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Editorial.

On the Sound Waves Radiated from Loud-speaker Diaphragms.

THE problem of the nature of the sound waves in the neighbourhood of a piston or rigid diaphragm vibrating either in free space or in a baffle or wall of infinite extent appears to have been first studied by Lord Rayleigh. Most subsequent workers quote his classical "Theory of Sound," published in 1877, as the basis of their investigations. Interest in the subject has increased very much during recent years due to the advent of the loud speaker, and a number of researches have been published which enable one to form a fairly clear picture of the acoustic field in the neighbourhood of such a vibrating diaphragm. Although the results of these researches are well known to those more intimately associated with the scientific side of loud-speaker design and development, it is thought that a *résumé* of the results will be of interest to other readers, especially as they explain peculiarities which a critical listener may detect in the output of certain loud speakers.

In 1926 Erwin Meyer, of the German Government Telegraph Department, published the results of a large number of measurements of pressure and velocity in the sound waves from various types of loud speakers, including an exploration of the field in the neighbourhood of a large horn, the mouth of which may perhaps be regarded as equivalent to a vibrating piston. The results showed, as he pointed out, that with

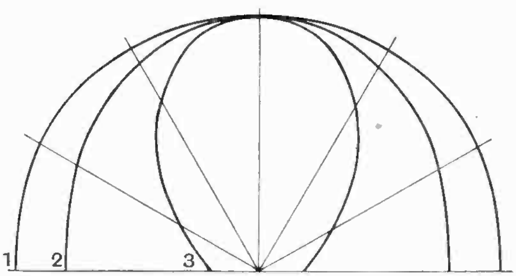

Fig. 1.

(1) $\frac{2R}{\lambda} = \frac{1}{4}$; (2) $\frac{2R}{\lambda} = \frac{1}{2}$; (3) $\frac{2R}{\lambda} = 1$;

$2R$ = *diameter of diaphragm*,
λ = *wavelength*.

increasing frequency the radiation became more directive, that is to say, the energy was concentrated into a narrower beam in front of the loud speaker and less of it was radiated sideways. In the same year Backhaus and Trendelenburg published the results of experiments made in the Siemens laboratories in Berlin with Riegger's Blatthaller, the rectangular diaphragm of which, more than that of any other type of loud speaker, may be regarded as a rigid piston. They also gave a theoretical investigation of the acoustic field of such a piston diaphragm based on the velocity potential, a conception first introduced into hydrodynamics by Lagrange, but applied to this problem by Lord Rayleigh. The potential at any point due to any small element of the diaphragm is equal to the axial velocity of the diaphragm divided by the distance between the point and the element and multiplied by $1/2\pi$. The velocity to be taken is not that at the moment considered but at an earlier moment, the interval being the time required for the sound to travel from the diaphragm to the point. It is thus strictly analogous to the retarded potential of electrical theory. The pressure of the sound wave at any point is proportional to the rate at which the velocity potential at the point is changing. Backhaus and Trendelenburg established a formula for the intensity of the wave at various points along the axis, and showed that there were certain points at which the intensity was zero; the distances of these points from the diaphragm depends on the frequency. The elimination of the sound of a given frequency at such a point is due to interference between the waves arriving in different phases from different parts of the diaphragm. Complete elimination can only exist for a finite number of points; as the distance from the diaphragm increases the interference effects become less marked. To avoid any anomalous results due to this phenomenon, measurements of sound intensity should not be made too close to the loud speaker. In the Bell Telephone Laboratories the minimum distance is taken as $D^2f/4{,}500$ ft., where D is the diameter of the diaphragm or piston in feet, and f is the frequency concerned. This working rule agrees with the results of Backhaus and Trendelenburg. Although they did not work out a formula for the intensity of radiation in various directions, they made a large number of careful measurements and plotted polar curves for various frequencies; these showed that as the frequency was increased the sound became more and more concentrated in a narrow axial beam. A person sitting towards the side, say, at an angle of 45 deg., will thus hear a different quality of sound from a person situated directly in front of the loud speaker, since the higher harmonics will be reduced more than the lower frequencies.

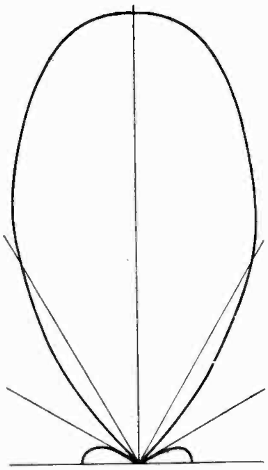

Fig. 2. $\frac{2R}{\lambda} = \frac{3}{2}$

A very masterly analysis of the directive problem was published in 1927 by Stenzel who, after investigating the properties of a row of point sources—a problem somewhat analogous to that of the beam aerial—established formulæ for the radiation in any direction from rectangular and circular diaphragms. His calculated polar curves agree very well with the experimental results obtained by Backhaus and Trendelenburg. For a circular diaphragm of radius R in an infinite baffle he showed that the ratio of the intensity of the sound wave at an angle α to the axis to the intensity on the axis is given by $2\frac{J_1(z)}{z}$ where $z = 2\pi\frac{R}{\lambda}\sin\alpha$, and $J_1(z)$ is the Bessel function of the first order, which may be expressed as a series, giving the result:—

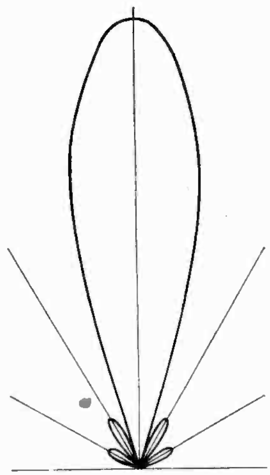

Fig. 3. $\frac{2R}{\lambda} = 3$

$$2\frac{J_1(z)}{z} = 1 - \frac{z^2}{2.4} + \frac{z^4}{2.4.4.6} - \frac{z^6}{2.4.4.6.6.8} + \ldots$$

$$= 1 - \frac{(z/2)^2}{1.2} + \frac{(z/2)^4}{(1.2)(1.2.3)} - \frac{(z/2)^6}{(1.2.3)(1.2.3.4)} + \ldots$$

On the axis $\alpha = 0$ and therefore $z = 0$ and the series reduces to unity. Stenzel gives a curve showing the value of the series for various values of z. From the formula for z it can be seen that for a given diameter $2R$ of diaphragm the angle corresponding to a given value of z and therefore to a given reduction of intensity, is the smaller the shorter the wavelength. We reproduce the calculated curves for values of the diameter ranging from a quarter of the wavelength to five times the wavelength.

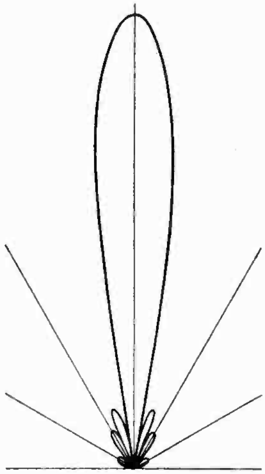

Fig. 4.
$\frac{2R}{\lambda} = 5$

Fig. 1 shows that the directive effect is negligible for wavelengths four times the diameter, but already quite pronounced for wavelengths equal to the diameter. Figs. 2, 3 and 4 show how the effect increases as the wavelength becomes a multiple of the diameter and also how small secondary maxima develop. Figs. 5 and 6 show the experimental results obtained by Backhaus and Trendelenburg with a giant Blatthaller with a pertinax membrane 53 cm. square; Fig. 5 was obtained with a frequency of 200 and Fig. 6 with a frequency of 4,500 cycles per second.

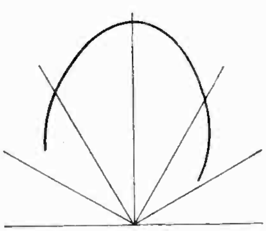

Fig. 5.
Diaphragm 53 *cm.* × 53 *cm.*, $f = 200$.

A general review of the subject has recently appeared in a series of articles by Trendelenburg in the *Zeitschrift für Hochfrequenz Technik*, and an article on Loud Speaker Measurements by Bostwick in the January issue of the *Bell System Technical Journal* contains some experimental polar curves taken at various frequencies, bringing out very clearly the concentration at high frequencies. Although the Blatthaller may approximate to the rigid piston, the ordinary centre-driven diaphragm does certainly not do so except at very low frequencies. Stenzel considers the problem of the diaphragm held rigidly at the edge and vibrating either at its fundamental or at one of its higher frequencies, and he indicates how approximate solutions may be obtained for the simplest cases, but such a problem is much more complicated than that of the rigid piston. The results of theory and experiment all tend to show that the large rigid piston type of diaphragm is unsuitable for the radiation of high quality music or speech, since the quality depends largely on the position of the listener. We give a bibliography of the subject for the sake of those who may wish to consult the articles to which we have referred.

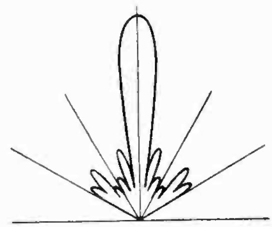

Fig. 6.
Diaphragm 53 *cm.* × 53 *cm.*, $f = 4{,}500$.

G. W. O. H.

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The Algebraic Representation of Triode Valve Characteristics.

By W. A. Barclay, M.A.

THE ordinary "lumped" characteristic of the triode valve is so well known as to require no explanation here. If $v_l = v_a + \mu v_g$, the relation between v_l and i_a is as depicted in Fig. 1, the symbols having their usual connotation. The curve as shown represents this relation for a given filament temperature. As v_l is increased, the current i_a approaches the "saturation" value I_s, which depends directly upon the filament temperature and thus upon the voltage at which the filament is being run. We may thus plot on the same diagram the several lumped characteristics of a valve pertaining to different filament voltages, and such families of curves are, of course familiar to readers of EXPERIMENTAL WIRELESS.

The problem of finding an algebraic equation which will conveniently symbolise the experimentally found lumped characteristic throughout its length is one of some difficulty. It is desirable that any such expression should be as simple as possible, containing few constants—not more than three or four—and that it should be of a form readily adapted for computation. Many expressions have from time to time been proposed which show the relationship for small values of v_l and i_a. These are usually of polynomial or exponential form, or sometimes a combination of the two, and are undoubtedly very convenient and easy to derive within a certain limited range of the variables. Thus we may write

$$i_a = A + Bv_l + Cv_l^2 + Dv_l^3 + \ldots$$

in which the constants $A, B, C, D \ldots$ are found by experiment. Again, the index may be fractional, thus,

$$i_a = (A + Bv_l)^{3/2}$$

or more generally,

$$i_a = (A + Bv_l + Cv_l^2)^n$$

Further, we have the exponential type in which the independent variable v_l itself appears in the index, *e.g.*,

$$i_a = Ae^{Bv_l} + C$$

The constants in these formulæ are all readily determinable from the observed related values of v_l and i_a. If more observations are available than are necessary to determine the constants, the method of Alignment offers an expeditious means of utilising the data to obtain the best values, and is to be preferred to the method of

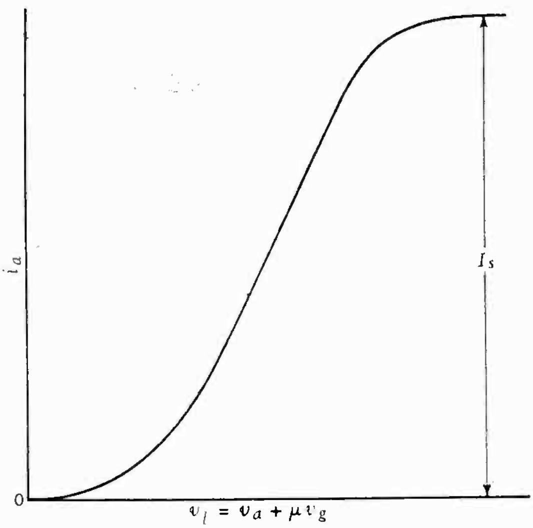


Fig. 1.—*Ordinary lumped characteristic at fixed filament voltage.*

Least Squares where time is lacking for the fuller enquiry. The writer hopes later to have an opportunity of dealing with the correlation of experimental data by the Alignment process.

The fundamental defect of such formulæ as have been cited is that beyond a certain limited range of values of v_l they cease to apply, so that in the region of saturation current they are quite unreliable, and, in fact, misleading. Now, the saturation current value for a certain filament temperature is a well-defined quantity, constant for that temperature, and might almost be expected to appear in an algebraic relation between v_l and i_a. It seems to the writer that any form of algebraic representation which neglects I_s is *ipso facto* defective, while it is desirable at the same time that the equation sought for should be representative of the variables throughout the complete range of their variation.

The type of equation immediately suggested by the form of the characteristic of Fig. 1 is:

$$i_a = I_s(1 - A^{-v_l^B})$$

in which A and B are positive constants, and $A > 1$. As will be seen, this formula contains three constants, and satisfies at sight the extreme pairs of values,

$$v_l = 0,\ i_a = 0\ ;\ v_l = \infty,\ i_a = I_s.$$

Nevertheless, the actual determination of A and B from the substitution in the formula of other related values of v_l and i_a (or points on the curve) is a matter of some mathematical difficulty, as will readily appear if

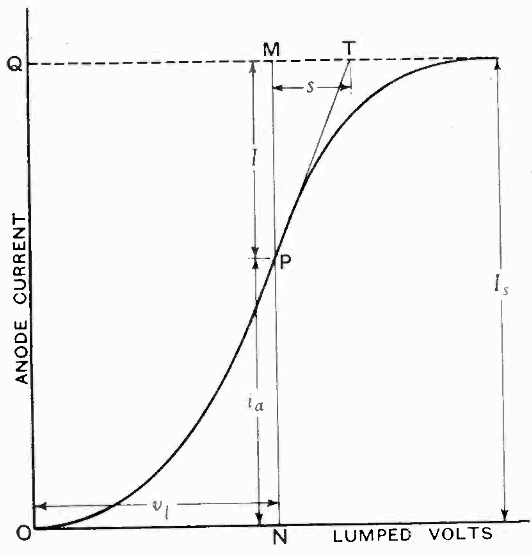


Fig. 2.—*Derivation of "s" from the lumped characteristic.*

trial be made. This disadvantage may, it is thought, have militated somewhat against the general use of this formula and others more complicated of similar type, and the writer believes that an account of a rapid means of estimating the constants of such formulæ may be found interesting and useful.

We shall take as our general form the equation

$$i_a = I_s\{1 - f(v_l)\} \quad \ldots \quad (1)$$

where as usual I_s is the saturation value of current, and f is a function the constants of which are to be determined. In Fig. 2 let P be the point on the characteristic curve corresponding to the values v_l and i_a. Draw the horizontal line QM of ordinate I_s, and through P draw the vertical line MN to meet QM in M and the voltage axis in N. Draw also PT, the tangent to the curve at P, and let it meet the line QM at T. Then PN is, of course, i_a and if PM be taken as a new variable, I, say, we have

$$I = I_s - i_a$$

From equation (1), therefore,

$$I = I_s f(v_l)$$

$$\therefore \log I = \log I_s + \log f(v_l)$$

Differentiating, $$\frac{1}{I}\cdot\frac{dI}{dv_l} = \frac{f'(v_l)}{f(v_l)}$$

Now, $$\frac{dI}{dv_l} = -\frac{di_a}{dv_l} = -\frac{PM}{MT}$$

Also, $$\frac{1}{I} = \frac{1}{PM}$$

Therefore, $$-\frac{1}{MT} = \frac{f'(v_l)}{f(v_l)}$$

If, then, we represent by s the number of volts corresponding to the length of the subtangent MT for any given point P on the characteristic, we can write,

$$\frac{f'(v_l)}{f(v_l)} \times s = -1 \quad \ldots \quad (2)$$

and from this relation the constants of the function f can, for the type of formula above considered, be readily determined.

For example, in the case of the equation

$$i_a = I_s(1 - A^{-v_l^B}) \quad \ldots \quad (3)$$

we have

$$f(v_l) = A^{-v_l^B}$$

Hence from equation (2) we have,

$$s \,.\, B \,.\, \log A \,.\, v_l^{B-1} = 1$$

or taking logarithms,

$$\log s + \log\{\log A^B\} + (B - 1).\log v_l = 0$$

This is a linear equation in log s and log v_l. If, then, with abscissa $\log v_l$ and ordinate log s several corresponding values be taken, these should be found to lie along a straight line whose position and slope will afford a means of determining the quantities A and B. The degree of closeness with which the points as plotted approximate to a straight line indicates the correctness of the assumed type of formula. If the points show a systematic deviation from the linear form, *i.e.*, tend to dispose themselves along a regular curve, this will mean that the deviations are not due entirely to errors of observation, but that another type of assumed formula must be sought.

The practical utility of this method of deriving an algebraic equation for the lumped characteristic of a triode may be illustrated by an example in which the type of formula at first selected does not give the necessary linear relation from which the constants could be derived, so that it becomes necessary to modify it in a manner which will be described. The method of procedure is, however, perfectly general.

Examples of lumped characteristics extending over the full range of current values from zero to saturation are seldom met with, it being usually considered sufficient to take the characteristic over the normal working range only. It seemed appropriate, however, to illustrate the present method by a characteristic which had appeared in *Experimental Wireless*, and the writer therefore selected that shown on p. 28 of Vol. II. (Oct., 1924) for the French "Métal" valve as one of the few available showing the complete characteristics for various filament voltages. The four characteristics for filament voltages 3.2, 3.0, 2.8, and 2.6 are reproduced in Fig. 3, and will be referred to respectively as 1, 2, 3, and 4.

To begin with, it was decided tentatively to assume for these curves formulæ of the type

$$i_a = I_s\,(1 - A^{-v_l^B})$$

in which, of course, the constants I_s, A and B vary with the filament voltage. In particular, the values of I_s are read off straight away from the characteristics, being, in milliamps., 4.2, 3.1, 2.3, and 1.5.

In order to facilitate the use of common logarithms, the formula was re-written

$$i_a = I_s\,(1 - 10^{-av_l^b}) \quad .. \quad (4)$$

where a and b were to be found for each of the four curves. We may thus write

$$f(v_l) = 10^{-av_l^b}$$

$$\therefore \quad \log_{10} f(v_l) = -\,av_l^b$$

Whence by differentiation,

$$\frac{f'(v_l)}{f(v_l)} \times \log_{10} e = -\,abv_l^{b-1}$$

where e is the base of natural logarithms,

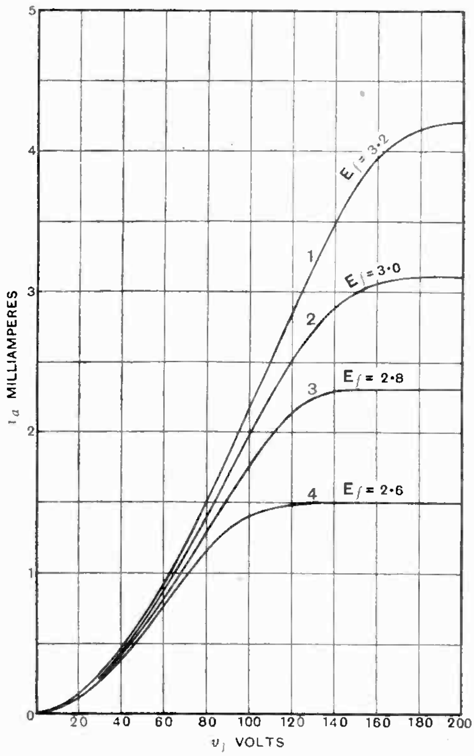


Fig. 3.—*Lumped characteristics of "Métal" for various filament voltages Ef.*

and $\log_{10} e = 0.434$. Therefore, by equation (2),

$$s\,.\,ab\,.\,v_l^{b-1} = 0.434.$$

Taking common logarithms,

$$\log s + \log ab + (b - 1).\log v_l$$
$$= \log(0.434) \quad .. \quad (5)$$

which is a linear equation in log s and log v_l.

Values of s for various values of v_l were now obtained from the characteristics of Fig. 3 as explained above, and tabulated as under:

TABLE I.

v_l	Values of s.			
	1.	2.	3.	4.
40	196	150	118	70
60	125	92	70	37
80	89	58	41	19
100	65	38	22	10
120	40	24	11	6
140	28	15	—	—
160	18	8	—	—
180	10	—	—	—

The common logarithms of these quantities were also tabulated as shown below:

TABLE II.

log v_l	Values of log s.			
	1.	2.	3.	4.
1.60	2.29	2.18	2.07	1.85
1.78	2.10	1.96	1.85	1.57
1.90	1.95	1.76	1.61	1.28
2.00	1.81	1.58	1.34	1.00
2.08	1.60	1.38	1.04	0.78
2.15	1.45	1.18	—	—
2.20	1.26	0.90	—	—
2.26	1.00	—	—	—

From Table II values of log s for the four curves were plotted against values of log v_l, the result being shown in Fig. 4. It was immediately apparent that the loci of the various points could not be regarded as linear, and that the discrepancies must be due to an error in the assumed formula. The uniform concavity of the curves suggested, however, that the values of the abscissæ were unduly crowded at the right-hand side of the diagram, and that could these be spread out more the curves might assume the linear form. The reason for this constriction of the larger values of v_l seemed to lie in the logarithmic scale to which they were plotted, and it seemed, therefore, that if a scale of natural values of v_l were substituted as abscissæ the points might dispose themselves along straight lines as desired. That this, in fact, proved to be the case is shown by Fig. 5, which preserves the same vertical scale as Fig. 4, while using a natural instead of a logarithmic scale for abscissæ. In this diagram the linear distribution of the points is quite marked, and such deviations as occur may legitimately be ascribed to errors of observation and measurement.

The assumed formula (4) for our characteristics is thus shown to be incorrect, inasmuch as equation (5) no longer represents the straight lines of Fig. 5. We have now, therefore, to find a characteristic formula which, when used as described in conjunction with our "subtangent" method of finding constants, will yield a linear relation between log s and v_l. Such a formula is not hard to find by an inverse process of integration, the details of which need not be given here. The result may be expected to be slightly more complicated than our original formula, though, as will be seen later, this complication is more

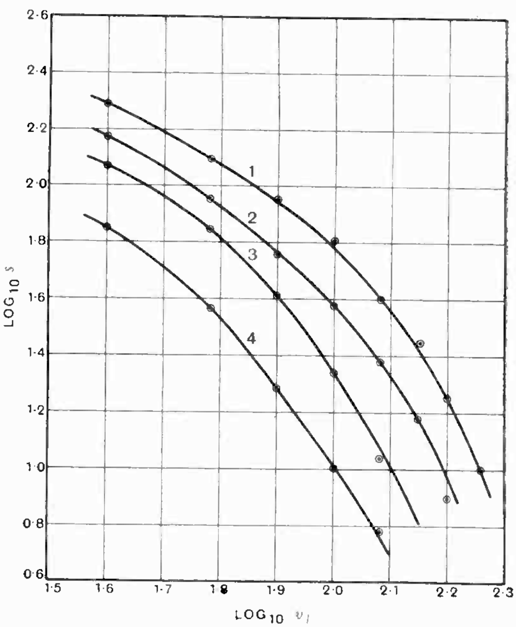


Fig. 4.—*Graph of data in Table II.*

apparent than real. In a form suitable for logarithmic computation, the desired formula may be written,

$$i_a = I_s \{1 - 10^{a(1-10^{bv_l})}\} \quad .. \quad (6)$$

where a and b are both positive constants.

