is possible when the voltages are fed to a separate amplifier over comparatively long leads subject to capacity leakage. The control of the valve, and also the supply of heating and plate voltages, is effected from a distance.

Patent issued to Telefunken Ges. für Drahtlose Telegraphie.

TRANSMITTING PICTURES IN COLOUR.

Convention date (U.S.A.), 20th March, 1928. No. 308277.

The picture is divided into a number of elementary areas by a rotating slotted screen, and each area is scanned in succession by light of one particular colour. Subsequently a number of other elementary areas, interspersed between the first, are similarly exposed by the same screen and are scanned by light of another colour. In this way two complete pictures, each of somewhat inferior quality, but in different colours, are transmitted. The resultant picture, formed by the combination of these two at the receiving end, is polychromatic and of good quality.

Patent issued to British Thomson Houston Co., Ltd.

AERIALS.

Convention date (Germany), 3rd March, 1928. No. 307059.

Relates to directional aerials of the kind in which "phasing" coils or similar means are inserted along the length of the antenna wire at intervals in order to suppress the reverse radiation from successive half wavelengths. According to the invention the desired suppression effect is secured by surrounding each alternate half wavelength by tubular conductors of corresponding length, or by screening these portions of the antenna wire with one or more parallel rod conductors.

Patent issued to Telefunken Ges Für Drahtlose Telegraphie.

Application date, 19th September, 1928. No. 322714.

Relates to directive aerials in which radiation is suppressed from intermediate portions of the aerial wire, so as to produce a maximum effect in one direction. As shown in Fig. 1, the antenna wire is several wavelengths long, each half wavelength, such as *EF* and *DC*, being separated by a

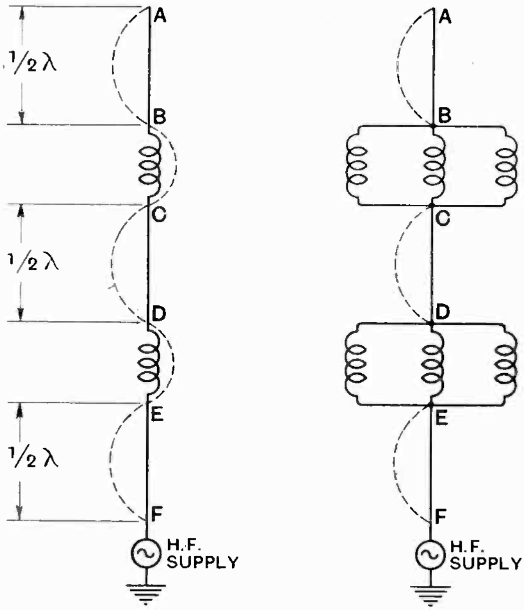


Fig. 1. Fig. 2.

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non-radiating solenoid *DE*. The current distribution is indicated in dotted lines, showing a maximum field to the left-hand side. Fig. 2 shows an alternative arrangement in which the "phasing" or non-radiating sections *BC* and *DE* consist of three solenoid windings in parallel.

Patent issued to E. Green.

GRAMOPHONE PICK-UP.

Application date, 26th June, 1928. No. 321144.

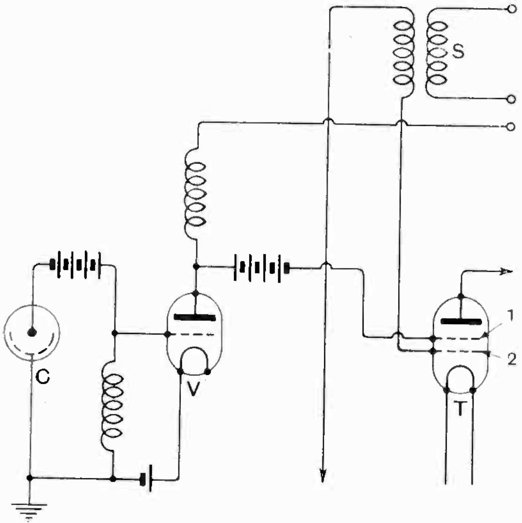
In order not to limit the movement of the armature by the proximity of the polepiece, the end of the armature is designed to move towards and under or over the polepiece in a plane parallel with that of the polepiece. To increase the efficiency of the magnetic circuit the armature may co-operate with a set of four polepieces.

Patent issued to P. D. Tyers.

TELEVISION.

Application date, 28th August, 1928. No. 321750.

When a light-sensitive cell is inserted in series with the input of an amplifying valve, the output of the valve varies only according to the rate of change of intensity of the light falling on the cell. Accordingly when the incident light remains constant, it is usual to interpose a rotating-disc interrupter in the path of the light ray so as to impose a continuously-varying component on the output current. In order to avoid this necessity the arrangement shown in the Figure has been devised. The output from the photo-sensitive cell *C* is applied through an amplifier *V* to the grid 1 of a tetrode *T*. The second grid 2 of the tetrode is fed with a constantly-varying voltage from any independent source *S* of oscillations. Under normal conditions little or no current flows through the plate circuit of the tetrode *T* until the cell *C* is energised by an incident light ray. When this



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occurs, however, the voltage on the grid 1 causes the passage of plate current, which is automatically modulated by the action of the separately-energised grid 2.

Patent issued to Universal and General Radio Co., Ltd., and L. M. Myers.

Application dates, 3rd and 17th May, 1928. No. 321194.

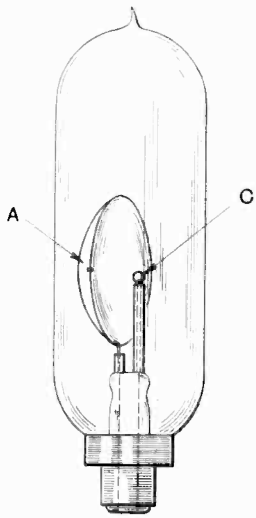
In a television receiver of the type in which the projection screen comprises a number of lamps allocated to separate areas of the screen, and receiving energy intermittently in rotation, means are provided in connection with each lamp for accumulating energy proportional to the received signal impulse applied to the lamp, and for then discharging it, so as to maintain the illumination of the lamp for a certain interval of time after the receipt of signal energy has ceased.

Patent issued to J. Johnston.

Application date, 4th May, 1928. No. 321196.

In order to secure a highly concentrated ray from a glow-discharge tube used in receiving television signals, the anode *A* is in the form of a concave or part-cylindrical reflector, and the cathode *C* is placed at its principal focus. The back of the reflecting electrode is coated with insulating material such as mica or micanite.

Patent issued to J. L. Baird and Television, Ltd.



No. 321196.

Application date, 5th June, 1928. No. 321389.

A system for securing television effects in natural colours comprises, at the transmitting station, a number of light-sensitive cells of varying sensitivity to different light-frequencies, together with means for exploring the object to be televised by each of the cells. At the receiving station a corresponding number of lamps are arranged, each adapted to emit light-rays of a distinctive colour. Synchronously-operated commutator switches are used to ensure the simultaneous operation of each cell and its corresponding lamp.

Patent issued to J. L. Baird and Television, Ltd.

DISTANT VOLUME-CONTROL.

Application date, 31st July, 1928. No. 321392.

A condenser, high-resistance, or other device normally used to regulate the output volume from a wireless receiver or electric gramophone is arranged to be controlled at a distance from the set, preferably by means of a Bowden-wire. The spindle of the volume-control condenser, etc., is fitted with a pinion which gears with a rack. The latter is moved to and fro by the Bowden wire, so as to rotate the control device to the required setting.

Patent issued to J. W. Cairns.