This formula holds for the extreme values

$$v_l = 0,\ i_a = 0\ ;\ v_l = \infty,\ i_a = I_s$$

Also, since

$$f(v_l) = 10^{a(1-10^{bv_l})}$$

$$\log_{10} f(v_l) = a(1 - 10^{bv_l})$$

whence by differentiation,

$$\frac{f'(v_l)}{f(v_l)} \times (\log_{10} e)^2 = -ab \,.\, 10^{bv_l}$$

Therefore, by equation (2),

$$s \,.\, ab \,.\, 10^{bv_l} = 0.1886$$

and taking common logarithms,

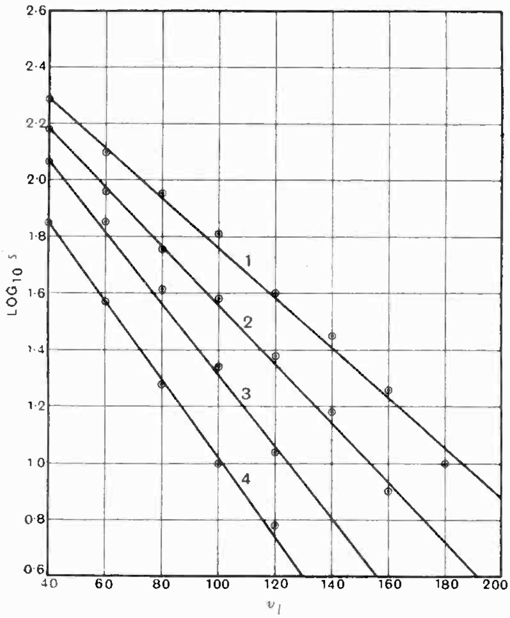


Fig. 5.—*Showing the effect of replotting Fig. 4, using linear instead of logarithmic abscissæ. The values of v_l are thus those of Table 1.*

$$\log s + bv_l + \log a + \log b + 0.724 = 0 \quad (7)$$

Equation (7) is the requisite linear relation between v_l and $\log s$ on the assumption of formula (6), and by means of it we can proceed to find the values of the constants a and b of equation (6) for the four straight lines of Fig. 5. Details of the calculation will here be given for No. 1 only. The best straight line having been drawn through the points for Characteristic No. 1 on Fig. 5, we note that the line passes through the values

$$(v_l = 40, \log s = 2.29) \text{ and } (v_l = 200, \log s = 0.88)$$

The equation of the line will therefore be

$$\frac{v_l - 40}{200 - 40} = \frac{\log s - 2.29}{0.88 - 2.29}$$

i.e., $$\log s + 0.0088\, v_l - 2.66 = 0 \quad (8)$$

Comparing this with equation (7) we have immediately,

$$b = 0.0088$$

and $$\log a + \log b + 0.724 = -2.66$$

Therefore, $$\log a = \bar{2}.68$$

and $$a = 0.048$$

Similar calculations having been effected for the constants of the other three characteristics, we may summarise the results as follows :

TABLE III.

	No. 1.	No. 2.	No. 3.	No. 4.
I_s	4.2	3.1	2.3	1.5
a	0.048	0.046	0.041	0.055
b	0.0088	0.0104	0.0126	0.0139

From this table it is evident that a remains approximately constant for the changes of filament temperature shown, maintaining an average value of about 0.048. On the other hand, b varies with the voltage applied to the filament. If E_f denote this voltage, we may write approximately

$$b = 0.0360 - 0.0085\, E_f.$$

It must, however, be remembered that these expressions for a and b hold only for the extremely limited range of filament voltages given, viz., from 3.2 to 2.6 volts, and that outside this range they may well cease to be applicable. Further numerical data in order to trace the variation of a and b over wider ranges of filament temperture would be interesting and useful.

The simplicity of the application of formula (6) to the direct computation of current values deserves more than passing mention. By means of a table of common antilogarithms, the actual calculation from the formula becomes a matter of extreme facility. Since, if $10^x = y$, $y = \text{antilog}\, x$ we may write formula (6) as follows:

$$i_a = I_s\{1 - \text{antilog}[a(1 - \text{antilog}\, bv_l)]\} \quad (9)$$

or,

$$i_a = I_s\{1 - \text{antilog}\, ap\}$$

where

$$p = (1 - \text{antilog}\, bv_l)$$

The convenience of the antilogarithmic function for the rapid evaluation of i_a will readily be appreciated. One example will suffice. Let us recompute values of i_a for the characteristic 1, using the values of a and b already obtained. We have,

$$i_a = 4.2\ (1 - \text{antilog}\ 0.048\ p)$$

where

$$p = (1 - \text{antilog}\ 0.0088\ v_l)$$

Then the work may be arranged as in Table IV in which, for purposes of comparison, has been included a column of values of i_a as read off direct from the characteristic of Fig. 3.

It will be observed that there is a fair measure of agreement between the observed and computed values of i_a. The writer might here point out that the calculations made in this article may all be considerably simplified by the method of Alignment, and that it is a simple matter to design charts which will effect at sight the various computations of Table IV. To this subject he may, perhaps, return.

TABLE IV.

DETAILS OF THE CALCULATION OF i_a FROM EQUATION (9).

v_l	.0088 v_l	antilog .0088 v_l	p.	.048 p.	antilog .048 p.	1 — antilog .048 p.	i_a (computed)	i_a (actual)
40	0.352	2.25	− 1.25	$\bar{1}$.940	0.87	0.13	0.55	0.47
60	0.528	3.37	− 2.37	$\bar{1}$.886	0.77	0.23	0.97	0.92
80	0.704	5.06	− 4.06	$\bar{1}$.805	0.64	0.36	1.51	1.51
100	0.880	7.59	− 6.59	$\bar{1}$.684	0.48	0.52	2.18	2.17
120	1.056	11.38	−10.38	$\bar{1}$.502	0.32	0.68	2.86	2.83
140	1.232	17.06	−16.06	$\bar{1}$.229	0.17	0.83	3.49	3.48
160	1.408	25.59	−24.59	$\bar{2}$.820	0.07	0.93	3.91	3.94
180	1.584	38.37	−37.37	$\bar{2}$.206	0.02	0.98	4.12	4.15
200	1.760	57.54	−56.54	$\bar{3}$.286	0.00	1.00	4.20	4.20

Meanwhile, his present purpose is to direct attention to a formula which, it is believed, represents the lumped characteristic with considerable accuracy, and is, moreover, quite simple in use. It may be added that the utility of formula (6) is not confined to lumped characteristics, but may be employed to represent the ordinary triode valve characteristics with variable grid and anode voltages.

Book Review.

MEHRFACHRÖHRENEMPFÄNGER (Multiple - valve Receivers). By Manfred von Ardenne. 71 pp., with 67 Figures. Rothgiesser and Diesing, Berlin. 1.70 Marks.

This is really a fifth edition of the author's "Home Construction of Receivers with Multiple Valves," but in view of the extensive revision and additions it has been decided to alter the title and regard this as a first edition of a new work. The author has been closely associated with Loewe in the development of the multiple valve and this booklet discusses all the possible applications of this type of valve either alone or in conjunction with other types for various classes of receivers. One section is devoted to a short-wave receiver with a screen-grid valve and a multiple valve whilst another deals with a portable receiver with three high-frequency multiple valves. The book can be thoroughly recommended to those who have the necessary acquaintance with the language and are interested in the special type of valve with which the book deals.

G. W. O. H.

The Super-Position of Circular Motions.

By T. S. Rangachari, M.A., Assoc.I.R.E.

(Indian Institute of Science, Bangalore, India.)

SYNOPSIS.—By simple analysis the equations for the patterns arising from the simultaneous super-position on a particle, of two circular motions whose frequency ratio may be integral or fractional, are derived. The patterns are plotted with the help of these equations for various ratios of frequencies these being verified by actual observations on a cathode ray oscillograph.

The varying velocity of the particle along the pattern is examined and the advantages in the comparison of frequencies resulting therefrom are explained.

An investigation into the relation between the size of the loops of the pattern and the ratio of the amplitudes of the two impressed circular motions leads to the very interesting result that the loops just collapse into spots when the ratio of amplitudes is equal to the reciprocal of the ratio of frequencies.

IN the comparison of frequencies, the use of Lissajous figures is well known. These figures are produced by the super-position of two simple harmonic motions at right angles to each other and they have been plotted for various ratios of frequencies and given in text-books for ready reference. (See, for example, Lord Rayleigh's "Theory of Sound," Vol I, Chap. II.) The greater advantages of the use of the looped patterns obtained by the super-position of two circular motions imparted to the cathode ray spot on the screen of a cathode ray oscillograph for the comparison of radio frequencies were first pointed out by D. W. Dye (*Proc. Phys. Soc.* 1925, 37, 158), who also suggested several practical methods for producing them. A modification of Dye's method was described by the author in the pages of this journal (May, 1928, p. 264). In view of the importance of Dye's method it would be useful to examine in more detail the nature of the patterns arising from the super-position of circular motions both when the ratio of frequencies is integral and also fractional so that the patterns may be plotted for ready reference as has been done in the case of the Lissajous figures. Incidentally the remarkable properties of these patterns and the special advantages arising therefrom may be elucidated.

The nature of the patterns is here investigated for the two cases where the two circular motions influencing the cathode ray spot are

(1) in the same direction,
(2) in opposite directions.

Under each of the above two divisions the following points are examined.

(*a*) The shape of the pattern when the ratio of frequencies is integral.

(*b*) The velocity of the cathode ray spot along the pattern and the advantages resulting therefrom.

(*c*) The dependence of the size of the loops of the pattern on the ratio of the amplitudes of the impressed potentials.

(*d*) The shape of the pattern when the ratio of frequencies is fractional.

(1) Case when the two Circular Motions are in the same Direction.

(*a*) *Equation for the shape of the pattern when the ratio of frequencies is integral.*

The equation for the path of the cathode ray spot which we may consider as a particle, can be derived from the fact that its position at any instant is determined by the combination of two vectors representing the two circular motions due to the applied potentials whose frequencies are to be compared. Referring to Fig. 1 let O be the origin and OP the reference vector for polar co-ordinates. Let OA be an instantaneous position of the vector representing the circular motion at the lower frequency. Let AB be the position at the same instant, of the vector representing the circular motion at the higher frequency. Let the ratio of frequencies be

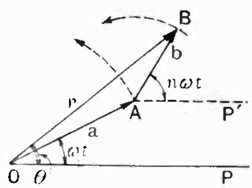
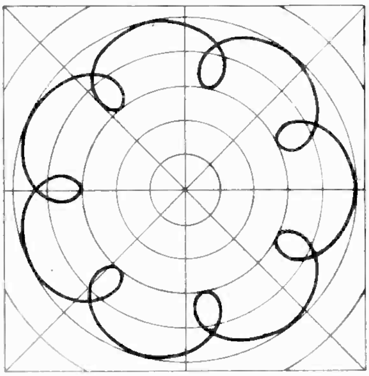


Fig. 1.

$n : 1$. If the vector OA makes an angle ωt with OP then the vector AB makes an angle $n\omega t$ with OP, assuming that the two vectors are in phase along OP and that ω is the angular velocity of the low-frequency vector. It is evident that the instantaneous position of the cathode ray spot due to both the



$n = 8$. a = 4 UNITS. b = 1 UNIT

Fig. 2.

vectors is the point B, and the vector OB is the resultant whose length r gives the distance of the spot at that instant from the origin and the angle θ which it makes with OP gives its orientation. r and θ completely define the position of the spot at time t when the vector OA is at an angle ωt. Let us evaluate r and θ in terms of ωt, a and b, where a and b are the radii of the lower and higher frequency circular motions respectively. It is easily seen that

$$OB = r = \{(a \cos \omega t + b \cos n\omega t)^2 + (a \sin \omega t + b \sin n\omega t)^2\}^{\frac{1}{2}}$$

or $$r = [a^2 + b^2 + 2ab \cos \overline{n-1}\,\omega t]^{\frac{1}{2}} \quad \ldots \quad (1)$$

$$\tan \theta = \frac{a \sin \omega t + b \sin n\omega t}{a \cos \omega t + b \cos n\omega t} \quad \ldots \quad \ldots \quad (2)$$

With the help of the equations (1) and (2) the path of the cathode ray spot, *i.e.*, the pattern can be plotted by varying ωt from 0 deg. to 360 deg. Equation (1) shows that the minimum value of r is $a - b$ and the maximum value $a + b$. As ωt varies from 0 deg. to 360 deg. the radius vector r of the pattern assumes all values between $a - b$ and $a + b$.

Before plotting the pattern, however, it is useful to find out the values of θ for maximum and minimum values of r. The condition for this is $\frac{dr}{d\theta} = 0$.

Now
$$\frac{dr}{d\theta} = \frac{dr}{dt} \cdot \frac{dt}{d\theta}.$$

From equation (1)
$$\frac{dr}{dt} = \frac{-ab\omega(n-1) \sin \overline{n-1}\,\omega t}{[a^2 + b^2 + 2ab \cos \overline{n-1}\,\omega t]^{\frac{1}{2}}} \quad \ldots \quad (3)$$

From equation (2)
$$\frac{dt}{d\theta} = \frac{a^2+b^2+2ab \cos \overline{n-1}\,\omega t}{\omega\{a^2+nb^2+(n+1)ab \cos \overline{n-1}\,\omega t\}} \quad \ldots \quad (4)$$

$$-\{a^2+b^2+2ab \cos \overline{n-1}\,\omega t\}^{\frac{1}{2}}$$

$$\therefore \frac{dr}{d\theta} = \frac{ab(n-1) \sin \overline{n-1}\,\omega t}{a^2+nb^2+(n+1)ab \cos \overline{n-1}\,\omega t}$$

If $\frac{dr}{d\theta} = 0$, then $(n-1)\,\omega t = 0$ or $n'\pi$ where n' is any integral number.

$$\therefore \quad \omega t = \frac{n'\pi}{n-1} \text{ or } 0.$$

Thus the maximum and minimum values of r occur when

$$\omega t = \frac{n'\pi}{n-1} \text{ or } 0.$$

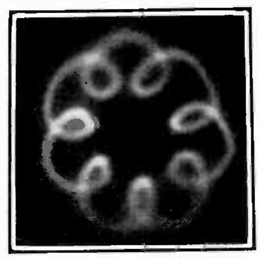


Fig. 3.

Now let us find out what relation θ bears to ωt at the maximum and minimum positions of r.

We have
$$\tan \theta = \frac{a \sin \omega t + b \sin n\omega t}{a \cos \omega t + b \cos n\omega t}$$
$$= \frac{a \sin \omega t + b \sin (\overline{n-1}\,\omega t + \omega t)}{a \cos \omega t + b \cos (\overline{n-1}\,\omega t + \omega t)}$$
$$= \frac{a \sin \omega t + b \sin \overline{n-1}\,\omega t \cos \omega t + b \cos \overline{n-1}\,\omega t \sin \omega t}{a \cos \omega t + b \cos \overline{n-1}\,\omega t \cos \omega t - b \sin \overline{n-1}\,\omega t \sin \omega t}.$$

Since $(n-1)\,\omega t = 0$ or $n'\pi$ when $\frac{dr}{d\theta} = 0$, the above equation reduces to
$$\tan \theta = \tan \omega t$$
or
$$\theta = \omega t.$$

Thus the maximum and minimum values of r occur at $\theta = \frac{n'\pi}{n-1}$ or 0.

For example, let the ratio n of the two frequencies be 8. Then it is easily seen that

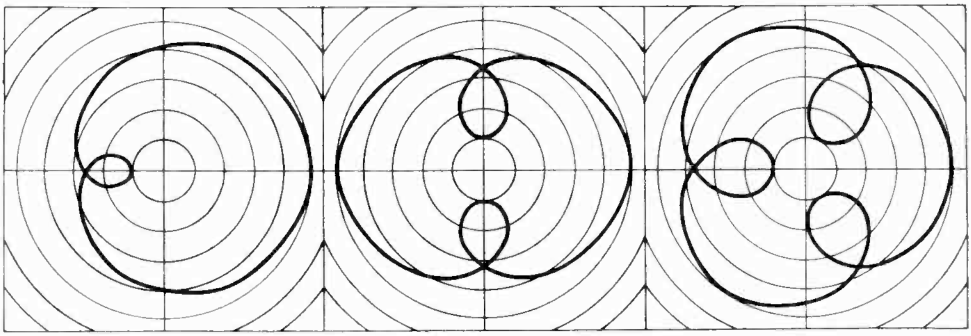
(i) maximum values of r occur at $\theta = 0°$, $51°\frac{3}{7}$, $102°\frac{6}{7}$, $154°\frac{2}{7}$, $205°\frac{5}{7}$, $257°\frac{1}{7}$, and $308°\frac{4}{7}$.

(ii) minimum values of r occur at $\theta = 25°\frac{5}{7}$, $77°\frac{1}{7}$, $128°\frac{4}{7}$, $180°$, $231°\frac{3}{7}$, $282°\frac{6}{7}$ and $334°\frac{2}{7}$.

Since these values occur at regular intervals it can be inferred that the pattern is a symmetrical figure. Hence if the values of r and θ are calculated for values of ωt varying from 0° to $51°\frac{3}{7}$ with the help of equations (1) and (2) the whole pattern can be plotted since the same values of r repeat with a period of $51°\frac{3}{7}$ in this case.

Table I shows the values of r and θ thus calculated for $n = 8$, $a = 4''$ and $b = 1''$. Fig. 2 shows the pattern plotted. Fig. 3 shows a photograph of the pattern observed on the oscillograph screen when $n = 8$.

In Fig. 4 the shapes of the patterns for various ratios, which are plotted in this manner, are shown. It is observed that the patterns have loops inside, their number being $(n - 1)$. Conversely, when the loops are inside, the number of loops plus one gives the ratio of the two frequencies superimposed. Thus the determination of frequency is extremely simple when one of them is known, in that it involves only a counting of the number of loops. This is in contrast with the extreme complexity of the Lissajous patterns for high ratios.



$n = 2$ $n = 3$ $n = 4$

Fig. 4.

(*b*) *The velocity of the cathode ray spots along the pattern.*

In Fig. 5 let *ABCDEF* represent one loop of the pattern. Considering a small element ds of the pattern we write the equation

$$(ds)^2 = (dr)^2 + (rd\theta)^2.$$

TABLE I.

ωt in degrees.	r in inches.	θ in degrees.						
0°	5.000	0°	$51°\frac{3}{7}$	$102°\frac{6}{7}$	$154°\frac{2}{7}$	$205°\frac{5}{7}$	$257°\frac{1}{7}$	$308°\frac{4}{7}$
5°	4.853	11° 47′	63° 13′	114° 39′	166° 5′	217° 31′	268° 57′	320° 23′
10°	4.443	22° 13′	73° 39′	125° 5′	176° 31′	227° 57′	279° 23′	330° 49′
12° 4′	**4.218**	**25° 43′**	77° 8′	128° 34′	180°	231° 26′	282° 52′	334° 18′
15°	3.864	29° 25′	80° 51′	132° 17′	183° 43′	235° 9′	286° 35′	338° 1′
20°	3.297	31° 14′	82° 40′	134° 6′	185° 32′	236° 58′	288° 24′	339° 50′
$25°\frac{5}{7}$	**3.000**	**25° 42′**	77° 8′	128° 34′	180°	231° 26′	282° 52′	334° 18′
30°	3.271	20° 56′	72° 22′	123° 48′	175° 14′	226° 40′	278° 6′	329° 32′
35°	3.690	20° 46′	72° 12′	123° 38′	175° 4′	226° 30′	277° 56′	329° 22′
39° 23′	**4.218**	**25° 42′**	77° 8′	128° 34′	180°	231° 26′	282° 52′	334° 18′
45°	4.760	36° 27′	87° 53′	139° 19′	190° 45′	242° 11′	293° 37′	345° 3′
$51°\frac{3}{7}$	5.000	$51°\frac{3}{7}$	$102°\frac{6}{7}$	$154°\frac{2}{7}$	$205°\frac{5}{7}$	$257°\frac{1}{7}$	$308°\frac{4}{7}$	360°

Since s, r, and θ are functions of time we may write

$$\frac{ds}{dt} = \left\{\left(\frac{dr}{dt}\right)^2 + r^2\left(\frac{d\theta}{dt}\right)^2\right\}^{\frac{1}{2}} \quad \ldots \quad \ldots \quad (5)$$

Equation (5) gives the velocity of the cathode ray spot along the pattern. Let us evaluate it.

From equation (3)

$$\left(\frac{dr}{dt}\right)^2 = \frac{\omega^2 a^2 b^2 (n-1)^2 \sin^2 \overline{n-1}\,\omega t}{a^2 + b^2 + 2ab \cos \overline{n-1}\,\omega t}.$$

From equation (4),

$$r^2\left(\frac{d\theta}{dt}\right)^2$$

$$= \frac{\omega^2\{a^2 + nb^2 + (n+1)ab \cos \overline{n-1}\,\omega t\}^2}{a^2 + b^2 + 2ab \cos \overline{n-1}\,\omega t}$$

$$\therefore \quad \left(\frac{ds}{dt}\right)^2$$

$$= \frac{\omega^2[\{a^2 + nb^2 + (n+1)\,ab \cos \overline{n-1}\,\omega t\}^2 + a^2 b^2 (n-1)^2 \sin^2 \overline{n-1}\,\omega t]}{a^2 + b^2 + 2ab \cos \overline{n-1}\,\omega t}$$

or

$$\frac{ds}{dt} = \omega\{a^2 + n^2 b^2 + 2nab \cos \overline{n-1}\,\omega t\}^{\frac{1}{2}} \quad \ldots \quad (6)$$

Equation (6) gives the velocity of the spot and can be calculated for various values of ωt or θ. In Fig. 6 is plotted the velocity of the spot for values of ωt from 0° to $51°\frac{3}{7}$, *i.e.*, for one loop, assuming $n = 8$, $a = 4''$, $b = 1''$ and $\omega = 2\pi \times 3{,}000$.

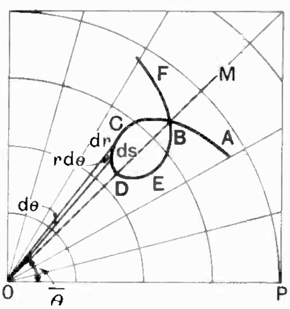


Fig. 5.

It is seen that the velocity is a maximum when r is maximum and minimum when r is minimum so that while the spot traces the loop, it has first a retarded motion till it reaches the minimum point of the loop, after which it has an accelerated motion. It is also seen that the velocity is symmetrical with respect to the radius vector passing through the minimum point of the loop. This is to be expected, for since the pattern is symmetrical there is no reason why the speed also should not be symmetrical. The advantage of this varying speed is that the loop is brighter than the other portions of the pattern. This contrast is intensified when the loop is reduced smaller and smalller by diminishing the amplitude of the higher frequency motion so that when it is reduced to a spot, the spot is the brightest portion of the pattern. When the ratio of frequencies is very high, of the order of 20, this property

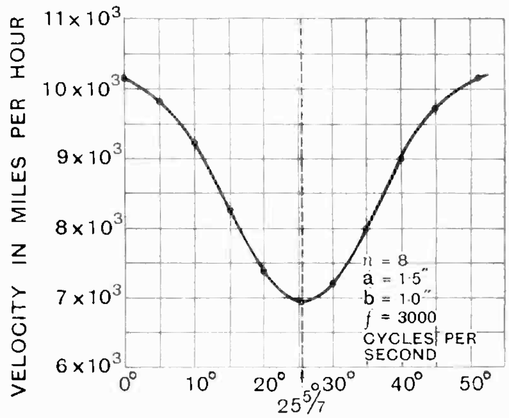


Fig. 6.

is of very great advantage since the pattern then consists of a number of circularly arranged bright spots connected by faint curves. By a mere counting of the number of the spots the ratio of frequencies is determined. On the other hand, if the whole of the pattern is equally bright, then the counting may not be so easy. Fig. 7 shows a photograph of the pattern when $n = 7$ and the loops are reduced to spots. The difference in brightness has not come out clearly in the photograph, but on the oscillograph screen it is well observed.

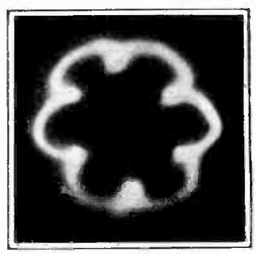


Fig. 7.

(c) *The size of the loops in relation to the ratio of amplitudes.*

It is interesting to enquire what relation the size of the loops bears to the ratio of the amplitudes of the two circular motions. For, it has already been pointed out that the reduction of the loops to bright spots is brought about by sufficiently diminishing the potential due to the higher frequency while keeping that due to the lower frequency constant.

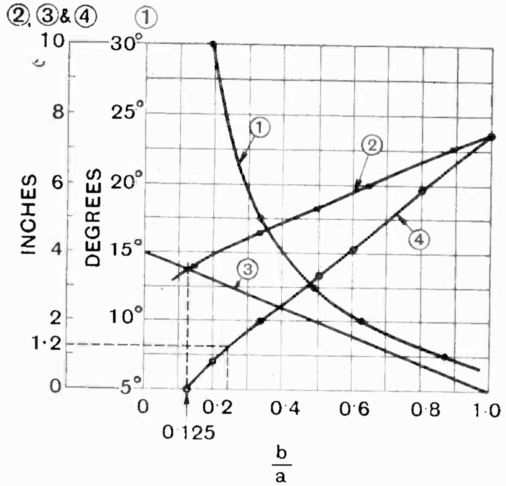


Fig. 8.

Referring again to Fig. 5 let *ODBM* be the vector passing through the minimum point *D* of the loop and consequently through the intersection point *B*. Let us take the length *DB* as a measure of the size of the loop.

Then

$$DB = OB - OD.$$

Now let us consider the length *OB*.

From equation (1)

$$OB = \{a^2 + b^2 + 2ab \cos \overline{n - 1}\, \omega t_1\}^{\frac{1}{2}} \quad .. \ (7)$$

where ωt_1 is the angle of the low frequency vector pertaining to the point *B*. Since our object is to determine how *OB* varies with $\frac{b}{a}$, we should first find out how ωt_1 in equation (7) depends upon $\frac{b}{a}$. Since the vector *ODB* passes through the minimum point *D* as well as the intersection point *B*, it is obvious there should be three values of ωt which give the same value of $\bar{\theta}$, where $\bar{\theta}$ is the angle *BOP* in Fig. 5. One of them must be equal to θ, which is the condition for r to be minimum as already shown. Let the other two be denoted by ωt_1 and ωt_2. Since r, *i.e.* *OB*, is the same both for ωt_1 and ωt_2, these must be connected by the relation

$$\omega(t_1 + t_2) = 2\pi$$

so that

$$\cos \overline{n - 1}\, \omega t_1 = \cos \overline{n - 1}\, \omega t_2.$$

Hence it is sufficient if we consider one value, viz.: ωt_1.

Let us now examine how the value of ωt_1 varies with the ratio $\frac{b}{a}$, keeping n constant.

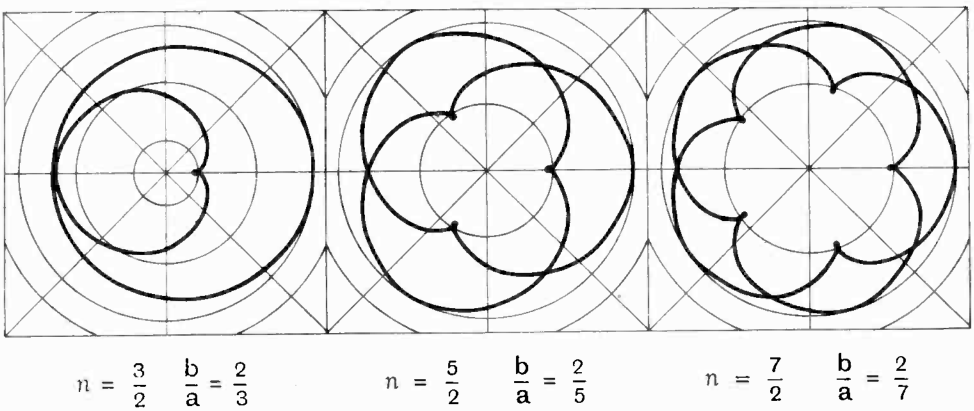


Fig. 9.

We may now write equation (2) as follows:

$$\frac{\sin \omega t_1 + \frac{b}{a} \sin n\omega t_1}{\cos \omega t_1 + \frac{b}{a} \cos n\omega t_1} = \tan \bar{\theta}$$

$= \text{a constant } k$, since n is constant.

Or $$\frac{b}{a} = \frac{\sin \omega t_1 - k \cos \omega t_1}{k \cos n\omega t_1 - \sin n\omega t_1}.$$

Let $n = 8$, then $k = \tan \frac{\pi}{n - 1}$

$$= \tan \frac{\pi}{7} = 0.4813.$$

$$\therefore \frac{b}{a} = \frac{\sin \omega t_1 - 0.4813 \cos \omega t_1}{0.4813 \cos 8\, \omega t_1 - \sin 8\omega t_1} \quad .. \ (8)$$

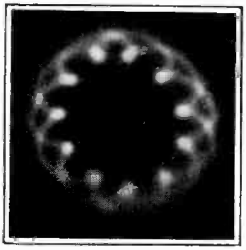


Fig. 10.

Equation (8) which gives the relation between ωt_1 and $\frac{b}{a}$ when $n = 8$, is plotted in Fig. 8 curve 1, for values of $\frac{b}{a}$ from zero to unity.

Now from equation (7),

$$OB = a\left\{1 + \left(\frac{b}{a}\right)^2 + 2\left(\frac{b}{a}\right)\cos \overline{n - 1}\, \omega t_1\right\}^{\frac{1}{2}} \quad .. \ (9)$$

Curve 2 in Fig. 8 is plotted with the help of equation (9) and curve 1 of the same figure. It shows how OB varies when $\frac{b}{a}$ varies from zero to unity assuming $a = 4''$.

Let us consider the length OD.

$OD = a - b$ since D is a minimum point for r.

Or $$OD = a\left(1 - \frac{b}{a}\right).$$

Curve 3 of Fig. 8 shows the variation of OD with $\frac{b}{a}$ when $a = 4''$.

From curves 2 and 3 of Fig. 8, curve 4 in the same figure is plotted from the relation

$$DB = OB - OD.$$

Hence this curve represents how the size of the loop varies for values of $\frac{b}{a}$ from zero to unity. Two important observations must be made from this curve.

(1) For $\frac{b}{a} = 0.25$ the size of the loop is $1.2''$ if $a = 4''$. Referring to Table I, which is calculated for these same constants, it is observed that $OB = 4.218''$ and $OD = 3''$. Therefore the size of the loop is $4.218'' - 3'' = 1.218''$, which agrees with the above

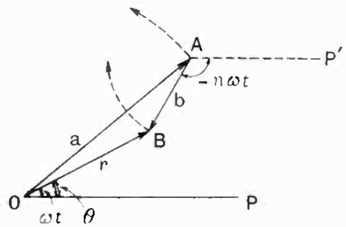
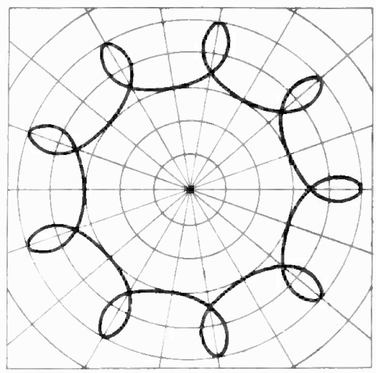


Fig. 11.

value. This verifies the correctness of curve 4 in Fig. 8.

(2) For $\frac{b}{a} < 0.125$ the size of the loop is zero. This is a very interesting observation. It leads to the inference that even when the cathode ray spot is an ideal point so that its trace on the screen is an ideally thin line, there is a minimum ratio of the amplitudes of the two circular motions below which the loops collapse into spots. This minimum ratio of amplitudes is given by the equation



$n = 8$. a = 4 UNITS. b = 1 UNIT.

Fig. 12.

$\frac{b}{a} = \frac{1}{n}$ where n is, as before, the ratio of frequencies.

(d) The form of the pattern when the ratio of frequencies is fractional.

The case when n is fractional is important, for, in the comparison of two frequencies, if their ratio is integral there is a tendency for the sources to interlock, "ziehen." If n is made fractional this effect is not present. In practice the only important case is when $n = \frac{3}{2}, \frac{5}{2}, \frac{7}{2}$, etc.

The equations 1 and 2 hold good even when n is fractional. The same solution holds good for the determination of the maximum and minimum values of r. These occur, as before, when $\theta = \frac{n'\pi}{n-1}$ or 0.

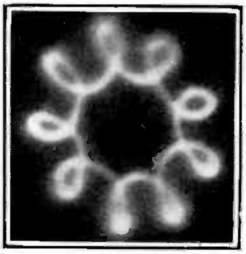


Fig. 13.

But when n is a fraction such as $\frac{3}{2}, \frac{5}{2}, \frac{7}{2}$, etc., the nature of the expression

$$r = \{a^2 + b^2 + 2ab \cos \overline{n-1}\, \omega t\}^{\frac{1}{2}}$$

suggests that for the same value of θ given by $\theta = \omega t = \frac{n'\pi}{n-1}$ or 0, r is both a maximum and a minimum. This can be shown as follows.

When n is integral the values of θ for maximum and minimum values of r repeat, *i.e.*, the pattern is re-entrant when ωt completes a cycle of 360 deg. This can be made clear by an example. Suppose $n = 5$. Then the values of θ for maximum and minimum values of r occur as shown in Table II.

Two things are to be observed in this table. One is the angles connected by lines in the table are the same in space. The other is that the values of the radius vector r corresponding to these connected angles are either both maximum or both minimum.

TABLE II.

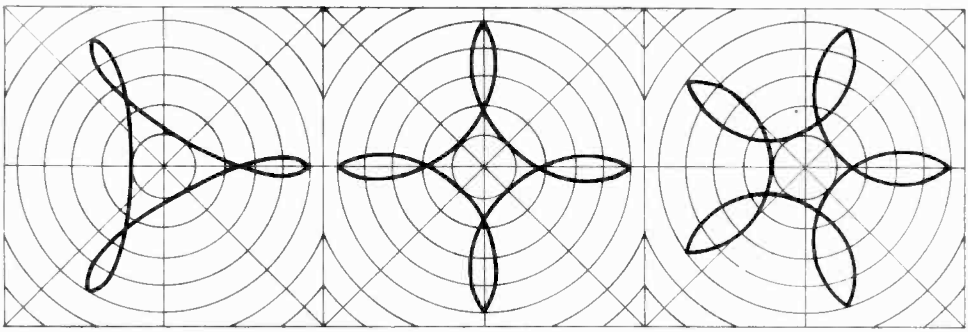
Max.	0°		90°		180°		270°	
Min.		45°		135°		225°		315°
Max.	360°		450°		540°		630°	
Min.		405°		495°		585°		675°

On the other hand when n is a fraction such $\frac{3}{2}, \frac{5}{2}, \frac{7}{2}$, etc., a cycle of $2 \times 360°$ is necessary for θ to repeat itself, *i.e.*, for the pattern to be re-entrant. For example let $n = \frac{11}{2}$. The maximum and minimum values of r occur as shown in Table III.

TABLE III.

Max.	0°		80°		160°		240°		320°
Min.		40°		120°		200°		280°	
Max.		400°		480°		560°		640°	
Min.	360°		440°		520°		600°		680°

Here it is seen that for the same value of θ in space r is both a maximum and a minimum. Fig. 9 shows the nature of the pattern for $n = \frac{3}{2}, \frac{5}{2}, \frac{7}{2}$, etc., when the loops are made sufficiently small to reduce them to spots. Fig. 10 shows a photograph of the pattern observed on the cathode ray oscillograph screen when $n = \frac{13}{2}$.



n = 2 n = 3 n = 4

Fig. 14.

A general method of recognising easily

fractional ratios such as $\frac{3}{2}$, $\frac{5}{2}$, $\frac{7}{2}$, etc., may be formulated as follows. If the alternate loops or spots are connected by the path of the cathode ray as in Fig. 10, then the denominator of n is 2. The numerator is given by the number of loops or spots plus two when the spots are inside the pattern.

(2) Case when the Two Circular Motions are in Opposite Directions.

(*a*) *Equation for the pattern.*

Referring to Fig. 11, if the low frequency vector OA revolves in the counter-clockwise

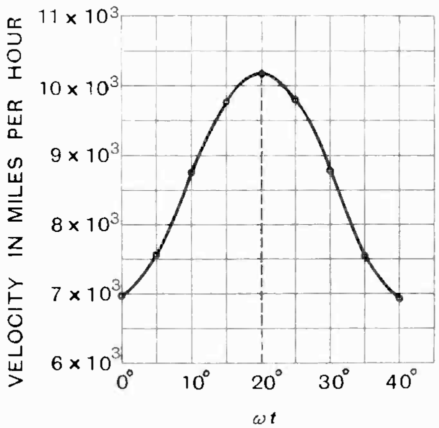


Fig. 15.

direction the high frequency vector must be considered in this case to revolve in the clockwise direction.

Then $\angle P'AB = -n\omega t.$

$$\therefore r = \{(a\cos\omega t + b\cos n\omega t)^2 + (a\sin\omega t - b\sin n\omega t)^2\}^{\frac{1}{2}}$$

$$= \{a^2 + b^2 + 2ab\cos\overline{n+1}\,\omega t\}^{\frac{1}{2}} \quad \ldots (10)$$

$$\tan\theta = \frac{a\sin\omega t - b\sin n\omega t}{a\cos\omega t + b\cos n\omega t} \quad \ldots \quad \ldots (11)$$

Equations 10 and 11 completely define the position of the cathode ray spot at any instant and the pattern can be plotted by giving values to ωt from 0° to 360°. Proceeding as before, it can be shown that the maximum and minimum values of r occur when $\theta = \frac{n'\pi}{n+1}$ or 0, and that at these values of r, $\theta = \omega t$.

For example when $n = 8$, Maximum values of r occur when $\theta = 0°, 40°, 80°, 120°, 160°, 200°, 240°, 280°$ and $320°$. Minimum values of r occur when $\theta = 20°, 60°, 100°, 140°, 180°, 220°, 260°, 300°$ and $340°$.

In Fig. 12 the pattern is plotted with the help of equations 10 and 11 for $n = 8$, $a = 4$ units of length and $b = 1$ unit of length.

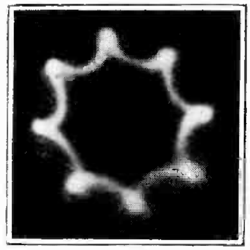


Fig. 16.

Fig. 13 is a photograph of the pattern for $n = 8$. Fig. 14 shows the nature of the patterns for various ratios. It must be observed that the patterns have loops outside, their number being $(n + 1)$. Conversely, when the loops are outside, as in Fig. 13, the number of loops minus one, gives the ratio of the two frequencies superimposed.

(*b*) *The velocity of the cathode ray spot along the pattern.*

The expression for the velocity is derived in a similar manner and is given by the equation

$$\frac{ds}{dt} = \omega\{a^2 + n^2b^2 - 2nab\cos\overline{n+1}\,\omega t\}^{\frac{1}{2}} \quad \ldots (12)$$

In Fig. 15 the velocity is plotted for values of ωt from 0° to 40°, *i.e.*, for one loop when $n = 8$, $a = 4''$, $b = 1''$ and $\omega = 2\pi \times 3{,}000$. It is observed that the velocity is a maximum when r is minimum and *vice versa*, so that here again the loops are brighter than other portions and the same advantages are obtained in the comparison of frequencies of high ratios as have been pointed out already. Fig. 16 shows a photograph of the pattern when $n = 7$ and when the loops are reduced to spots.

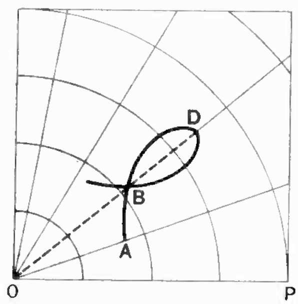


Fig. 17.

(*c*) *The size of the loops in relation to the ratio of amplitudes.*

Referring to Fig. 17 which represents one loop of the pattern, BD is the size of the loop according to the previous notation.

$$BD = OD - OB.$$

Considering OB, we have

$$OB = \{a^2 + b^2 + 2ab \cos \overline{n+1}\ \omega t_1\}^{\frac{1}{2}}$$

where ωt_1 is the angle of the low frequency vector pertaining to the point B. To find out how OB varies with $\frac{b}{a}$ it is first necessary to determine how ωt_1 varies with $\frac{b}{a}$ for given value of n.

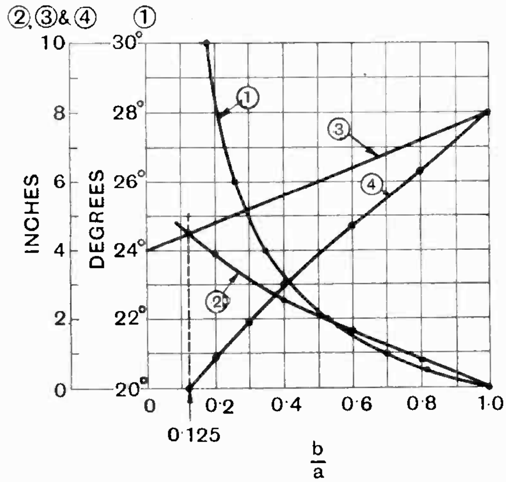


Fig. 18.

Proceeding as before,

$$\frac{b}{a} = \frac{\sin \omega t_1 - k \cos \omega t_1}{\sin n\omega t_1 + k \cos n\omega t_1}.$$

When $n = 8$, $k = \tan 20° = 0.364$.

$$\therefore \frac{b}{a} = \frac{\sin \omega t_1 - 0.364 \cos \omega t_1}{\sin 8\omega t_1 + 0.364 \cos 8\omega t_1} \quad \ldots (13)$$

Equation (13) which gives the relation between $\frac{b}{a}$ and ωt_1 is plotted in Fig. 18, curve 1 for values of $\frac{b}{a}$ varying from zero to unity.

Now

$$OB = a\left\{1 + \left(\frac{b}{a}\right)^2 + 2\left(\frac{b}{a}\right) \cos \overline{n+1}\ \omega t_1\right\}^{\frac{1}{2}} \quad \ldots (14)$$

Curve 2 in Fig. 18 is plotted with the help of equation (14) and curve 1 of the same figure. It shows how OB varies when $\frac{b}{a}$ varies from zero to unity assuming $a = 4''$.

Let us now consider OD.

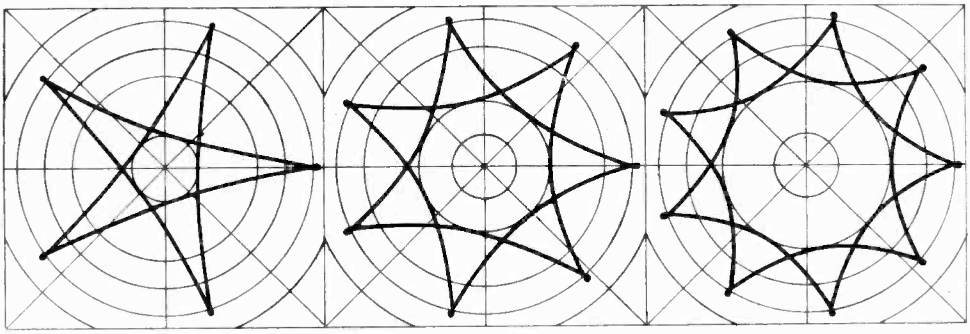
$$OD = a + b \text{ (since } D \text{ is a maximum point for } r)$$

$$= a\left(1 + \frac{b}{a}\right).$$

Curve 3 of Fig. 18 represents the variation of OD with $\frac{b}{a}$.

Finally curve 4 of the same figure is plotted from curves 2 and 3 with the help of the relation $BD = OD - OB$. This curve therefore represents how the size of the loop varies when $\frac{b}{a}$ varies from zero to unity.

Here again it is to be observed that when $\frac{b}{a} < 0.125$ the size of the loop is zero. Hence the minimum ratio of amplitudes for reducing the loops to spots is given by $\frac{b}{a} = \frac{1}{n}$ where n is the ratio of frequencies.



$n = \frac{3}{2}$ $\frac{b}{a} = \frac{2}{3}$ $n = \frac{5}{2}$ $\frac{b}{a} = \frac{2}{5}$ $n = \frac{7}{2}$ $\frac{b}{a} = \frac{2}{7}$

Fig. 19.

(d) The form of the pattern when the ratio of frequencies is fractional.

Equations 10 and 11 hold good even when n is fractional. The only important case in practice is when $n = \frac{3}{2}, \frac{5}{2}, \frac{7}{2}$, etc. The nature of the expression

$$r = \{a^2 + b^2 + 2ab \cos \overline{n+1}\, \omega t\}^{\frac{1}{2}}$$

again suggests that for the same value of θ given by

$$\theta = \omega t = \frac{n'\pi}{n+1}$$

or 0, r is both a maximum and a minimum. Fig. 19 shows the nature of the patterns when $n = \frac{3}{2}, \frac{5}{2}, \frac{7}{2}$, etc.

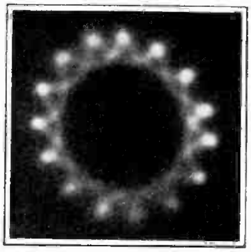


Fig. 20.

Fig. 20, shows a photograph when $n = \frac{13}{2}$. It is observed that alternate spots are connected and the number of spots when $n = \frac{13}{2}$ is 15. Hence, when the spots are outside, a general method of recognising fractional ratios such as $\frac{3}{2}$, $\frac{5}{2}$, $\frac{7}{2}$, etc., is as follows. The numerator of n is given by the number of spots minus two, and the denominator is 2 when the alternate spots are connected as in Fig. 20.

In conclusion, it is found that the method of analysis as outlined in this article enables one to predict the nature of the pattern for any complicated ratios of frequencies but such ratios are not so useful in practice as the simple ones $\frac{3}{2}$, $\frac{5}{2}$, $\frac{7}{2}$, etc.

Radio Frequency Phenomena Associated with the Aurora Borealis.

By F. Dearlove.

NEARLY everyone has noticed, at some time or other, the phenomenon known as the "Aurora Borealis" in the northern half of the globe, and as the "Aurora Australis" in the southern half, but it is not generally realised that the Aurora has any effect on the propagation of the electric waves used in radio communication, and it is with the hope that a little light may be thrown on this interesting subject that the following is written.

For the past eighteen months I have been installing radio stations operating on short waves, for the Grenfell Mission in Labrador, so that communication could be established between their hospitals, many hundreds of miles apart, and in doing this I have been in a position to observe the effects of the Aurora very closely, as it was one of the greatest obstacles to success.

Two Types of Aurora.

There are two types of Aurora, one which I shall call type "A," a very faint glow, generally seen in the Northern sky, but not necessarily so, extending faint streaks or fingers of pale greenish light in all directions, appearing at a great altitude, generally moving slowly though sometimes remaining stationary as a barely perceptible glow for the greater part of the night; the other, which I shall term type "B," usually appears suddenly in the Northern sky, and consists of undulating patches of vivid greenish light, moving at times fairly rapidly, and extending occasionally over the whole sky. This type appears to be fairly low, and in some instances has been observed only a few hundred feet from the ground. Though the greenish colour usually predominates, very exceptionally all the colours of the spectrum will radiate from a huge arc in the Northern sky making a truly awe-inspiring spectacle. Whilst type "A" appears slowly, and lasts anything from a day to a week, type "B" lasts but an hour or two, though it may recur many times during a manifestation in which type "A" predominates. The Aurora seems to be of comparatively rare occurrence outside Newfoundland and Labrador on the American side of the world, but in my experience type "B" has been of nightly occurrence for weeks together within those countries.

With regard to the effect of the Aurora on radio waves, in these days of Broadcasting, everyone has noticed periods of poor reception, but on short waves these are very common, and occasionally we have periods when no signals can be heard on any wavelength below one hundred metres. In Newfoundland and Labrador, however, a few weeks after the first radio station was installed, it was definitely decided that these periods coincided with the appearance of the Aurora Borealis on the one hand, and with a change in the weather on the other. Periods of poor reception due to changes in weather conditions could invariably be forecasted by careful barometric observation, but no such prognosis was possible for those due to the Aurora.

Putting on one side variations due to weather changes, we were left with periods of variable communicability, due to the Aurora affecting adversely both the transmitted and the received waves. In the endeavour to discover something on the subject the following facts were disclosed.

On the appearance of Aurora type " A," signals on forty and eighty metres underwent a very slow fading effect, and it would be almost impossible to communicate with anyone; this was particularly noted when, as sometimes happened, the Aurora appeared in the Southern sky, for signals would disappear entirely. Strangely enough, occasionally during this period the Aurora itself would be barely visible, but the effect persisted usually from two to three, though sometimes four and even occasionally five, days. The signals of the world's high-power stations would disappear, until " WIZ " alone was left with a most peculiarly thin reedy note, until finally, just before the signals disappeared entirely, it would be noticed that the dots and dashes had " tails " till the transmission resembled just a long-drawn-out wavering whisper, absolutely unintelligible.

On twenty metres the change which took place was rather different; for an hour or two after the Aurora type " A " manifested itself communication would be possible in many cases with stations whose forty metre signals had just disappeared, whilst stations which had been inaudible before the appearance of the Aurora would slowly appear and increase in audibility, whilst others would disappear completely. This would continue for a while, when it would be noted that the only stations to be heard would be ones at incredible distances, such as Asiatic, South American, and Pacific stations and, of course, at a time widely different to that at which those countries would normally be heard. As a matter of fact, the only Asiatic station ever heard on twenty metres was copied during one of these periods.

Though, of course, the Aurora was not visible in the daytime, its effect persisted, and it would be impossible to communicate with anyone, even stations usually easily worked during the daytime, local or long distant. A striking example of the effect of the Aurora type " A " on local signals was given when my portable station was taken out to a distance of ten to twelve miles, and its signals almost disappeared, whilst normally they were strong at that short distance and for a hundred miles further. Aurora type " B " would often be present during a manifestation of type " A," though, owing to the pronounced effect of the latter, it was difficult to observe any phenomena which could be attributed to type " B " alone.

When Aurora type "B " appeared alone, signals on forty metres at distances of two or three hundred miles would undergo pronounced fading, alternating with periods of just as pronounced amplification, the signal strength being in many cases three to four times as great as in normal conditions. Signals coming from stations at distances of three to four thousand miles would fade more slowly, but even they would experience the amplifying effect. This phenomenon would gradually give place to a condition when all signals would be unusually poor, for two or three hours, returning quickly to normal when the Aurora type " B " had disappeared. The effect of type " B " was easily proved to be quite local by the fact that an English station G 2XY, with whom I was working when the Aurora appeared, suddenly had difficulty in receiving my signals, whilst to me his also had become very faint, but he easily carried on a conversation with the Grenfell Mission main station NE 8AE, only two hundred and fifty miles to the south of my own station XNE 8FD, a portable which I was carrying around Labrador for the purpose of ascertaining the best time for inter-communication. Before the appearance of the Aurora, NE 8AE's signal had been reported by 2XY as little louder than my own, and as the phenomena commenced my own signals were not readable at 2XY, but little diminution in signal strength, if any, was noticed at either NE 8AE or 2XY on each other's signals. Very little effect on twenty metres was noticed when Aurora type " B " was present, neither was any effect noticed on very local signals, at a distance of ten or twelve miles or so, on forty-five metres. They did, however, affect the Broadcast bands where reception would be exceptionally poor when either type was present.

It was noticed particularly that the effect of either type of Aurora was always accentuated when it appeared in the path of the received signals, whilst with type " B," when the Aurora was in the opposite direction to that in which it was desired to communicate, though signals would not appear to be very much affected by the Aurora, it would be absolutely impossible to work any station on forty metres and with the utmost difficulty on twenty.

It must be noted also that, although naturally the effect of the Aurora was usually observed to begin at night, when the same was visible, yet when fading effects such as were known to be identical to those produced by the Aurora occurred in the daytime, as night drew on the latter would invariably be in evidence. In the rare cases when this was not so, it was due to poor visibility owing to low lying mist or fog, which is very prevalent during the spring and summer in both Northern Newfoundland and Southern Labrador.

Although many observers state they have seen the Aurora type " B " accompanied by a faint crackling sound as of an electric discharge, this has never been my experience, and, moreover, the radio phenomena associated with the Aurora of either type are usually noted particularly to take place with a complete absence of static or atmospheric disturbances.

From the foregoing observations it will at once be apparent that the Aurora type " A " is the one we are most concerned with as affecting the propagation of Radio waves to the greatest extent. This type, appearing as it does at a great altitude, seems to be capable of producing an accentuated " daylight " effect, the fading out of forty and eighty metre signals completely at any great distance, the complete absence of skip distance on those waves coupled with the extremely short distance workable, and finally the enormous skip distance noticed on twenty metres. For the daylight effect we have the Kennelly-Heaviside layer theory, whilst, as far as I am aware, for the effect of the Aurora we have none, and yet the effect of the latter, though accentuated as compared to that of daylight, is identical to it. I think we may take it that ionisation takes place to a rather unusual extent. It has been clearly shown that the propagation of the waves is not affected, apart from using an actual reflector, except by a change in the medium—*i.e.*, the ether, such as takes place during ionisation by ultra-violet or polarised light. The light given off by the Aurora seems to contain very little ultra-violet component, as its actinic effect is but slight, or it may be that absorption takes place before it reaches the surface of the earth ; it is but feebly polarised, as is that of the moon, whilst its effect is out of all proportion with that of the latter, which cannot be determined even after twelve months' observation, and out of all proportion also, within the sphere of its influence at least, with the daylight effect, caused by ionisation due to radiation of ultra-violet and other rays from the sun, though it is easily shown that the sun's Corona (visible only during an eclipse, but shining all the time nevertheless) gives off more ultra-violet light in five minutes than the Aurora or the moon could do in twelve months.

It is with a feeling of regret that I must admit I am no nearer the solution of the mystery than when the observations began. I am not a physicist by any manner of means, but I present these notes in the hope that they may at least be of interest if not of actual utility to those who, like myself, have the interests of radio-communication at heart.

The Operation of Several Broadcasting Stations on the Same Wavelength.

Paper by Capt. P. P. Eckersley, M.I.E.E., and A. B. Howe, M.Sc., read before the Wireless Section, I.E.E., on 6th March, 1929.

ABSTRACT.

SECTION I.

THEORY OF SINGLE WAVELENGTH WORKING FOR BROADCASTING STATIONS.

In an introductory portion the authors point out that sharing one wavelength between several stations, either in the same or in different counties, is of considerable help in making the best use of the wavelengths available for broadcasting services, and briefly discuss the subject of wavelength allocations.

TABLE I.

Point.	Condition.	Result to a receiver installed at the given points.
C & E	Zero energy.	No reception.
D	Strong side-bands. No carrier.	Carrierless telephony and distortion for ordinary reception.
F	Double carrier and double sidebands.	No distortion.
G	Strong carrier and No sidebands.	No modulation.
H	Elimination of one sideband; relative strengthening of other	Distortion with most types of detector.

They then proceed to the theory of single wavelength working.

If two broadcasting stations emit carrier waves of identical frequency, an interference pattern will be set up in areas where the field strength of both is appreciable. Assuming the stations of equal power, to be exactly synchronised, and to be modulated by the same low frequency, f_m, frequencies of f_c $(f_c + f_m)$ and $(f_c - f_m)$ will be set up with corresponding wavelengths λ, λ_1 and λ_2. For a 150 k.c. per sec. carrier (2,000 m.)

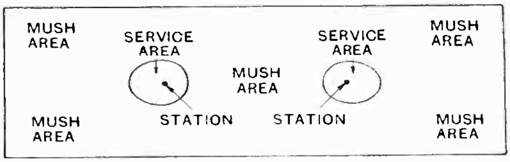


Fig. 2.—*Showing small service area and large "mush" area (where quality of transmission is bad) around two stations sharing the same wavelength.*

modulated at 10,000 k.c. per second, the interference conditions resulting are as shown in Fig. 1*, and the states at certain points are set out in Table I.

As we move away from close proximity to one station towards the other, the distortion produced by the interference pattern becomes more and more appreciable until a point is reached at which the interfering station produces noticeable distortion and we may say that we can no longer expect good service from the nearer station. There will be around each station an area in which the distortion will not be noticeable, but there will also be a large area where service conditions cannot be said to exist, as shown in Fig. 2.

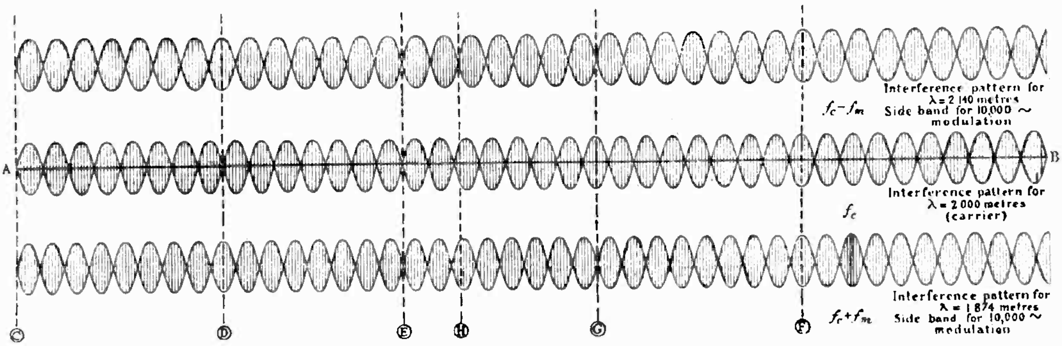


Fig. 1.—*Interference pattern produced by two broadcasting stations using the same wavelength of* 2,000 *m. and having the same modulation of* 10,000 *cycles per sec.*

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

EXPERIMENTS TO TEST GENERAL THEORY AND DETERMINE EMPIRICAL QUANTITIES.

Experiments to determine the boundaries of the service area were conducted from 5GB and 5IT (the local Birmingham transmitter, not now used), with exact synchronisation of the carrier, simultaneous modulation by identical or by different programmes, and with exploration of the territory between the stations. 5GB had 20 kW. aerial power and 5IT had 1 kW., each at 610 k.c. (491.8 m.), the frequency being controlled by a 305 k.c. transmitter at Daventry. This transmission was picked up by 5GB and 5IT and used through a frequency doubler to produce the carrier of 610 k.c. per second.

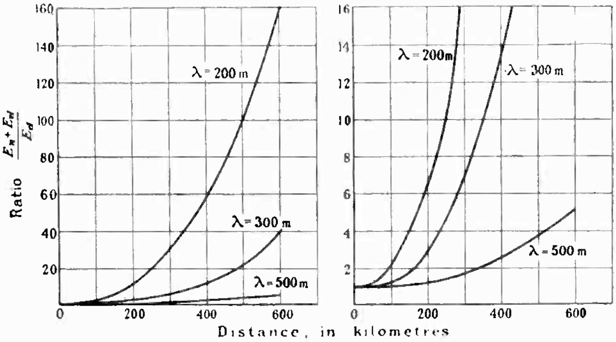


Fig. 5.—*Curves of maximum fluctuation of signal expressed as a ratio to unity for various wavelengths against distance from station.*

It was first determined that, without modulation, there was a stationary interference pattern. Arrangements were made for 5-minute periods of radiation of the same programme by both stations, interspersed by 5-minute periods of radiation of the programme by one or the other singly. Distortion was noticed, as was to be expected, where the field strengths of the stations were comparable. Even within the "mush" area, however, it was possible to receive good quality, but theory indicates that good reception in a "mush" area is possible, although fortuitous.

It was found that when the strength of one station at a point was five or more times that of the other, reception from the former was normal. In other words, the service area of station A is found by drawing a line through the points where the field strength of A is 5 times that of B, and vice versa.

If the stations are not exactly synchronised, but differ by an amount Δf, which makes a beat between carrier waves so slow as to be below audition, say, 20 cycles p.s., the effect is as if a receiver passed through the states C to H (of Fig. 1) consecutively, at a velocity determined by the frequency difference. It was found that if Δf was greater than 5 cycles p.s., the strength of one station had to be, at the boundaries of the service area, at least 10 times greater than the other to preserve good quality—as compared with a factor 5 obtained for perfect synchronisation.

If different programmes were radiated, it was proved that the strength of one station at a given point had to be 100 to 200 times that of the interfering station. The service area of a station sharing a wave with another is thus much less if each station transmits a different programme.

THE RANGE OF STATIONS SHARING WAVELENGTHS.

This question is discussed by the quantitative study of typical cases.

Making various assumptions as to the strength of the direct and indirect rays, the results of the authors' calculations are shown in Figs. 5, 6 and 7. In Fig. 5, if E_n is the night ray and E_d the direct ray, the curves give a measure of fluctuation or "fading." Fig. 6 sums E_n and E_d and gives (very approximately at long distances) values of the maximum radiation from a station radiating 1 kW. Fig. 7 gives the range of two stations sharing one wave, for complete synchronisation (factor 5) and for imperfect synchronisation (factor 10). From this it can be seen that, with large

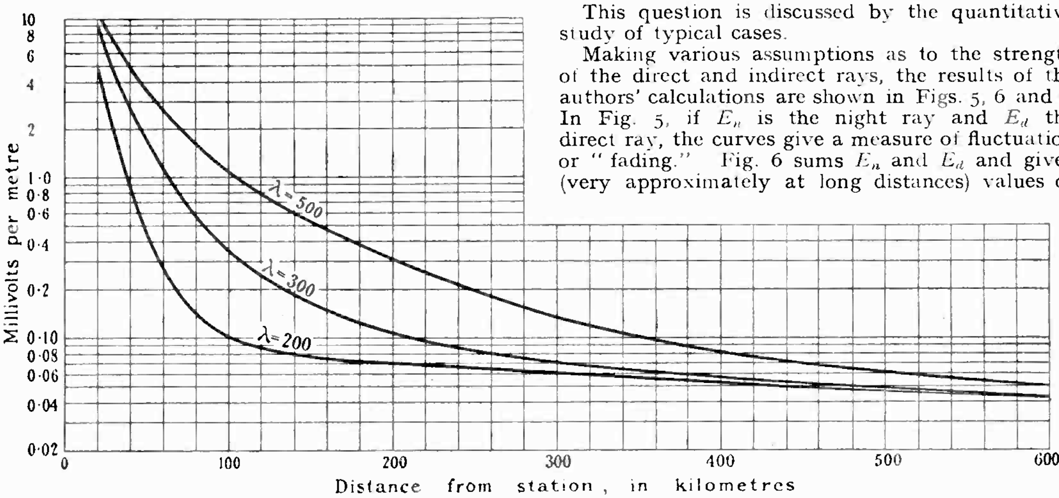


Fig. 6.—*Variation of total radiation ($E_d + E_n$) with distance 1 kW. radiated.*

separation of stations, it is better to use long wavelengths, while if the indirect ray no longer plays a part (*i.e.*, where the stations are close together) the short wavelength gives a better service range.

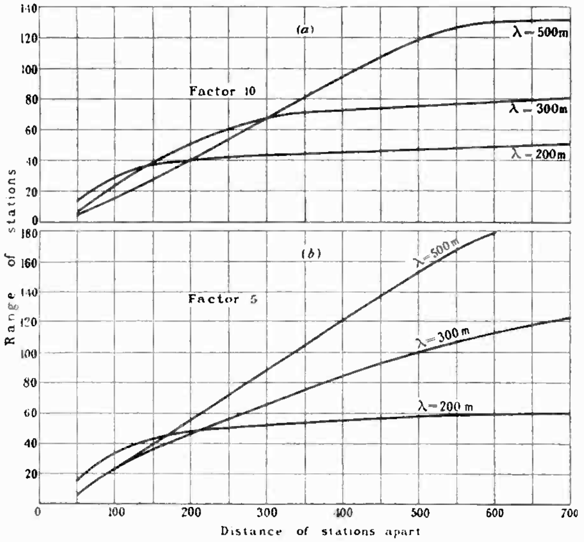


Fig. 7.—*Range of two equal power stations sharing same wavelength, at different distances apart and different factors.*

The case of more than two stations sharing a wave is then discussed, and a model described in which a number of alternators (up to 18) were employed to represent different stations. It is concluded that in practice the range of a station sharing a wavelength with others will not be seriously decreased after more than 6 or 7 stations share the wave, because the probability of the averaging out of the peaks of field strength is greater with more stations. No doubt large peaks will occur, but at such rare intervals that the listener will not notice their occurrence.

As a general conclusion, the authors infer that waves shared between local low-power stations will be useful to cover large towns with good conditions of broadcasting if such towns happen to be outside the range of high-power regional stations.

Section 2.

This section discusses the practical question of synchronising the stations involved. Three general methods are possible :—

(1) By a C.W. transmitter giving a steady radiation of frequency f_d, which is received by the broadcasting stations and multiplied n times, so that $nf_d = f_c$.

(2) By supplying, *via* landline, a steady low-frequency f_l, which is multiplied n times, so that $nf_l = f_c$.

(3) By supplying separate drives so accurate and so carefully calibrated that synchronisation is given without any common source of master frequency.

Method (1) would involve a powerful long-wave transmitter, with obvious difficulties. Method (2) is practicable, but any sudden change of line constants would produce large relative phase changes in the carrier. Method (3) involves facing the factor 10 and finding a source which can be maintained to 1 part in 150,000. Even methods (1) and (2) still involve a source accurate to 1 in 100,000. The B.B.C. have based their system on method (3), using tuning-fork control. The fork is made by the Marconi Co. The change in frequency is about $\frac{1}{8}$ cycle per degree C., with automatic control of the temperature.

The frequency of the forks is 1,015.625 cycles per second. This is passed through a series of frequency-doublers, and brought up to 1,040 k.c./sec. There are thus 10 stages of frequency-doubling, using, in all, about 25 valves.

At the time when this paper was written, four such sets were working in Great Britain—*i.e.*, at Edinburgh, Hull, Bradford and Bournemouth. It is the intention of the B.B.C. in time to equip 10 stations with similar gear and to achieve thereby a measure of single wavelength working.

Results of Practical Working.

While the Bradford station formerly shared a wave with other European stations, transmitting different programmes and badly synchronised, it had a range of $\frac{1}{2}$ to $\frac{3}{4}$ km. Now, on the same programme as the other British stations sharing the wave, it has a range of 10 km. Considering the local density of population, the number of extra listeners brought into "A" service area conditions is enormous. The range of Hull has been raised from 2 km. to 10 km. Bournemouth appears to be satisfactory up to 20 km. and Edinburgh up to 10 km. It is, as yet, too early to define service and "mush" areas, but the relay station is again a useful unit in the B.B.C. system.

The authors conclude that in Britain, the method bids fair to restore service to all relay stations which were formerly hopelessly jammed when working on international common waves. Even with regional stations, single wavelength working may make for an economy in the use of wavelengths and still continue service to isolated towns not sufficiently covered by regional stations.

Amongst general conclusions on common wavelength working, the authors also suggest that it is useless in a Continent to share wavelengths between stations belonging to different nationalities or groups.

DISCUSSION.

The discussion which followed the reading of the paper was briefer than usual.

In opening the discussion Mr. T. L. Eckersley congratulated the authors on the closeness of frequency attained. He thought that they had not put sufficient stress on the necessity for absolute synchronisation, and showed the distorting effect of beating due to the sidebands from a transmitter slightly detuned, which would not result with perfect synchronisation. He criticised the calculation of the strength of the indirect ray, used in the construction of Figs. 4, 5 and 6, and quoted recent measurements of the downcoming ray.

Mr. Lucas said at the time of these experiments the choice of tuning fork was no doubt justified, as the piezo-crystal was not then stable as a frequency control. He then referred to recent progress in crystal control, more especially in America. As a modern frequency standard 1 in 100,000 was attainable and he had watched three for two years and had been unable to detect variation greater than this value. As a frequency control the crystal had the advantages of very small temperature coefficient, *i.e.*, 2 in one million, while it also shifted the standard directly into the radio frequency gamut. He suggested that this might have been used with a considerable reduction of the stages necessary to attain the final frequency. There was perhaps the disadvantage to crystal control of the difficulty of adjusting crystals to each other which might not be possible to better than 5 in a million.

Mr. R. H. Barfield suggested that directional reception might advantageously be used to eliminate the interfering station on the common wavelength. This, however, involved frame reception while the use of aerials was more general. He also suggested altering the polar diagram of one station so as to give a blind spot from it near to the other town on the common wavelength. This might be done by a tuned aerial suitably placed, a rough calculation of the effect of this being quoted.

Dr. E. H. Rayner asked for information as to how the authors would allocate wavelengths to different stations in a small country. As regards the effect of several stations on the same wave, he compared the net result to that of an orchestra, where it was known that the effect varied with the square root of the number of instruments.

Mr. J. F. Herd criticised the use of the word synchronisation as employed by the authors to mean identity of frequency. Synchronisation also involved identity of phase. He also referred to the type of polar curve mentioned by the authors as semi-circular. Doubtless they referred to the type of polar curve quoted in a previous paper, but the point should be made clear.

Dr. D. W. Dye said he was still convinced that the tuning fork was a standard of very high accuracy, despite the fact that it involved the large number of stages necessary. He was surprised at mild steel being used instead of elinvar, and was doubtful if the damping was best in mild steel. A good deal of work had still to be done on mechanical oscillators. The use of the large number of stages could be avoided by a special circuit for harmonic multiplication, and he illustrated a circuit for the production of a fundamental and a harmonic. The fifth harmonic had been found possible to pick out in this way. He also suggested that the condition of stationary waves (shown in Fig. 1) might be utilised for experimental measurement of wavelength.

Capt. P. P. Eckersley briefly replied to the discussion. In reply to Mr. Lucas, he said that the tuning fork had proved very satisfactory in practice as a frequency standard. In reply to Dr. Rayner he outlined a scheme of wavelength distribution in a small country for a common wave and for an exclusive wave (as for a regional station) and discussed the extension of the principle to adjacent countries.

On the motion of the Chairman (Commander J. A. Slee, C.B.E.) the authors were cordially thanked for their paper.

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.

Output Characteristics.

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

Sir,—In the summary of the article on "Output Characteristics of Thermionic Amplifiers" it is stated that the method of using plate current/plate voltage characteristics for combining the characteristics of a valve and its output circuit is due to Messrs. Warner and Loughren.

I should like to point out that Capt. H. J. Round was using this method in 1919. In the *Journal of the Institute of Electrical Engineers* for March, 1920, there is a paper by him on "Direction and Position Finding"; and as Appendix II of this paper he dealt with the case of a simple resistance amplifier, by means of plate current/plate voltage characteristics. In 1923 he explained the method to me, and realising that it might be of value to others, I set myself to write out and to some extent apply his method to various cases. The resulting article was accepted by the Editor of *E.W. & W.E.* in December, 1924, but it was not published until July and August, 1926.

E. Green.

Chelmsford.
1st March, 1929.

Effect of Anode-Grid Capacity in Detectors and L.F. Amplifiers.

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

Sir,—Mr. Medlam, in his reply to my criticisms of his article on the above subject, says that my letter contains a whole series of unfortunate assumptions, but omits to mention any but the first "term" of the "series." This, it appears, is that I assumed that he was led to his conclusions as the result of a mathematical analysis. I think I may be pardoned for this particular "assumption," for, though he now states that he first became aware of the distortion experimentally, he certainly did not give the impression that his article was merely intended to account theoretically for certain experimental results. On the contrary, without any prior reference to experimental work, he stated : "In the present article the effects of the anode-grid capacity on the audio-frequency characteristic of the detector and L.F. stages are shown to be serious." The method of showing it was by a mathematical analysis, not by a presentation of any experimental data, and it was as a mathematical analysis, therefore, that I criticised it. As such, I think it is quite legitimately open to criticism, whether it be intended to deduce certain previously unknown facts, as I thought, or merely to account theoretically for certain observed results.

If the distortion which Mr. Medlam says he has observed in anode-bend detectors is really due to feed-back, the fact is certainly not accounted for by his theoretical investigation, which is unsound in more respects than I realised when I wrote my previous letter.

Mr. Medlam admits that the equation $e_r = \omega L_e i_g$ should read $e_r = L_e \frac{di_g}{dt}$, but on correcting for this he still finds an expression for E_g which indicates a large reduction of the carrier-wave input voltage due to feed-back, *even with such a very small value of* μ *as* 0.15. This is one of his deductions which I query. That there may be a very large reduction of the carrier-wave input voltage with a normal value of μ I quite agree, but not, I contend, with a valve operating under such conditions as to have such an abnormally low value of μ as 0.15.

The experiments he cites showing a reduction of the input voltage by feed-back to some 5 or 10 per cent. are for valves operating with a normal value of μ, but if we substitute, say, $\mu = 10$, in his amended formula for the carrier-wave input voltage, we find $E_g/E = 0.0090$—*i.e.*, an input voltage less than one-fifth of the lowest of the above-mentioned experimental values. This is the "enormous reduction" which I referred to in my letter.

The reason that Mr. Medlam's analysis leads to such a result is on account of his entire neglect of the effect of the resistance of the input circuit, a point to which I referred in my previous letter. I did not press the point because, on finding the other error which has now been corrected, I did not examine very closely the subsequent mathematical work and accepted his statement that the resistance terms in his expression for the impedance of the tuned circuit to the feed-back voltage could be neglected. Closer examination reveals that this is by no means the case. Though these terms —with a resistance of 10 ohms—are only about 4 per cent. of the terms which Mr. Medlam retains, they cannot be neglected for the simple reason that the coefficient k_2 vanishes at the carrier frequency when those terms are neglected. If they are retained, the correct value of k_2, with the above resistance, is not zero but 0.440, which is considerably larger than the corresponding value of k_1, namely, -0.091. Consequently, the ratio E_g/E, with $\mu = 0.15$, comes out at 0.895 instead of 0.377.

This, of course, is not really the correct value of E_g/E because, as it is now evident that the resistance of the input circuit cannot be neglected, Mr. Medlam's equations

$$\frac{dv}{dt} = \frac{i}{C_{ga}} + L_e \frac{d^2 i_g}{dt^2}$$

and

$$e_r = L_e \frac{di_g}{dt}$$

are no longer even approximately valid and must be replaced by the equations

$$\frac{dv}{dt} = \frac{i}{C} + \frac{de_r}{dt}$$

and

$$LC \frac{d^2 e_r}{dt^2} + rC \frac{de_r}{dt} + e_r = L \frac{di_g}{dt} + ri_g ,$$

The substitution of these equations does not lead, as Mr. Medlam suggests, to a differential equation of the fifth order with 2,146 terms in the coefficient of $\frac{d^4 e_g}{dt^4}$, but to an equation of the third order involving e_r and e_g, quite a respectable equation containing only a few additional terms in the coefficients.

If we then use Mr. Medlam's equation (11), $e_g = (e - e_r)$, we obtain a solution of the same form as his with the following expressions for k_1, k_2 at the carrier frequency under the particular tuning condition which he uses.

$$k_1 = -\left\{\frac{C_{ga}}{(C_{ga} + C_a)} + \frac{rr_a}{\omega_c^2 L^2}\left(\frac{C_a}{C_{ga}} + 1\right)\right\}$$

$$k_2 = \frac{r}{\omega_c L}\left\{\frac{C_{ga}}{(C_{ga} + C_a)} + \frac{1}{\omega_c^2 LC_{ga}}\right\}$$

As a matter of fact, Mr. Medlam's equation (11) is not strictly correct, because it omits to take into account the fact that the input voltage is modified to some extent by the introduction of the A.C. anode resistance of the valve when the latter is lighted, quite apart from the effect of the feed-back voltage e_r.

The equation should therefore strictly be $e_g = (e_1 - e_r)$, where e_1 denotes the modified value of e due to the valve resistance, and the solution mentioned above really gives the ratio E_g/E_1. This, therefore, requires to be multiplied by E_1/E to obtain the total effect produced by the valve when its filament is energised. This latter ratio can be obtained quite independently. Its value for the carrier frequency in the same example is 0.982, while the ratio E_g/E_1 is 0.971, so that $E_g/E = 0.953$. This is identical, to three places of decimals, with the value which I find by my method, the figure of 3 per cent. increase of resistance mentioned in my previous letter being for an input circuit resistance of 15 ohms.

If we take normal values of μ and r_a of, say, 10 and 25,000—which appear to be quite possible values under anode-bend rectification conditions, judging from an examination of the characteristic curves of some well-known makes of valves—we find from the formulæ for k_1, k_2 above, $E_g/E_1 = 0.116$, while the ratio E_1/E is 0.932, so that $E_g/E = 0.108$, which is again exactly the value I find from my formula.

Thus Mr. Medlam's method, when corrected to allow for the effect of the resistance of the input circuit, leads to results as regards the reduction of input voltage at the carrier frequency which are in entire agreement with those derived by my somewhat different method. Incidentally, the fact that the values of E_g/E calculated by the two different methods agree so exactly is in accordance with Mr. Medlam's observation that the effect of retuning is in this respect negligible, but it still appears to me quite possible that the omission to retune may cause to some extent an unsymmetrical variation of input voltage with side-band frequency on opposite sides of the carrier frequency.

From the above it is clear, I think, that there is perfectly satisfactory general agreement between theory and experiment as regards the effect of the feed-back on the carrier-wave input voltage. Mr. Medlam does not appear to realise, however, that this effect in no way indicates distortion, but is entirely in accordance with my theoretical conclusion that the effect of the feed-back is solely to cause an increase of the effective resistance of the input circuit. As I have shown in my article, the input voltage is nearly inversely proportional to $\sqrt{\frac{r_o^2}{r^2} + 4\frac{m^2L^2}{r^2}}$, where r_o denotes the effective resistance of the input circuit as modified by the feed-back. Therefore, when Mr. Medlam finds, in his experiment with a P.M.4DX valve, that the carrier-wave input voltage is reduced, by the feed-back, to 50 per cent. of its original value, $\frac{r_o}{r} = 2$ and the ratio E_g/E for a side band corresponding to an audio-frequency of 8,000, with a radio-frequency of 800 kc., $r = 10$ and $\omega_c L = 1{,}500$, is $\sqrt{1 + 4\left(\frac{150}{100}\right)^2} \Big/ \sqrt{4 + 4\left(\frac{150}{100}\right)^2} = 0.877$.

Thus there is a comparatively small reduction of the input voltage at frequencies correspondingly to the higher audio-frequencies. This does not indicate distortion, but, on the contrary, a *reduction* of the distortion which in any case results from the selectivity of the tuned circuit. If the selectivity of his input circuit is greater than is represented by the value $\omega_c L/r = 150$ used above, there would be still less reduction of the input voltage at the higher audio-frequencies than is indicated above. Also, as Mr. Medlam does not retune his circuit to allow for the detuning effect of the feed-back, it is quite possible—in fact, I think, probable—that he may find different values of input voltage for corresponding positive and negative side bands. Mr. Medlam says that the question of the distortion of the L.F. current wave-form in the anode circuit is "outside bounds." Why? The object of his article was, in his own words, to show that "the effects of the anode-grid capacity on the *audio-frequency* characteristic of the detector and L.F. stages" are serious. The italics, which are mine, are sufficient comment on this point.

Lastly, Mr. Medlam thinks his reply makes it unnecessary for him to comment on the theoretical results which I claimed to have obtained and by way, I suppose, of indicating *his* opinion of the value of those claims remarks that on this matter he will "only take up the statement to the effect that the rectified current of modulation frequency is proportional to the square of the input modulation voltage."

This is indeed a curious comment, because reference to my letter will show that I said nothing which could possibly be construed as meaning what the above alleged statement means, and made no reference at all to the specific relation between the quantities mentioned! The only explanation I can think of for this comment is that Mr. Medlam saw the original draft of my article, where the question is discussed, but he must have given it scant attention or he would never have alleged such a statement, as will be seen when the second part of the article is published. In any case, to comment on a statement which has not yet been published is very decidedly "outside bounds."

E. A. BIEDERMANN.

Brighton.

The Transmitting Station actually sends out Waves of One Definite Frequency, but of Varying Amplitude.

SIR,—My thanks are due to Mr. A. B. Howe for his letter published in the February issue, not only for satisfactorily clearing up a point which has occasionally puzzled me in idle moments, but also for the manner in which he has done so.

From my point of view it is clearly unfortunate that I made no mathematical analysis of the problem, seeking instead some physical explanation. The difficulty, however, appeared to commence with the introduction of mathematical analysis, and this did not encourage further investigation. It would seem that I have displayed that little learning which is proverbially dangerous.

The analysis contained in the letter of Mr. E. A. Biedermann, published in the March issue, is substantially similar and calls for no further comment. He also takes me to task for not unquestionably accepting a mathematical conclusion. I do not wish to disparage the use of mathematical investigation in physical problems, but unhesitatingly say that in such cases the final test should be a physical one. It is not uncommon for mathematical results to be rejected or tacitly ignored for physical reasons.

The simple formula for the resonant frequency of an oscillatory circuit, obtained mathematically, gives it as the square root of a product. Now we learn very early that a square root is either positive or negative. Thus the mathematical investigation gives in addition to the correct result an alternative one, which, in our world at least, has no physical interpretation whatever.

As a result of the correspondence I shall await with renewed interest any answer to the original challenge of Mr. A. W. Ladner to explain single side-band working on a single frequency basis. The case of suppressed carrier—*i.e.*, double side-band working is comparatively simple.

FRANK AUGHTIE.

Abstracts and References.

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PROPAGATION OF WAVES.

SHORT WAVE ECHOES AND THE AURORA BOREALIS.—L. H. Thomas. (*Nature*, 2nd February, 1929, V. 123, p. 166.)

Referring to the suggestion made independently by van der Pol and Appleton (February Abstracts, pp. 97, 98) that the Störmer echoes might be explained by the disturbance spending a long time in a region containing so many electrons per c.c. that the group velocity of the disturbance was very small, the writer evaluates the resulting signal intensity, using the expression given there by Appleton combined with an equation of his own giving a value for f. Assuming Pedersen's value (1.2×10^7) for the velocity of the electron under the supposed conditions, a delay of 10 seconds would reduce the signal intensity to $e^{-125000}$ of its initial value. "The suggested explanation seems, therefore, to be untenable, unless it is assumed that v is much larger. If v were 30 times as large ($v = 3.6 \times 10^8$, corresponding to 37 volts) the minimum reduction for a 10-second delay would be to $e^{-4.6}$ ($= 1/100$) of its initial value. The above objection does not apply to the second explanation put forward by Professor Appleton."

THE ELECTRICAL CONDUCTIVITY OF THE ATMOSPHERE AND ITS CAUSES.—V. F. Hess. (Review of English Translation, *Nature*, 2nd February, 1929, V. 123, pp. 155–156.)

The reviewer states: "Of the causes which produce ionisation, the most important is the highly penetrating radiation discovered by Hess himself, and to many readers the section dealing with this radiation will prove the most interesting part of the book . . . . It is to be noted that Hess still regards it as possible that the ultra-gamma radiation is produced in the outer atmosphere of the earth in response to some stimulus from the sun. He suggests that measurements of the penetrating radiation in the auroral zone would settle this question. Less cautious philosophers are convinced that the radiation comes from distant space." The reviewer himself, after quoting Jeans, suggests that there is no reason to doubt that some day we shall have telescopes designed to give measurements of the ultra-gamma radiation from individual nebulæ, measurements which will lead to new knowledge of the structure of the universe. Turning to the main subject of the book, he quotes: Near the ground, the conductivity of the air is such that the half-time period for the dissipation of the charge on an exposed conductor is roughly 15 mts. At 9 km., the air conducts 10 times as well. The small ions to which the conductivity is due have but short lives—their usual fate is to be caught by the Aitken nuclei within a minute after their creation. On land, they are mostly generated by radioactivity—about 8 ions per c.c. per sec. by this (5 by α, 3 by γ rays) and $1\frac{1}{2}$ by ultra-gamma radiation. Over the oceans, the latter is the (main ?) cause.

"The important subject of the ionisation of the upper layers of the atmosphere is dealt with very briefly. . . . The sketch of the part played by the Heaviside layer in the transmission of wireless waves is brought up-to-date, but there is no account of the evidence from terrestrial magnetism for the existence of such a layer. . . . It is hoped that in another edition some account of the brilliant work of Schuster and Chapman in elaboration of Balfour Stewart's idea will be given."

MEASUREMENTS OF THE AMOUNT OF OZONE IN THE EARTH'S ATMOSPHERE AND ITS RELATION TO OTHER GEOPHYSICAL CONDITIONS. PART III.—G. M. B. Dobson, D. N. Harrison, and J. Lawrence. (*Proc. Roy. Soc.*, 4th February, 1929, V. 122 A, pp. 456–486.)

Parts I and II were published in 1926 and 1927. The main object of the research was to study the distribution of ozone in cyclones and anticyclones: seven stations in different parts of the world collaborated in the work. Daily ozone observations show that there is a well-marked area, with much ozone, immediately to the west of cyclones; ozone is generally small in anticyclones. Among the mass of detail contained in the present part, the following points may be mentioned: It is shown that there is no appreciable change in the relative energies of the wavelengths used, as emitted by the sun. In general, the ozone values deduced from measurements of different pairs of wavelengths agree very closely, but occasionally small differences—the reason for which is not yet known—appear and continue roughly constant for a few days. Effect of different latitudes on the annual variations: in the autumn all stations have roughly equal ozone values, while in the spring the northern stations have much more ozone. 1927 results confirm that there is a small but definite tendency for days with much ozone to be associated with magnetically disturbed conditions. But comparison of the *mean* ozone values (for N.W. Europe) with the *mean* magnetic character for several stations in the same region, instead of showing a still closer relation, shows no relation at all: this result is not yet understood. A depression is associated with a fall in ozone, followed by a sharp rise: there is a negative correlation between the amount of ozone and the temperatures up to a height of 8 km. Previous hypotheses (in the first papers) as to the cause of the relation between the amount of ozone and the temperature and pressure in the troposphere are abandoned in favour of the view that the variations are due to the transportation, from one region of the globe to another, of large masses of air, including the whole atmosphere up to at least the height of the ozone layer. "The origins of the air currents in the upper part of the troposphere have a close connection with the fluctuations of ozone, polar air having a high ozone content and tropical air a low ozone content. This is the more interesting when we remember that the ozone is probably all in the stratosphere, the measurements indicating a height of about 40–50 km. for the centre of gravity of the layer (the base of the stratosphere being at a height of roughly 10 km.). . . . The ozone measurements thus give evidence that the great polar and tropical air currents extend to a great height and bring their own stratosphere with them, if we suppose that they retain their original ozone contents as they travel." Contrary to the usual idea that the chief cause of the formation of ozone is the sun's ultra-violet radiation, it is more in accordance with observation that the main effect of sunlight is the decomposition of the ozone already formed by some other cause (electric fields ?); though this decomposition is very slow, the change in one day being hardly detectable. (But Chalonge's moonlight observations, indicating a greater amount of ozone by night than by day, will—if confirmed—demand a very rapid drop about sunrise.)

UNTERSUCHUNGEN ÜBER DIE AUSBREITUNGSVORGÄNGE ULTRAKURZER WELLEN (Investigations into the Propagation of Very Short Waves).—F. Gerth and W. Scheppmann. (*Zeitschr. f. Hochf. Tech.*, January, 1929, V. 33, pp. 23–27.)

Previous tests of various workers have led to the assumption that waves below 10 metres follow the laws of propagation of light; this paper describes tests undertaken to confirm this. They were between ground station and aeroplane and between the summit (and other points) of the Brocken mountain and the surrounding neighbourhood. Like light, these (3-3.20 m.) waves are screened by obstacles large compared with their wavelength; only a small fraction is diffused into the shadow zone. The amplitude decreases as the square of the distance in the region of the direct ray: outside this, it falls off very quickly. Unlike waves longer than 10 m., these waves have up to the present been found free from fading phenomena; apparently therefore there is no re-radiation from the upper atmosphere. From geometrical reasoning, the maximum distance for transmission of the direct ray is given by the equation $x = 3550 (\sqrt{h_1} + \sqrt{h_2})$ in metres, where h_1 and h_2 are the heights of transmitter and receiver above the earth's surface. Although both in the aeroplane tests and in the mountain tests the theoretical values were never quite reached, results agreed generally with the theory. Particularly striking was one mountain test, in which when a certain critical distance was reached (80 km., compared with about 110 km. calculated), an 80-fold increase of transmitting energy hardly increased the range at all; showing that the direct (straight line) ray is mainly responsible for the range, the small increase obtained by the higher power being due to the fact that in the region of diffused radiation the threshold of receptivity is reached sooner by the smaller power than by the larger. In the path of the direct ray the use of a receiving aerial had no effect; in the diffused ray region, it increased the range by a few kilometres. The writers lay stress on the importance of these waves as a means of communication for special purposes, the outstanding points being *the definite limitation of their range*, the possibility of concentrating them by comparatively small reflectors, the small amount of power required, and the fact that—unlike light rays—they pass through smoke and fog without appreciable loss. *Cf.* Esau, Ritz and Beauvais, all in March Abstracts under "Transmission."

WELLEN-INDUKTION IN DER DRAHTLOSEN TELEGRAPHIE (Wave Induction in Wireless Telegraphy).—K. Uller. (*Zeitschr. f. Hochf. Tech.*, January, 1929, V. 33, pp. 15–22.)

The keynote of the whole paper is expressed by the opening epigram "Wireless waves are wired waves." The writer refuses to consider them as free waves reflected and refracted: they are bound or conducted waves, the conductors being surfaces of discontinuity. "The production of conducted waves is named wave-induction: direct, when the source lies in a discontinuity surface; indirect, when it lies outside the surface and the emitted wave, by its 'special incidence,'* is partly or wholly converted into a conducted wave." Elastic round-the-earth waves have long been known as earthquake phenomena: the analogous wireless return waves have only recently been recognised.

Conducted waves travel either on the surface of one medium or on both sides of the surfaces of separation of two different media or two similar media in relative motion. These surfaces impress a definite velocity and damping on the conducted waves. The general theory of these waves has never yet been recognised, owing to lack of knowledge of the writer's universal wave-theory, which he calls the Interference Principle (published 1917). For twenty years he has published paper after paper expounding the principles of the nature and origin of these waves, and apparently no one has understood him. The present paper, in its mathematical treatment of conducted waves, obtains as the "Condition for Induction" the equation $a_{e2}\sqrt{a^2_{e1}} + a_{e1}\sqrt{a^2_{e2}} = 0$. Direct induction is always possible; indirect, only when this condition is fulfilled. The waves must be complex: in general, a wave has a duality of wave-surfaces—that of phase and that of damping—which can cut each other at any angle. The writer explains Fading as a result of wave-induction, and points out the fallacy of attributing the velocity of Light to the round-the-earth waves in order to derive the length of path and—from this—the height of the Heaviside layer.

* *i.e.*, where $N = 0$, N being the function of the diffraction index in the equation $A_d = \frac{Z_d}{N} \cdot A_a$.

FADING CURVES AND WEATHER CONDITIONS.—R. C. Colwell. (*Proc. Inst. Rad. Eng.*, January, 1929, V. 17, pp. 143–148.)

An extension of the paper referred to in Abstracts, February, describing and illustrating the sunset fading curves at Morgantown from KDKA, which is approximately on the same meridian. The curves taken on fine days show more irregularity during the daylight hours than those taken on cloudy days. It was found that the strength of signals during the dark hours sometimes fell far below the daylight strength. Observations made in the very static-free summer of 1928 showed that the weather conditions had such a decided effect on the signal strength that it was possible to foretell the weather one day ahead by the form of the fading curves. If the curve continued to rise after sunset, a wet or cloudy day followed; if the curve fell, the weather tended to clear.

EFFET D'UN CHAMP MAGNÉTIQUE SUR DES PHÉNOMÈNES DE RÉSONANCE DANS LES GAZ IONISÉS (Effect of a Magnetic Field on Resonance Phenomena in Ionised Gases).—H. Gutton. (*Comptes Rendus*, 28th January, 1929, V. 188, pp. 385–386.)

Continuing his investigations (Abstracts, March; also 1928, V. 5, p. 222), the writer has tested the effect of a magnetic field on that absorption band in an ionised gas which he explains by assuming that the displacement of an electron creates a restoring force proportional to the displacement. The magnetic field was set at right angles to the direction of the variable H.F. electric field. The results when plotted in a curve show that the absorption band for $i_0 = 1.03$ divides itself, under the influence of the magnetic field, into two bands corresponding to the currents $i_1 = 1.50$ and $i_2 = 0.31$; an effect analogous to the Zeeman effect. The subdivision of the band by a magnetic field confirms the existence of resonances, and the value worked out for the ratio e/m (1.61×10^7 e.m.u., m being the mass and e the charge of the particle involved) shows that the electron is concerned. Tests on 1.804, 2.487 and 4.80 metres give the same result.

ATMOSPHERICS AND ATMOSPHERIC ELECTRICITY.

ON THE THEORY OF THE SOLAR DIURNAL VARIATION OF THE EARTH'S MAGNETISM.—S. Chapman. (*Proc. Roy. Soc.*, 4th February, 1929, V. 122A, pp. 369–386.)

Various theories are compared. The "dynamo" theory suggested by Balfour Stewart (attributing the variation "*S*" to overhead electric currents induced by convective motion of the air across the earth's magnetic field) has held its ground for more than a generation: it gives a good account of the general form of the current system as derived from the author's spherical harmonic analysis of *S*. When, however, it attempts to explain the phase and intensity of the currents, it is handicapped by our lack of knowledge as to the convective motion which induces the currents, and as to the total conductivity of the layer in which they flow. Schuster and the author—rather differently—have each tried to connect the convective motion at the higher levels with the effects observed in the lower atmosphere: their results agree in making the dynamo theory place the *S* current foci about 2 to 2¾ hours later than is actually observed. This discrepancy is about twice as great as that given by the "drift-current" theory (see later) or by Gunn's diamagnetic theory (Abstracts, 1928, V. 5, p. 578), but this objection to the dynamo theory would vanish if an inversion or large change of phase could be shown to exist for the upper atmosphere diurnal convection.

The only objection then remaining against the dynamo theory would be that it demands a total electrical conductivity of the current-layer of the order of 10^{-5} e.m.u.—20 times as great as Pedersen's estimate. The writer shows, however, that this estimate could well be quadrupled by correcting certain assumptions made by Pedersen (*e.g.*, $T = 220$ deg. at all heights in the stratosphere, and that mixing by convection ceases at 12 km.). If the dynamo theory by itself is to be accepted, this quadrupling would not be enough and still higher conductivity would have to be proved. On the other hand, if the "dynamo" and the "drift current theory" (which gives, as a main cause for *S*, the drift motion—always eastward—of the free charges under the influence of the earth's magnetic field) are combined as joint causes of *S*, they would account satisfactorily for all the phenomena, unless the large change of phase (mentioned above) in the diurnal convection in the upper atmosphere is proved to be non-existent. If it exists, the "dynamo" component would account for the phase discrepancy referred to above, which the "drift-current" component could not explain; while the two components would combine to fit in with a conductivity of a reasonable value. The writer's rejection of Gunn's diamagnetic theory is based on his calculation that if the number of diamagnetically effective free charges were large enough to explain *S*, the drift currents would be great enough to produce a value of *S* 250 times as intense; "the diamagnetism of the outer atmosphere makes only an insignificant contribution to *S*." Other interesting points in the paper are: the electrons contribute almost their full quota to the diamagnetism from 90 km. upwards, so that the conducting layer is rendered diamagnetic by the electrons; the ions only begin to contribute fully to the diamagnetism at about 150 km., *near where the conducting layer ceases*: for in a previous section it is shown that the upward extension of the layer is subject to "a hitherto unsuspected limit" depending on the specific conductivity for directions transverse to the magnetic field: the layer must probably lie between 100 and 170 km. height above the ground.

THE DISTRIBUTION IN SPACE OF THE SUNLIT AURORA RAYS.—C. Störmer. (*Nature*, 19th January, 1929, V. 123, pp. 82–83.)

Krogness has suggested that the great heights of these sunlit rays may be due to the sun's radiation pressure pushing away the upper atmosphere tangentially like a small tail of a comet: if the corpuscular rays hit this tail they produce aurora at unusual heights. The writer brings experimental evidence in support of this theory, based on simultaneous photographs from two stations which fixed the altitude of these rays on two occasions.

THE TIME INTERVAL BETWEEN MAGNETIC DISTURBANCE AND THE ASSOCIATED SUNSPOT CHANGES.—J. M. Stagg. (*Geophys. Memoirs*, No. 2, 1928, V. 5, 16 pp.)

A correlation of observations over thirty-five years at Kew and Greenwich shows, in agreement with Maurain (Abstracts, 1929, V. 6, p. 41), that the greatest sunspot-area-number occurs about 2¾ days before the maximum magnetic disturbance on the earth. The author, however, suggests that for studying the length of time between the emission of the solar particles and their arrival at the earth, the day-by-day fluctuations of sunspot-numbers have more to say than the sunspot-numbers themselves—since the emission is thrown out presumably during the development of the spot rather than at the stationary point of greatest extension. Various groups of years and various ways of averaging show that the sunspot areas increase most rapidly from the (n-5) to the (n-4) day, *i.e.*, round about the fourth day before the maximum magnetic disturbance. In years of slight sunspot activity, the greatest area-increase occurs perhaps a day earlier, but is less marked. The writer considers the four days to be, not the actual time of passage of the particles, but the upper limit of this: for the letting loose of a magnetic storm depends also on the state of ionisation of the upper atmosphere and occasionally will only take place after a number of small impulses.

DIE HÄUFIGKEIT (MITTLERE DAUER) APERIODISCHER WELLEN DES LUFTDRUCKES UND DER TEMPERATUR (The Frequency—mean Duration—of the Aperiodic Waves of Atmospheric Pressure and Temperature).—F. Travniček. (*Met. Zeitschr.*, No. 7, 1928, V. 45, pp. 241–251.)

The pressure-wave frequency all over the world lies between the comparatively narrow limits of 115 and 71 per year. The temperature-wave frequency is even more uniform—between 113 and 92. Many other details are given.

HIGH-VOLTAGE PHENOMENA IN THUNDERSTORMS.—M. A. Lissman. (*Journ. Am. I.E.E.*, January, 1929, V. 48, pp. 45–49.)

Lightning phenomena are analysed in the light of laboratory experience with high-voltage phenomena in the atmosphere. Special emphasis is placed on the effect of space charges in producing high local stresses when they are "mobilised" through channels of high conductivity ("filaments") caused by high temperatures.

LIGHTNING AND OVERHEAD ELECTRIC POWER LINES.—E. Beck. (Summarised in *Nature*, 19th January, 1929, V. 123, p. 109.)

The article describes the apparatus and methods used by the Westinghouse Company in investigating the exact nature of the disturbance caused by a lightning flash in the immediate neighbourhood of an overhead line. The position of the lightning stroke is located by an instrument called the "osiso" which accurately measures the time between the beginning of the oscillograph transient and the arrival of the noise of the thunder. A photographic film speed of 12,000 ft. per minute is only suitable for recording (by Dufour Oscillograph) slow lightning transients; to record the more rapid effects, a quick oscillatory motion is given to the electron beam.

PROPERTIES OF CIRCUITS.

ON THE VARIATION OF GENERATED FREQUENCY OF A TRIODE OSCILLATOR DUE TO CHANGES IN FILAMENT CURRENT, GRID VOLTAGE, PLATE VOLTAGE, OR EXTERNAL RESISTANCE.—K. B. Eller. (*Proc. Inst. Rad. Eng.*, December, 1928, V. 16, pp. 1706–1728.)

Author's summary: "The general expressions for the generated frequency of the grid-tuned and the plate-tuned oscillators are developed. In developing these expressions it is assumed that the grid takes a convection current and that there are external resistances in the circuits. The equations which represent the frequency of oscillation of the two types of oscillators are similar and indicate that in order to transform from one type of generator to the other it is only necessary to interchange the plate-circuit constants with the grid-circuit constants.

"The effect of making any change in the circuit conditions which causes the grid current to increase is observed to cause the frequency of oscillation to decrease; and likewise any change which does not affect the grid current does not affect the frequency.

"For fixed grid-battery voltage and plate-battery voltage the effect of decreasing the filament current below its rated value is to increase the generated frequency for both types of oscillators. This change in frequency is greatest for positive values of grid-battery voltage and low plate-battery voltage. With fixed filament current and plate-battery voltage, the effect of changing the grid-battery voltage from negative to positive values is to cause at first a decrease and then an increase in the generated frequency. This change in frequency is greatest for low plate-battery voltages and high (near rated) filament currents.

"For fixed filament current and grid-battery voltage the effect of increasing the plate-battery voltage is first to lower the generated frequency and then to raise it.

"For both types of oscillators, the effect of inserting a resistance (0 to 600 ohms) in series with the condenser is to increase the generated frequency for all values of E_c, E_b and I_f. The presence of this resistance does not greatly affect the shape of the frequency-grid voltage curves. For low values of plate-battery voltage the effect of a resistance in series with the tuned coil is to cause the frequency of oscillations to increase for both types of oscillators. However, for high values of plate-battery voltage the effect of this resistance is opposite for the two oscillators. For high E_b the effect of increasing the resistance in the inductance branch is to decrease the frequency in the case of a grid-tuned oscillator and to increase the frequency in the case of a plate-tuned oscillator. The equations developed in this paper indicate that the grid current is responsible for the decrease in frequency with increase of the resistance in the inductance branch in the case of a grid-tuned oscillator with high plate voltage.

"For both types of oscillators, the effect of inserting a resistance in series with the tuned circuit as a whole is observed to cause the frequency at first to increase rapidly and then to become constant. For high values of this resistance (10,000 ohms) the frequency of oscillation is practically independent of grid voltage and particularly so for high plate voltage. For low values of plate-battery voltage the effect of a resistance in series with the exciting or tickler coil is to cause the frequency to increase rapidly for values of this resistance less than about 10,000 ohms and to cause only a slight further increase in frequency for values of resistance greater than 10,000 ohms. However, for high values of plate-battery voltage the effect of a resistance in series with the tickler coil is to decrease at first the frequency and then to increase it. The effect of this resistance is in general the same for both types of oscillators. The frequency variation is greatest for positive values of grid-battery voltage.

"The grid-tuned generator will oscillate over a much wider range of variables than will the plate-tuned oscillator and frequency variation for the same change in circuit conditions will in general be less for the grid-tuned than for the plate-tuned oscillator.

"The above discussion applies to oscillators without a grid-leak and grid condenser.

"With properly selected values of grid-leak resistance and grid capacity both the grid-tuned and the plate-tuned oscillators may be made to generate a frequency which is very nearly that given by the equation $f = \frac{1}{2\pi\sqrt{LC}}$ for relatively large changes in E_c, E_b and I_f. In this work, by using a grid capacity of 0.025 μF. and a grid leak of 0.5 megohm the frequency variations were about 0.1 per cent. for a 60 per cent. change in plate-battery voltage and 0.08 per cent. for a 30 per cent. change in filament current for the grid-tuned oscillator. For the plate-tuned oscillator the frequency variations were 0.087 per cent. and 0.027 per cent. for 60 per cent. change in E_b and 30 per cent. change in I_f, respectively. These figures represent experimental results obtained near 1,000 cycles per second. The theoretical equations developed seem to explain all of the experimental curves obtained.

"The results of this work indicate that with the given methods of operation, and by holding the values of the grid voltage, plate voltage and filament current constant within practical limits, the plate-tuned oscillator can readily be made to generate a frequency constant to one part in 20,000. By more refined precautions the constancy can be made still greater."

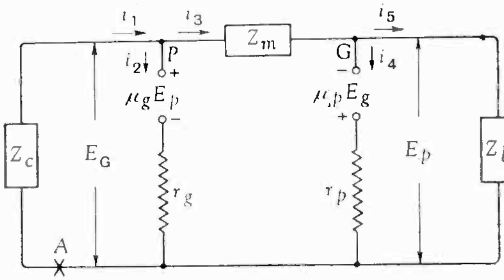
EFFECT OF ANODE-GRID CAPACITY IN ANODE-BEND RECTIFIERS: PART I.—E. A. Biedermann. (*E.W. & W.E.*, February, 1929, V. 6, pp. 71–76.)

The writer rejects Medlam's analysis (*ibid.*, October, 1928), which led to the conclusion that the reaction due to anode-grid capacity causes considerable distortion, and proceeds to outline (using impedance operators) what he believes to be the correct theory. At the end of this first part he sums up: "Thus, in so far as the feed-back causes an increase of the effective resistance of the input circuit, it decreases any distortion which may arise from phase shift of the side-bands, of which phase shift there is always a certain amount present."

There is a correspondence on this subject in the same journal, pp. 93–95, where Medlam defends his methods and mentions experimental results which led him to the theoretical investigation.

THE CONDITION OF SELF-OSCILLATION OF A GENERAL TRIODE SYSTEM.—P. S. Bauer. (*Proc. Nat. Acad. Sci.*, January, 1929, V. 15, pp. 25–29.)

Miller and Chaffee have shown that under the hypotheses of the equivalent plate and grid circuit theorems for voltages and currents of small amplitudes, the general equivalent circuit of a valve is that shown in the figure, where Z_c, Z_m and Z_b are the grid-circuit, mutual-circuit and plate-circuit complex impedances, and μ_p, μ_g, r_p and r_g are the usual valve parameters, assumed to be constant.



The present paper develops the general relations, between the circuit parameters, which cause the condition of self-oscillation. Two theorems are established, the second following from the first: "the self-oscillatory relation between the circuit parameters is invariant of the point of application of the applied voltage": and "a necessary and sufficient condition for self-oscillation is that the determinant of the coefficients of the equations of the currents in the system is equal to zero."

From these theorems it is shown that the condition for self-oscillation is :—

$$\triangle = Z_b Z_c[\{r_p(\mu_g - 1) - r_g(\mu_p + 1)\} - Z_m(\mu_g\mu_p + 1)] - Z_m(Z_c r_p + Z_b r_g) - r_p r_g(Z_b + Z_c + Z_m) = 0$$

The significance of the variables in this equation, and the method of using it to determine the frequency of self-oscillation and the relation between the inductances, capacitances, and resistances, are then explained.

SUR LES OSCILLATIONS D'ORDRE SUPÉRIEUR D'UN CIRCUIT OSCILLANT (The Higher Frequencies of an Oscillating Circuit).—Chenot. (*Journ. d. Phys. et le Rad.*, No. 5, 1928, V. 9, pp 74 and 75.)

Tests, on parallel wires bridged at one end by a copper plate and connected at the other end each to a small electrometer condenser, showed that Rayleigh's formula for the partial frequencies of a string of length L and thickness d, fixed at one end and weighted at the other with a mass M, holds also for the resonance frequencies in the electrical analogy; L now representing the length of the wires, M and d the capacities of the end condensers and of the wires per centimetre. The equation is

$$\text{Cot}\,\frac{2\pi L}{\lambda} = \frac{2\pi}{\lambda} \cdot \frac{M}{d}$$

DER PARALLELKONDENSATOR IN FREQUENZVERVIELFACHUNGS-SCHALTUNGEN (The Parallel Condenser in Frequency-multiplying Circuits).—Gg. Hilpert and H. Seydel. (*E.T.Z.*, 31st January, 1929, pp. 149–154.)

In connection with H.F. generators, the method of operation of the "parallel condenser" (in parallel with the iron-core choke) is described, and its optimum value for a given generator calculated. The great improvement which it produces is due to the gradual handing-on of the energy to the secondary circuit, instead of the shock process which takes place if no parallel condenser is present. The ratio L/C can be increased a hundredfold, with a consequent great decrease in damping: the wide wave-band in the aerial shrinks up, leaving only one overtone which is so weak that it can be filtered out. The mathematical treatment is supported by oscillograph curves. The value of the condenser is of the order of 9,000–30,000 cm.

A METHOD OF TREATING RESISTANCE-STABILISED RADIO-FREQUENCY AMPLIFYING CIRCUITS.—B. L. Snavely and J. S. Webb. (*Proc. Inst. Rad. Eng.*, January, 1929, V. 17, pp. 118–126.)

Recently there has been considerable use of tuned radio-frequency amplifying circuits employing a resistance in the grid circuit for the purpose of preventing oscillation. Steady oscillation cannot occur if the value of R exceeds the value of the negative input resistance of the valve. The value of R for which oseillations are just maintained when once started is here termed the critical value. Since the input capacity of the valve is generally not negligible in comparison with the tuned-circuit capacity, any increase of R beyond the critical value causes an effective increase in the resistance of that circuit. It therefore becomes desirable to have some means of calculating the critical value.

An equation is here developed for a resistance-stabilised amplifier having a tuned grid circuit and a pure inductance plate load: it has been necessary to assume at first that no current flows between grid and filament, that the plate-to-filament capacity is negligible, and that the grid-to-filament capacity is zero. Later, the conditions for a plate load of any type are considered, and approximation formula which will take into account the grid-filament capacity. An experimental curve shows the great change of the critical resistance for a small change in this capacity. The great steepness of this curve, combined with the accuracy with which the critical resistance can be determined (within a fraction of 1 per cent.) suggests a method for measuring very small capacities—which could be connected between grid and filament. A variable condenser thus connected would provide a control of regeneration in such a type of circuit—the grid-circuit resistance being kept fixed and the critical value being made to approach this fixed value by varying C_{gf}.

THE THEORY OF OSCILLATIONS AS ALTERED BY RADIO-TELEGRAPHIC DEVELOPMENT.—J. Zenneck. (*Proc. Inst. Rad. Eng.*, January, 1929, V. 17, pp. 90–101: part of a long paper, "The Importance of Radiotelegraphy in Science.")

The old Kirchoff-Kelvin equation: the decay of amplitude in circuit including a spark—linear rather than exponential: the increase of current at closing of arc generator—negative resistance: resonance curve of a valve generator impressed with an E.M.F. of constant amplitude but variable frequency—oscillating audion—another result of a resistance whose sign and value depend on amplitude of current: voltage-current characteristic of circuit containing closed iron core—resonance curves of such a circuit: non-reciprocal inductive coupling between two circuits coupled through a valve: shock excitation by quenched gap, etc.: magnetic synchronised shock excitation: the writer's original frequency-doubling suggestion (non-saturation)—Epstein's frequency-doubler (with saturation): demultiplication: circuit arrangement (generator circuit tightly coupled to circuit containing closed iron core) for producing self-modulated oscillations in primary and secondary currents, contrary to the general assumption that when a generator of constant frequency and amplitude acts upon a system of circuits, the currents in these circuits will have constant amplitude, at any rate after the transient phenomena have disappeared.

TRANSMISSION.

DIE ERZEUGUNG KÜRZESTER ELEKTRISCHER WELLEN MIT ELEKTRONENRÖHREN (The Generation of the Shortest Electric Waves by Electronic Valves).—H. E. Hollmann. (*Zeitschr. f. Hochf. Tech.*, January, 1929, V. 33, pp. 27–30.)

A survey of results up to date, starting with the damped (spark-produced) half-metre waves of Hertz and the still shorter ones of Righi, Lebedew, Lampa and Möbius; Nichols and Tear obtained a fundamental of 1.8 mm., while Arkadiewa—with his 0.13 mm. wave—invaded the region of long wave heat radiation. All these spark-generated waves are very feeble in energy and their great damping makes them almost useless for dispersion or absorption measurements, etc. The rest of the paper deals with valve methods of production: (1) by reaction methods—Gutton and Touly (1919) 1.5 m.; three-point circuits with parallel wires—Hollmann, 92 cm. continually increasing to 10 m.; Huxford, 1 m.; Bergmann, 82 cm., with considerable energy: balanced or symmetrical two-valve circuits first proposed by Eccles and Jordan; Holborn's push-pull generator, down to 2.4 m.: Hollmann's modification, with cross-connections and inductive reaction—very serviceable for waves of a few metres, or (with special low-capacity valves) down to 1.7 m.—Bergmann—and 1.5 m.—Mesny; Gutton and Pierret, keeping inductive reaction but not the cross connections, reached 110 cm. Englund, with a special double valve (to cut short the connections) could not get much energy into a 1.05 m. wave. This is apparently the lower limit for symmetrical circuits. For all reaction arrangements, the frequency is limited not only by the increase of current at the expense of alternating voltage at the electrodes (due to changes in the relation C/L) but also by the electron time between electrodes becoming comparable with the length of the period of oscillation. By the equation $t = \sqrt{\frac{d}{v \cdot \frac{e}{m}}}$, for an anode radius of 0.5 cm. and an anode voltage of 500 v. the electron time works out at 0.7×10^{-9} sec. The half-period of a 1 m. wave is 1.7×10^{-9} sec.; it is comprehensible, therefore, that the 1 m. wave is about the limit. The next part of the paper will deal with the generation of oscillations by influencing the electron motion by control fields.

Recent Developments in Low Power and Broadcasting Transmitters: Discussion. —E. L. Nelson. (*Proc. Inst. Rad. Eng.*, December, 1928, V. 16, pp. 1776–1778.)

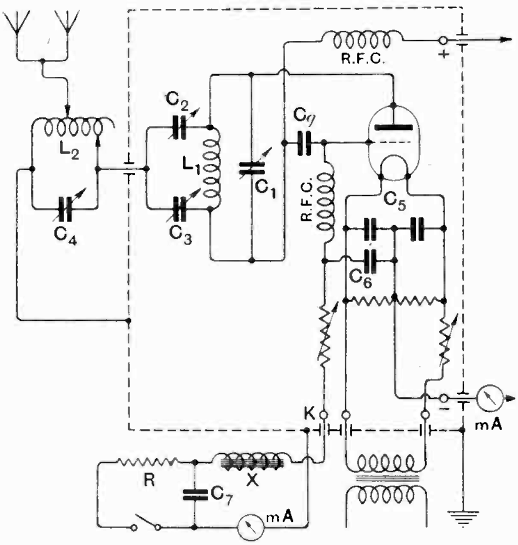
Byrnes, in his paper in the May "Proceedings," discusses the rating of transmitters and stresses the importance of excluding losses in the antenna coils in computing the output power. While agreeing with this, the writer calls attention to a point even more frequently neglected—modulation capability: *i.e.*, the maximum degree of modulation possible without serious distortion, employing a single-frequency sine-wave input and using a rectifier coupled to the antenna in conjunction with an oscillograph or harmonic analyser to indicate the character of the output. There is evidence to show that the average modulation capability of American broadcasting stations is not greater than 50 per cent. (But *cf. G.E. Rev.*, under "Stations.") "Having in mind that beat-note interference and power limitation are the most serious problems that confront the broadcasting industry to-day, it is of interest to note that . . . the same signal-to-noise ratio could be produced by stations of one-fourth the carrier power output provided their modulation capabilities were doubled, that is, made to approach 100 per cent." He then discusses the difficulties in obtaining 100 per cent. modulation of high quality, mentioning the condition, with the Heising system "now generally employed," for complete modulation—that the peak value of the alternating voltage superimposed upon the direct plate voltage impressed on the oscillator or modulated amplifier shall be equal to the direct voltage. The obvious way to make this possible is to supply the modulator valves with a higher anode voltage than is used for the radio-frequency valves; and since the power in a completely modulated wave is 50 per cent. greater than that represented by the unmodulated carrier, and this extra power must be supplied by the modulator, the ratio of modulator power to oscillator power might well have to be as much as 3 or 5 to 1. "These conditions favour that type of system in which the modulation is effected at low power levels and the requisite power output obtained by subsequent power stages amplifying modulated radio-frequency power."

Modulation Methods.—(*German Patents*, 465,501, Lorenz, and 467,022, Könemann, pub. September and October, 1928.)

The first patent states that in long-wave telephony the whole frequency band to be transmitted is so broad, compared with the carrier frequency, that the side-band frequencies are considerably weakened in the aerial circuit with the resonance-curves as actually used. Broadening these curves has the disadvantage of bringing out harmonics and side-waves. It is here proposed to produce the carrier wave in a lightly damped circuit and then to apply the modulation in an oscillatory system with a broad resonance curve. In the diagram the aerial circuit consists of a two-wave circuit (into which the carrier wave is induced) out of which emerge the aerial and the earth lead, in the latter of which the modulating arrangement is found. In the second patent, a rejector circuit in the aerial has its wavelength modified by the modulation current (*e.g.*, by having its inductance formed by the secondary winding of a microphone transformer).

A Poor Man's M.O.P.A.—J. T. McCormick. (*QST*, January, 1929, V. 13, pp. 25–28, 78.)

Description of the reasoning-out and construction of a 3,500/7,500 kc. telegraph transmitter, one



valve (self-excited oscillator), to give a constant note comparable with that given by a crystal-controlled set. Starting from the fact that the oscillations of a *receiver* can be kept reasonably constant, it is shown that this is because, compared with a usual transmitter, the valve runs perfectly cool and there is very little load on the control circuit. Applying these facts to a transmitter, the writer obtains the circuit shown in the diagram, which he finds very satisfactory.

ON THE DETERMINATION OF THE OPTIMUM RADIATION ANGLE FOR HORIZONTAL ANTENNAS.—A. Meissner and H. Rothe. (*Proc. Inst. Rad. Eng.*, January, 1929, V. 17, pp. 35–41.)

A paper on the Berlin to Buenos Aires tests (Abstracts, 1928, V. 5, p. 637). They were made between 11 a.m. and noon and between 6 and 9 p.m., in winter. Reception tests on the same aerial systems showed that no marked improvement could be obtained by using a receiving system inclined to the horizontal: but these tests were limited, being possible only in the morning owing to local reasons. As regards transmission, the writer suggests that the angle 0 deg. is so particularly favourable (but *cf.* Hendricks, March Abstracts under "Aerials") because the very dispersed radiation of the reflector (as shown by the polar diagram) may be concentrated more strongly by the reflecting influence of the earth: in the emission of horizontally polarised waves the influence of the earth on the upward bending of the rays is apt to be very great.

RECEPTION.

DAS PROBLEM DER ÖKONOMISCHTEN VIELFACHTRANSPONIERUNG (The Problem of the most economic Multiple Frequency-Changing Reception).—F. Aigner. (*Zeitschr. f. Hochf. Tech.*, January, 1929, V. 33, pp. 9–15.)

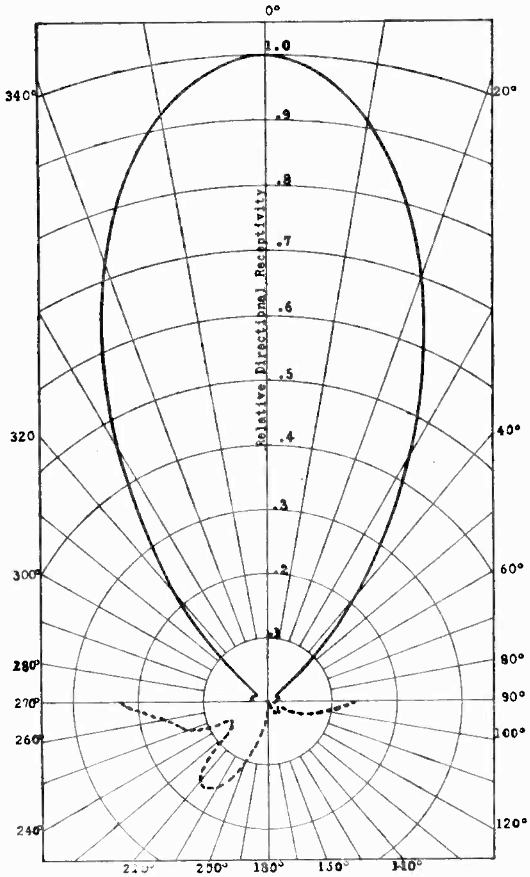
The paper begins by a comparison between Neutrodyne and Frequency-Changing methods. It mentions "an erroneous idea" that a superheterodyne is, on theoretical grounds, more selective than a neutrodyne, and shows that no such superiority exists in theory. On practical grounds, however, the frequency-changing method has the advantage, and the writer's first object is to put this on the most economic basis by reducing to a minimum the number of fixed local oscillators. His second object (dealt with in the part of his paper still to appear) is to develop apparatus, for un-modulated and modulated waves, which shall retain all the advantages of the method and possess as well advantages attainable with no existent apparatus—particularly with regard to sharpness of separation. The present paper deals with apparatus with normal selectivity; only two local oscillators, or one yielding two harmonics, are found to be necessary; or one oscillator giving a fundamental and harmonics can, by a combination of difference frequencies with these harmonics, yield a whole series of suitable oscillations.

APERIODIC H.F. AMPLIFICATION WITH MODERN VALVES.—F.L.D. (*Wireless World*, 13th February, 1929, V. 24, pp. 173–174.)

Suggestions for the application of recent developments in valve and H.F. choke design. Attempts at aperiodic H.F. amplification with H.F. choke coupling have hitherto met with small success for waves much less than 1,000 m. The advent of such valves as the P.M.4DX, with a rated amplification factor of 15 and an A.C. resistance as low as 7,500 ohms, and the general improvement in the characteristics of commercial H.F. chokes, make it worth while to reconsider this method of amplification; particularly as a preliminary stage in superheterodyne or portable receivers.

THE RECEIVING SYSTEM FOR LONG-WAVE TRANSATLANTIC RADIO TELEPHONY.—A. Bailey, S. W. Dean and W. T. Wintringham. (*Proc. Inst. Rad. Eng.*, December, 1928, V. 16, pp. 1645–1705.)

Authors' summary: "Transmission considerations and practical limitations indicate that in the lower frequency range, frequencies near 60 kc.



Wave-Antenna Array Directional Characteristic. Calculated Relative Directional Receptivity of Array of 4 Houlton Antennæ. (From Average Measured Unit Antenna Characteristic.) Dotted Curve—Magnified × 10.

are best suited for transatlantic radiotelephone transmission. A radio receiving location in Maine gives a signal-to-noise ratio improvement over a New York location equivalent to increasing the power of the British transmitter about 50 times.

Various types of receiving antennæ are briefly discussed. The wave-antenna is selected as being most suitable for long-wave radio telephony. The various factors affecting wave-antenna performance and methods for measuring the physical constants of wave-antennæ are discussed in detail. High-frequency ground conductivities determined from wave-antennæ measurements are given. Combination of several antennæ to form arrays is found to be a desirable means of decreasing interference. The use of a wave-antenna array in Maine decreases the received noise power by an additional 400 times. If the receiving were to be accomplished near New York using a loop antenna, we would have to increase the power of the British transmitting station 20,000 times to obtain the same signal-to-noise ratio. Comparisons of calculated and observed directional diagrams of wave-antennæ and wave-antenna arrays are presented and discussed.

"The transmission considerations governing the design of a radio receiver for commercial telephone reception are outlined.

"Mathematical discussions of the wave-antenna, antenna arrays, quasi-tilt angle, and probability of simultaneous occurrence of telegraph interference are given in the appendices."

The polar diagram reproduced is considered to represent about the best that can be done economically in a general reduction of back-end area and narrowing of the diagram by means of wave-antennæ.

NEUE EMPFANGSSCHALTUNGEN MIT NEUEN MEHRFACHRÖHREN (New Receiving Circuits with New Multiple Valves).—M. v. Ardenne. (*Rad. f. Alle.*, November, 1928, pp. 488–499.)

The writer and Loewe have designed a new type of double valve for the special purpose of cascade H.F. amplification in the Broadcast band, for distant reception on frames. The writer was led to do this because he finds that—except perhaps in America—a total H.F. amplification up to the maximum 5,000 (which he considers the limit) is hardly ever obtained with ordinary valves (even screen-grid valves) owing to the multiplicity of stages necessary. The new valve has only a single grid, and various changes in the internal structure make it very different from the older H.F. double valve, though its external size, etc., is the same and its amplification equal to or greater than that of the old type. Its frequency-dependence in the Broadcast band is much less—an important advantage. Internal capacities are so reduced that L.F. amplification hardly exists, so that with the circuit which he specifies six H.F. stages are obtainable without trouble. The necessary screening is described. In one arrangement recommended, the connecting wires to the tuned circuits take the form of cable with earthed sheaths. The amplifier also works well as an intermediate frequency amplifier for short-wave reception; the lay-out of a complete scheme for this purpose is given.

AUTOMATISCHE LAUTSTÄRKEREGELUNG (Automatic Volume Control).—H. Kröncke. (*Rad. f. Alle*, December, 1928, pp. 529–531.)

After describing the need for automatic control especially for long distance broadcast reception where fading comes in, the writer says that there are signs that in America every broadcast receiver will soon incorporate such a device. He considers the problem on general lines and then concentrates on the Wheeler circuit (Abstracts, 1928, V. 5, pp. 35 and 165) which he estimates as giving (for a three-stage control) a regulation of 1 in 1,000, provided the individual stages are properly neutralised.

PROGRESS IN RADIO RECEIVING DURING 1928.—A. N. Goldsmith. (*Gen. Elec. Review*, January, 1929, V. 32, pp. 74–81.)

Illustrated by photographs of American apparatus. The incorporation of automatic volume control is mentioned (*cf.* Kröncke, above). Photophone apparatus for sound-motion pictures is included. The development of "Centralised Radio" (*e.g.*, for blocks of flats, hotels, etc.) is discussed.

TWO-CIRCUIT TWO: SELECTIVITY WITHOUT LOSS OF SIGNAL STRENGTH.—H. F. Smith. (*Wireless World*, 6th February, 1929, V. 24, pp. 143–148.)

Description of the construction of a two-valve set in which the use of a reacting detector and one stage of L.F. amplification is combined with a tuned aerial circuit auto-coupled with the inductance of the "Hartley" circuit. "Selectivity is, of course, hardly up to the standard of a really first-class set with a single H.F. stage and 'un-tuned' aerial, but it is of a distinctly higher order than that of an indifferent circuit arrangement of this kind, even if matters are not improved in this respect by loosening aerial coupling beyond the point giving loudest signals."

RECEIVING SETS FOR AIRCRAFT BEACON AND TELEPHONY.—H. Pratt and H. Diamond. (*Bur. of Stds. Journ. of Res.*, October, 1928, V. 1, pp. 543–563.)

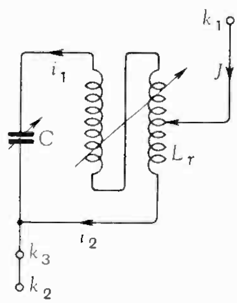
Design details for three sets of slightly different types, with numerous characteristic and performance curves, are discussed, with a brief discussion of practical flight tests. The receivers have to be small, light and yet rugged. The tuning system should be of a uni-control type over the whole frequency band 285–350 kc. As the distance is changing so rapidly, a simple volume-control with a uniform action from zero to maximum is necessary. Shielding is necessary to limit ignition interference to that induced in the aerial. The set must be capable of operating a beacon course indicator (see these Abstracts, under "Directional Wireless"): the audio-frequency amplification must be nearly uniform over a frequency range of 40–3,000 cycles (40–120 for the beacon signals and 200–3,000 for good speech intelligibility). Sensitivity (to allow the use of short vertical pole aerials) and selectivity must both be high. These two features, and that of uni-control, are obtained with 3 or 4 tuned radio-frequency circuits with gang variable air condensers. Some regeneration in the detector circuit is provided. Although low-voltage valves would have been welcome, both for their smaller dimensions and for the smaller size of battery, the standard low-voltage valves were found to be not sturdy enough—being often mechanically weak and usually causing microphonic noises. Either special low-voltage valves have to be used, or standard 5-volt valves. "There is much need for better tubes for aircraft sets."

DIE VORRÖHRE BEI TRANSPONIER-EMPFÄNGERN. (The Preliminary Input Valve for Frequency-Change Receivers).—O. Knies. (*Rad., f. Alle*, November, 1928, pp. 503–505.)

Such a preliminary high-frequency stage, in front of the main superheterodyne receiver, not only increases the sensitivity but also prevents re-radiation (which the use of a frame aerial does not avoid entirely). One of the best methods of coupling to the first stage of the receiver is by tuned transformer, auxiliary adjustments being a variable condenser and the grid-bias potentiometer. Other methods are illustrated and discussed.

DER RIEDELSCHE SPERRKREIS (The Riedel Wave-Stopper).—H. Bock. (*Rad. f. Alle*, December, 1928, pp. 541–545.)

The writer has had such good results with this form of rejector circuit that he considers it worth while to investigate it mathematically; this he does here, and then considers some of the practical difficulties; *e.g.*, the difficulty in cutting out harmonics of the local station.



The designer's specification (which the present writer confirms) gives 60 turns to the centre-tapped coil and 50 to the other, both basket-wound (in the same sense) and variably coupled. The finely-adjustable condenser is of the order of 500 cm. The usual precautions against induction into the receiver, and electrostatic action between condenser and coils, are necessary. The connection recommended is k_1 to aerial, k_2 to receiver; k_3 when connected to aerial cuts out the stopper.

EIN 3 M. EMPFANGER: FREQUENZBEREICH N = 94 BIS 111 MILLIONEN (A Receiver for 3 m. Wavelength: Frequency Range 94–111 Millions).—H. Rutenbeck. (*Rad. f. Alle*, November, 1928, pp. 508–509.)

Description with illustrations of an audion receiver with capacity-reaction, specially designed to obtain fine adjustment and smooth reaction.

THE THEORY OF PUSH-PULL: CONSIDERATION OF LOUD SPEAKER WINDINGS FOR OPTIMUM PERFORMANCE.—N. W. McLachlan. (*Wireless World*, 30th January, 1929, V. 24, pp. 114–118.)

AERIALS AND AERIAL SYSTEMS.

THE DESIGN OF TRANSMITTING AERIALS FOR BROADCASTING STATIONS.—P. P. Eckersley, T. L. Eckersley, and H. L. Kirke. (*E.W. & W.E.*, February, 1929, V. 6, pp. 86–92.)

Full illustrated abstract of the paper read before the Wireless Section, I.E.E. "The paper deals with the important technical aspect of the design of the transmitter aerial, and it is suggested that attention to this subject might help to improve broadcasting conditions in Europe generally. Difficulties of mutual interference between stations and of the limited service areas of stations indicate the need for an aerial which produces only a direct or ground ray. The indirect ray interferes with other distant stations, produces fading and bad quality in the local service area. . . ." The authors advocate the use of the highest possible aerials, to give the strongest possible horizontal radiation while diminishing upward radiation; a series of half-wave aerials one above the other, with phasing coils to reverse the phase at each join (Franklin beam aerial), would be best but could hardly be used for waves greater than about 213 m. since mechanical and economic conditions impose a limit of about 800 ft. for the height of masts; but simple half-wave aerials can be used on most [broadcast] wavelengths. If a T aerial is used, the current in the vertical part should be a maximum at the greatest possible height from the earth. Preliminary tests (using a kite balloon) to confirm the theoretical decrease of power to aerial necessary to produce a given field strength, on changing from a quarter-wave to a half-wave aerial, gave good agreement. Unfortunately, only one fading test could be carried out, and this showed less improvement as to fading than was expected. (In the discussion Amis quoted the considerable fading noticed from Germany—the home of the high aerial.) But further investigations under more suitable conditions are to be made. The paper includes sections on Effective Height ("a misleading term for loaded aerials—effective current is more definite," *i.e.*, the average value of the current in the vertical part of the aerial; metre-amperes being found by multiplying the actual height of that part by this average current), and on the Attenuation of Waves.

TRANSMITTING AERIALS.—G.W.O.H. (*E.W. & W.E.*, February, 1929, V. 6, pp. 59–61.)

An Editorial dealing first with Meissner's tests (from Germany to Buenos Aires) on the best inclination to the horizontal for a short-wave beam, and then with the Eckersleys-Kirke paper referred to above. Meissner's second series of tests, on wavelengths 15–20 m., gave signals 5 times as strong when the beam was directed horizontally along the ground as for an angle of 40 deg., and twice as strong as for 10 deg. (see Abstracts, 1928, V. 5, p. 637). This agrees with the Marconi practice of horizontal beam-direction; the apparent paradox, that such horizontal direction is advocated for broadcasting in order to confine the radiation to a limited area round the transmitter, is explained by the difference in behaviour between 15–20 m. waves and 200–600 m. waves.

DIE UNHOMOGENE BELASTETE ANTENNE (The Unevenly Loaded Aerial).—A. Witt. (*Journ. Applied Phys., Moscow*, No. 1, 1928, V. 5, pp. 3–21.)

Investigation of the oscillations of an aerial earthed at one end through an inductance: based on the theory developed by Kneser.

INCREASING TRANSMITTING ANTENNA EFFICIENCY.—S. L. Seaton. (*QST*, January, 1929, V. 13, pp. 43–44 and 68.)

Experiments to determine the best type of aerial for a receiver mounted on a truck led to the choice of the resonant wave coil, in preference to short wires, loops, etc. Such a resonant coil was then found very effective (for the space occupied) as a transmitter. Finally, such a coil was added to each end of a half-wave aerial, with good results. A comparison is made to the metal plates of a Hertz oscillator, and the final conclusion is that the addition of a concentrated structure to the ends of an antenna, of a value not exceeding 10 per cent. of the effective capacity or inductance of the antenna itself, may be expected to increase the effectiveness about 14 per cent. provided that the same potential amplitude is assumed in both cases. An end-loading-coil successfully used for a 40 m. wavelength consisted of 22 turns spaced winding of heavy copper on a 2½-inch diam. insulating frame.

BÄUME ALS ANTENNEN FÜR REISE-EMPFÄNGER (Trees as Aerials for Knapsack Receivers).—F. Zolleis. (*Rad. f. Alle*, November, 1928, pp. 522–523.)

Using a tree (non-resinous) as an aerial and its roots as an earth, a screen-grid valve in reaction-audion connection, with another as L.F. amplifier (two flash-lamp batteries providing the anode voltage), will give "distant reception" by day. Connection is made to the tree by two small gimlets penetrating about 10 cm. into the trunk.

ON THE DETERMINATION OF THE OPTIMUM RADIATION ANGLE FOR HORIZONTAL ANTENNÆ.—Meissner and Rothe. (*See* under "Transmission.")

VALVES AND THERMIONICS.

THE MEASUREMENT OF e/m WITH A THREE-ELECTRODE VALVE WITH SIMULTANEOUS MEASUREMENT OF ITS AMPLIFYING FACTOR.—D. S. Kothari. (*Indian Journ. of Phys.*, No. 4, 1928, V. 2, pp. 485–490.)

The method is a modification of Greinacher's, using a valve with cylindrical anode and grid. The lines of force of the electrical field run radially, those of the magnetic field (Helmholtz coil) axially. If a value for e/m is assumed, the amplification factor of the valve can be calculated from the curves plotted.

ALIGNMENT VALVE CHARACTERISTICS.—W. A. Barclay. (*E.W. & W.E.*, February, 1929, V. 6, p. 96.)

A letter referring to Reed's article (*ibid.*, October, 1928): the writer, an enthusiastic advocate of alignment methods, considers that Reed is unduly limiting their scope by applying them to formula-results instead of directly to the original experimental data. *Cf.* Barclay's article, *E.W. & W.E.*, May, 1927.

VALVES WE HAVE TESTED.—(*Wireless World*, 6th February, 1929, V. 24, pp. 156–158.)

Review of the Mazda Series of 4-volt valves.

A SCREEN GRID TRANSMITTING VALVE.—(*Gen. Elec. Review*, January, 1929, V. 32, p. 37.)

Illustration of a 750-watt screen grid power valve specially useful for short wave transmission. On pp. 39 and 40 there is an illustration (and short description) of a 1 kW. transmitter for 15–50 m. wavelengths, with crystal oscillator and three stages of radio amplification, using six four-electrode valves.

NEW GERMAN RECEIVING VALVES.—(*Rad. f. Alle*, December, 1928, pp. 558–560.)

A new Telefunken power valve (RE 604) is mentioned, with an emission of 200 mA. (max. anode voltage 200 v.) and a slope of 3.5 mA./volt. Filament consumption is only a third of that of the RV 218 (whose place it takes for loud speaker purposes) and it is described as "comparatively cheap." The new Te-Ka-De Valves are tabulated on p. 559, full data being given of over 20 types. These include double and triple multiple-valves, and indirect A.C. heated valves.

THE MANUFACTURE OF BARIUM OXIDE FILAMENTS.—B. Hodson, L. S. Hartley and O. S. Pratt. (*Electrician*, 8th February, 1929, V. 102, pp. 160–161.)

Extracts from a paper read before the I.E.E. The only difference between a barium filament and a barium oxide filament is found to be that the former will retain its barium hardly long enough for measurements to be taken. The authors conclude that in a barium oxide filament—*e.g.*, a platinum core coated with the oxide or with the oxide in combination as a platinate—some of the barium oxide is electrolysed and free barium is formed on the surface: the oxide being essential as a support or carrier for the barium, which would otherwise vaporise. Four ways of manufacture are described, several advantages being ascribed to the last of these—the deposition of barium vapour on an oxidised filament (*e.g.*, oxidised tungsten) in vacuo. Curves showing the variation of saturation current with life, for vapour-made filaments and paste-made filaments, show greater constancy of emission and less variation from valve to valve. No comparison, however, is shown between the vapour-made filaments and the filament made by repeated evaporation (in CO_2) of a barium salt solution into which the core wire is dipped 50–100 times. The avoidance of "hot spot" trouble, by making the emitting layer of a composite nature—by the addition of strontium or calcium oxides—and by adopting thin layers, is discussed.

METINGEN OVER DE SOORTELIJKE WARMTE VAN WOLFRAM TUSSCHEN 90 EN 2,600°. ABSOLUUT (Measurement of Specific Heat of Tungsten between 90 deg. and 2,600 deg. K.).—C. Zwikker and G. Schmidt. (*Physica*, No. 9/10, 1928, pp. 329–346.)

New measurements show that above 300 deg., C_p increases linearly with temperature; C_v increases less than linearly and does not exceed 8 cal/gr. atom degree at high temperatures.

OXIDE CATHODES.—(*German Patent*, 467,675, Huth, pub. 26th October, 1928.)

A base fusible with difficulty (tungsten and molybdenum) is mixed in powder form with an oxide or chloride of the 3rd or 9th Mendeléeff's group, and after being pressed into bars is heated up to its own melting point. Strontium or calcium oxide, barium peroxide, palladium chloride, platinum-ammonium chloride, and calcium chloride are specially mentioned.

INCANDESCENT CATHODES. — (*German Patent*, 466,462, Siemens and Halske, pub. 8th October, 1928.)

A coating of hafnium is deposited on a base with high fusing point, by the reduction of a hafnium compound (*e.g.*, hafnium oxide) with the help of an alkali metal.

ELECTRODES.—(*German Patent*, 467,467, Siemens and Halske, pub. 23rd October, 1928.)

To improve the life of strongly heated electrodes, the use of metallic hafnium for the anode is suggested.

ELECTRON EMISSION AT THE SURFACE OF PLATINUM THROUGH WHICH HYDROGEN IS PASSING.—L. T. Jones and V. Duran. (*Phys. Review*, No. 5, 1928, V. 31, p. 916.)

When hydrogen diffuses through the walls of a glowing platinum tube, an electron emission takes place at the emerging surface of the hydrogen which is greatly in excess of the platinum emission at the temperature in question, as given by Richardson. The result is further investigated.

VALVE CURRENT FROM THE MAINS: OBTAINING OPTIMUM PERFORMANCE WITH A.C. VALVES: REMARKABLE CHARACTERISTICS OF THE NEW SCREEN GRID VALVE FOR A.C. MAINS.—E. Y. Robinson. (*Wireless World*, 13th February, 1929, V. 24, pp. 180–184.)

An article based on the new Metropolitan-Vickers valves. These have a non-inductive hairpin-shaped heater coated with porcelain and enclosed in a nickel tube, which itself is coated with a mixture of barium and strontium oxides. "The constituents of the porcelain are such that at the operating temperature of the cathode it is slightly conducting, which is also a factor in preventing mains hum."

CHOOSING THE RIGHT VALVE: THE IMPORTANCE OF SELECTING THE VALVE WITH REFERENCE TO THE COMPONENT IN ITS ANODE CIRCUIT.—A. L. M. Sowerby. (*Wireless World*, 13th February, 1929, V. 24, pp. 168–172.)

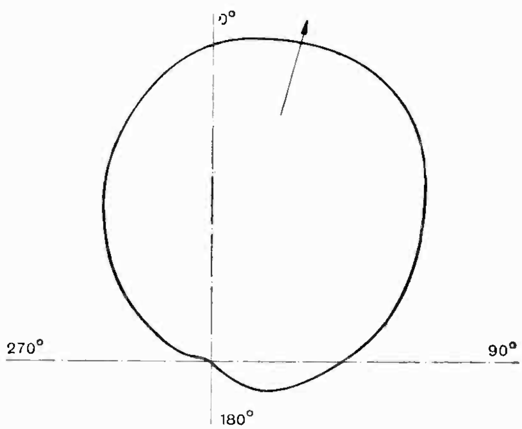
ON GROUPS OF ELECTRONS IN THE GEISSLER DISCHARGE.—K. G. Emeléus and W. L. Brown. (*Phil. Mag.*, January, 1929, V. 7, No. 41, pp. 17–31.)

"Measurements of collector characteristics have been made in the Geissler discharge from a cold cathode in argon, neon, hydrogen, and oxygen, at pressures of about 0.1 cm. Hg., for conditions not far from those at normal cathode fall of potential, from which it is concluded that there is present in the negative glow, and at the low pressures, in the Faraday dark space, a group of fast electrons with a distribution of velocities that is approximately Maxwellian, and an average energy of the order of 25 electron-volts. It is suggested that they are produced initially by electrons passing into the negative glow from the cathode dark space, and that they are maintained by a process which is the reverse of ionisation by collision. A possible effect of the Ramsauer minimum of the free paths of electrons is pointed out, in the persistence of two groups of slow electrons in the discharge."

DIRECTIONAL WIRELESS.

UNIDIRECTIONAL RADIOBEACON FOR AIRCRAFT.—E. Z. Stowell. (*Bur. of Stds. Journ. of Res.*, December, 1928, V. 1, pp. 1011–1022.)

During the development by the Bureau of a directive beacon for guiding aircraft (Abstracts, 1928, V. 5, pp. 463, 466, 521, 582) it appeared that its usefulness could be increased by making the radiated field unidirectional. This paper describes the gradual evolution of an arrangement giving a polar characteristic which is, it is believed, "about



the optimum for aircraft use." Starting with a modified Bellini-Tosi loops-and-vertical wire system, the vertical wire was replaced by using the loops (closed at the top) as the non-directive aerial, by earthing (through a variometer) their common mid-point. The disappointing result was found to be due to the transfer of power to the non-directive circuit being chiefly capacitively through the transformer; so that instead of the non-directive field being in phase with the directive, it was nearly 90 deg. ahead. A delay circuit improved the diagram but not enough, back radiation still being excessive. Finally, the power for the non-directive field was obtained from an auxiliary goniometer whose primary windings (at 90 deg.) were in series with the primaries of the direction-controlling goniometer; both goniometers were wound so as to minimise capacity transfer between windings. The phase of the non-directive field was controllable by the variometer, and its amplitude by change of the primary turns of the goniometer. By independent adjustment of these two factors, the best result was attained; this was with the non-directive field 55 deg. ahead of the directive field.

In the figure, the arrow represents the angular position of the centre of the equi-signal zone. There is only one radiated course and this occurs practically at the maximum of the field. The diagrams resulting from the non-directive field being 55 deg. behind the directive, or at some intermediate value, are inferior in various ways.

Design of Tuned Reed Course Indicators for Aircraft Radiobeacon.—F. W. Dunmore. (*Bur. of Stds. Jours. of Res.*, November, 1928, V. 1, pp. 751–769.)

This paper describes the development of the reed indicators mentioned in Abstracts 1928, V. 5, p. 582, with special reference to the choice of the modulation frequencies. The frequencies finally adopted were 60 and 85 p.p.s., which were found very satisfactory both from the beacon point of view and from that of the tuned reed operation. The type *F* indicator finally evolved uses polarised, rear-drive reeds. The polarisation (by permanent magnets) greatly increases the sensitivity: it was made possible by constructing the reeds of steel, instead of the temperature-constant but non-magnetic elinvar, and arranging for automatic temperature compensation by a small bi-metallic strip soldered to the free end of the reed. As the temperature increases this strip bends towards the fixed end of the reed and compensates for the change in Young's modulus. Used with a 6-valve receiving set in the tail of the aeroplane, these indicators work well even when ignition interference makes aural reception almost impossible. Their note selectivity also prevents them from being interfered with by other stations, such as the marine beacons, which work on 1,000 p.p.s. modulation.

Abhängigkeit der Funkbeschickung von Meteorologischen Einflüssen (The Dependence of Wireless Transmission on Meteorological Influences).—P. Duckert. (*Mitteil. Aeron. Obs. Lindenberg*, May, 1928, pp. 154–160.)

More of the author's work on this correlation (*cf.* Abstracts, 1929, V. 6, p. 106). On his D-F results at Nordholz, Borkum and List, he points out that within any one weather-period the bearings vary from the mean value for that period only by a small amount of the order of the observation-error of the apparatus. He suggests that the accuracy of D-F would be increased by a plotting of the results for each main type of weather.

Determination of the Inclination of Aircraft.—(*German Patent*, 465,502, Dieckmann and Hell, pub. 21st September, 1928.)

The voltage induced in a dipole by a distant station is proportional to the dipole length multiplied by the sine of the dip-angle between dipole and the horizontal plane. This fact is here applied to aircraft. Two dipoles can be fitted, one longitudinally and one transversely.

ACOUSTICS AND AUDIO-FREQUENCIES.

Acoustic Photographs by the Shock Test and Tone Test.—J. Zenneck. (*Proc. Inst. Rad. Eng.*, January, 1929, V. 17, pp. 107–112; being part of a Paper entitled, "The Importance of Radiotelegraphy in Science.")

The shock test is carried out by a shot from a small 22-calibre pistol, the time curve of the air pressure at some point in the room being registered by means of a Reiss microphone, a multi-stage amplifier with resistance-capacity coupling, and a Siemens oscillograph. This method has the power—owing perhaps to the directive property of the pistol shot—to place with great exactness that portion of a room in which a reflection takes place and which may be the source of a disturbing echo. It is so reliable that, in a case mentioned, results conflicting with the official plan of the auditorium under test led to the discovery that this plan was incorrect. The tone test uses an audio-frequency valve generator and loud speaker, in conjunction with a rotary interrupter: the time curve here also being oscillographed. The two tests work in together: the tone test gives a picture of the result, and the shock test investigates the sources.

Pressure Distribution in a Fluid due to the Axial Vibration of a Rigid Disc.—N. W. McLachlan. (*Proc. Roy. Soc.*, 4th February, 1929, V. 122 A, pp. 604–609.)

There is a distinct change in the quality of reproduced music according as one stands in front of, or at the side of, a loud speaker. This is due to non-uniform pressure distribution from the diaphragm at various frequencies. When the wavelength of sound is comparable with the radius of the diaphragm there is a focusing effect. This occurs at the higher audio-frequencies and upsets the tonal balance unless the listener is situated on the axial line of the diaphragm. The writer examines analytically the pressure distribution in the space surrounding a flat rigid disc vibrating in a plane of infinite extent, so that there is no interference between the waves emitted by the two sides of the disc. He then gives polar curves of pressure distribution of discs 5 and 10 cm. in diameter at frequencies corresponding to the pianoforte middle (256 p.p.s.; polar curve a semi-circle in both cases) and top (4,096 p.p.s.; polar curve for 10 cm. disc is only about half the width of that for 5 cm. disc, and in area is only about one-ninth of the semi-circle). For uniform pressure distribution over a hemispherical surface, the disc ought to approximate to a point source, though this is impracticable owing to limitations imposed by the driving agent and due to the relatively large amplitudes required to radiate the lower frequencies.

Sound Measurements and Loud Speaker Characteristics.—I. Wolff. (*Proc. Inst. Rad. Eng.*, December, 1928, V. 16, pp. 1729–1741.)

Author's summary : " A brief description of the method used to measure loud-speaker response is given. The Rayleigh disc and condenser microphone are compared as sound detectors. A number of loud-speaker sound pressure response curves are shown, and interpreted in terms of pleasantness of reproduction, as determined by low- and high-frequency cut-off, smoothness of response, and tone balance. Tube overloading and the effect of loud-speaker response on its apparent accentuation or diminution is discussed. The effect of room absorption characteristics, room resonances, position of the loud speaker in the room, and position of the listener with respect to loud speaker on loud-speaker reproduction is explained by means of diagrams and loud-speaker response curves."

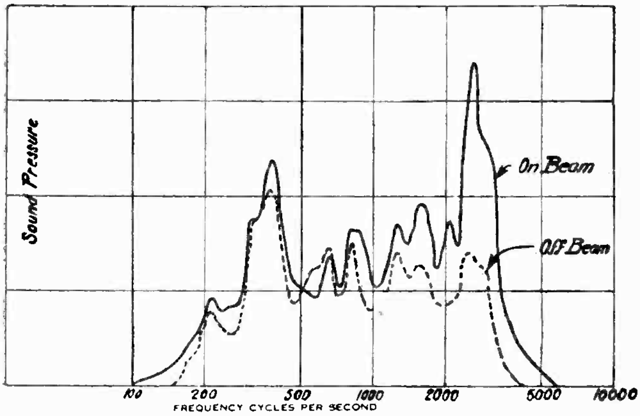


Fig. 1.

Fig. 1 illustrates the effect on the higher frequencies of listening directly in front of the loud speaker. Fig. 2 gives one particular example of cavity resonance (*e.g.*, loud speaker placed in a corner of a room), the effect of which may be pleasing or otherwise, according as the resonance is or is not of such a frequency as to supply a region which is lacking.

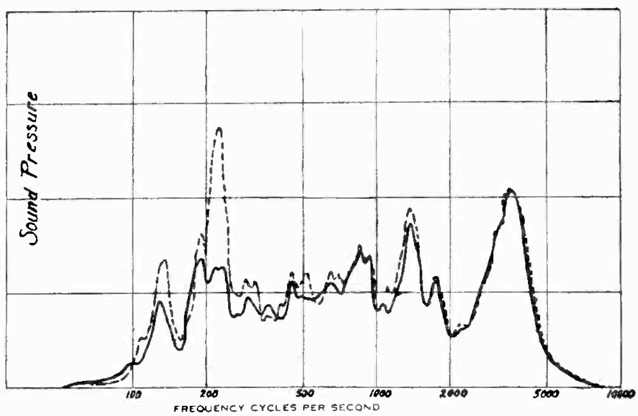


Fig. 2.

An Apparatus for the Projection of Frequency-Output Characteristics.—C. G. Garton and G. S. Lucas. (*E.W. & W.E.* February, 1929, V. 6, pp. 62–70.)

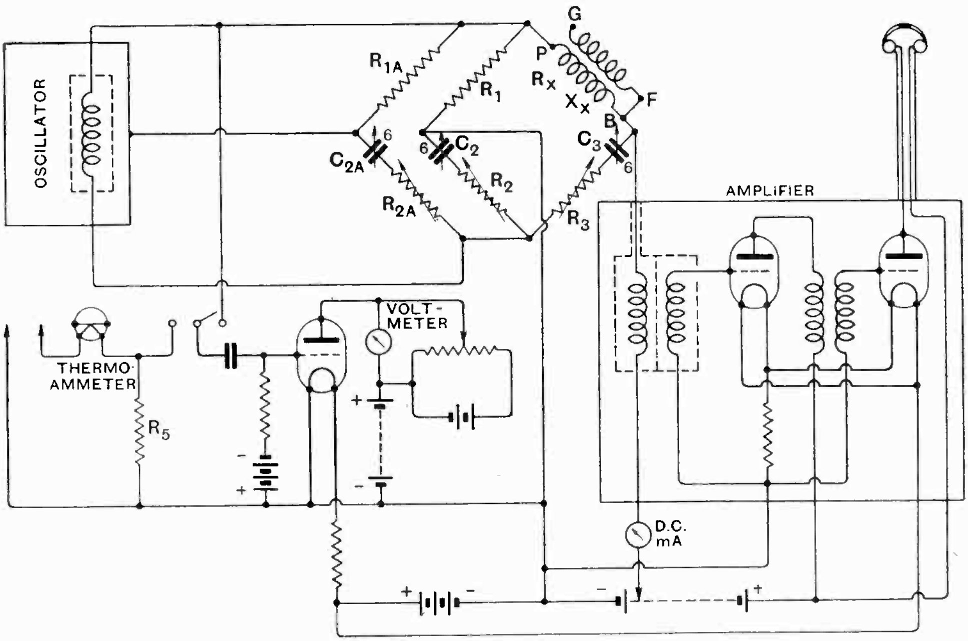
The curve connecting the frequency of input power and the amplitude of the resultant output (for amplifiers, intervalve transformers, loud speakers, etc.) is thrown on a screen ; a rapid non-permanent indication is thus obtained, making it possible for the experimenter to see quickly the results of any change made in the apparatus under investigation. The basic idea of the apparatus is the same as that of Cohen, Aldridge and West (*Journ. I.E.E.*, October, 1926), but the latter method was photographic only. In the present apparatus the horizontal frequency scale is given by reflection of the galvanometer beam at a mirror (rotating about a vertical axis) mechanically coupled to the frequency-changing condenser. No rectification of the output is necessary owing to the use of a special form of hot wire galvanometer, a fine tungsten filament controlling the rotation (about a horizontal axis) of a small galvanometer mirror, and thus providing the vertical "output" scale. The constant-voltage generator of variable frequency is a heterodyne combination, a special filter circuit being used to keep out the unwanted radio-frequency components. For obtaining loud-speaker characteristics, a calibrated condenser microphone is employed, with a linear characteristic amplifier (resistance-capacity) using a screen-grid valve in the first stage. " Although the use of this type of valve for audio-frequency amplification is not yet common, very satisfactory results are obtainable where a high voltage amplification is desired, and when adequate plate voltage is available. With the values given . . . a 'step-up' of about 50 to 1 on the first stage is obtained." Details are given of the apparatus and methods, which were developed at the B.T.H. laboratories and were demonstrated at the recent Physical Society's Exhibition in London.

THE DESIGN OF TRANSFORMERS FOR AUDIO-FREQUENCY AMPLIFIERS WITH PRE-ASSIGNED CHARACTERISTICS.—G. Koehler. (*Proc. Inst. Rad. Eng.*, December, 1928, V. 16, pp. 1742–1770.)

Author's summary: "The requirements of an ideal transformer are stated, and the difficulties encountered in attempting to build transformers for interstage coupling units which will meet these requirements are pointed out. The aim in design for audio amplifiers is stated to be a reasonable voltage amplification for one tube and one transformer which is independent of the frequency over a range necessary for broadcast reception.

"The equivalent A.C. circuit for some types of transformers with tube source and tube load is set up and solved. The impedance and voltage amplification characteristics are explained from the solution of the equivalent circuit. Expressions for calculating the constants of the transformer are given. A study of the design relations and voltage amplification characteristics reveals difficulties which are encountered in design and some methods for overcoming these difficulties. The effect of the continuous flux in the core of the transformer is illustrated and a scheme is given for balancing out the continuous flux.

"A rather universal type of bridge for making the necessary impedance measurements in connection with transformer studies is shown. This bridge is adapted to measuring iron core coils, which carry both alternating and continuous currents, when either inductive or capacitative reactive." See diagram: the scheme has been so worked out that the bridge can be balanced without disturbing the D.C. through the transformer. The D.C. is measured by means of an ammeter in the balance indicator circuit. The A.C. voltage across the transformer is measured by a detector voltmeter across the bridge arm which is adjacent to the transformer. This voltmeter should not be left on when the final balance is made. The purpose of the auxiliary, or guard, arm is to bring the oscillator shield to the same potential as the amplifier shield and detector voltmeter. It must, to be effective, be balanced at the same time that the main bridge is balanced: roughly by making the values of its components equal to the corresponding values in the main bridge, or more accurately by actual balancing if greater precision is needed. *Cf.* Landon, under "Measurements and Standards."



ÜBER DIE WIRKUNGSWEISE DES KATHODOPHONS (The Method of Action of the Kathodophone).—E. Meyer. (*E.N.T.*, January, 1929, V. 6, pp. 17–21.)

The kathodophon is used in one system of talking films and has also been employed as pick-up transmitter in German broadcasting. A hot cathode (oxide coated, heated internally by a platinum spiral) is fixed close to a perforated anode, which forms the small end of a mouthpiece or horn. The direction of flow of current from cathode to anode corresponds with the direction of the sound: how exactly the latter affects the ionised gap is not yet understood, but it causes current fluctuations which are led through a high ohmic resistance to an amplifier. The present paper describes an investigation into the behaviour of a simpler form of apparatus working on the same lines. Results show that the action is a motion-effect, the resulting

E.M.F. being proportional to the elongation (of path ?) of the air particles : the effect is greatest at a velocity antinode of a stationary wave, but even here it depends on sound wave and ion directions agreeing.

THE USE OF THE ELECTRET IN A CONDENSER TRANSMITTER.—S. Nishikawa and D. Nukiyama. (*Proc. Imp. Acad. Tokyo*, No. 6, 1928, V. 4, pp. 290–291.)

Euguchi's electret is here used for maintaining the electrical field of a condenser microphone or telephone. In conjunction with a three-cascade amplifier, a better result was obtained than that given by a condenser microphone with battery.

DAS "RADIOPHON" (The Radiophon).—G. Eichhorn. (*Zeitschr. f. Hochf. Tech.*, January, 1929, V. 33, pp. 30–33.)

A new way of communicating to the auditory centre the output currents of a valve receiver, chiefly to enable deaf people to hear broadcast programmes. The instrument comprises a handle with a contact putting the listener's body in connection with one of the amplifier output terminals, and a diaphragm made of some semi-conductor (cellophane appears to be one of the best) which is metallised on one side—the side away from the listener. This metal film is connected to the second amplifier output terminal, and the non-metallised side of the diaphragm is pressed against the ear or some part of the head near the organs of hearing. A high resistance (about 100,000 ohms) contained in the handle is shunted across the two electrodes (the handle contact and the metallised diaphragm) and allows the D.C. component of the output current to pass. The D.C. voltage has an important action in the process : if the A.C. voltage is small, the optimum D.C. voltage is about 120–150 v. ; if the A.C. voltage is larger, the D.C. voltage can be decreased considerably. A deaf person whose tympanum does not function can hear well with this apparatus, provided that his central organ is intact ; the condenser action between metallised diaphragm and skin conveys the vibrations direct to the hearing organs. Quality is extraordinarily good.

PHOTOTELEGRAPHY AND TELEVISION.

A PHONIC MOTOR AND SLAVE FORK AND AN ELECTRICALLY MAINTAINED TUNING FORK WITH A CALIBRATED SPEED ADJUSTMENT.—D. C. Gall. *See under* "Measurements and Standards."

MEASUREMENTS AND STANDARDS.

MAGNETOSTRICTION OSCILLATORS.—G. W. Pierce. (*Proc. Inst. Rad. Eng.*, January, 1929, V. 17, pp. 42–88.)

This is the original paper (read before the Am. Acad. of Arts and Sciences) referred to in Abstracts, 1928, V. 5, p. 643. Among other interesting points may be mentioned the following : (1) The electrical feedback between grid coil and plate coil is the reverse of that usually employed in producing electrical oscillations : but with certain values of circuit constants the circuit will oscillate with the rod restrained from vibrating. When working on low frequencies (500–3,000 p.p.s.) it is preferable to work with the circuit in a non-oscillatory state : at higher frequencies (3,000–300,000 p.p.s.) it is more convenient and just as reliable to allow the system to be oscillatory even when the rod is restrained, and to employ the magnetostrictive rod merely to stabilise an already existing frequency ; (2) pure iron and irons with various carbon contents have too small a magnetostrictive effect : pure nickel is a good vibrator with some lack of stabilising power in that detuning slightly affects the frequency ; alloys of the two are good vibrators but have a large temperature coefficient of frequency ; alloys of chromium, nickel and iron are good, commercial Nichrome being one of the best practical materials. But, generally, in combinations of three metals a vanishing temperature coefficient is usually associated with non-magnetism or non-magnetostriction. Monel metal is a very powerful oscillator which has too small a residual magnetism to oscillate without an auxiliary polarising means (a small permanent magnet nearby is sufficient). Alloys of cobalt and iron are strong vibrators. By combining a tube of material with a negative temperature coefficient of frequency and a tight-fitting core of metal with a positive coefficient (*e.g.*, nickel tube with stoic metal core) a vibrator practically independent of temperature can be obtained. But even a simple Nichrome vibrator has a temperature coefficient of only −0.00107/deg. C. ; (3) the author's curves, for alloys of various percentage compositions, of velocity of sound and of temperature coefficient of frequency of vibration suggest as a possible law that in a binary alloy the temperature coefficient of frequency is a maximum or minimum at the composition at which the velocity is a maximum or minimum *or the reverse* ; (4) all vibrators are improved by annealing ; (5) changes of plate voltage from 135 to 67 v. changes the frequency of the system (annealed Nichrome vibrator) by only 1 in 30,000.

An Elementary Theory of Dynamic Magnetostriction is given, while an appendix gives the more exact treatment including the Theory of the Propagation of Sound in a Viscous Magnetostrictive Medium. A short section deals with the magnetostrictive production of sound and ultrasound, and another with the production of high-frequency stabilisation (best method probably the beaded rod, an example of which showed strong stabilisation of frequency 295,480 p.p.s.).

THE PIEZO-ELECTRIC CRYSTAL OSCILLATOR.—J. W. Wright. (*Proc. Inst. Rad. Eng.*, January 1929, V. 17, pp. 127–142.)

The original MSS. was submitted in April, 1928. The writer says that there are several very good articles on the piezo-electric crystal resonator, but that little information has been made available, for general use, concerning the operation and theory of the piezo-electric crystal oscillator. In this article he examines just what takes place when a zero-angle crystal is put in a typical oscillating crystal circuit. The crystal is first considered as a simple mechanical oscillator, and the required plate circuit adjustment for sustained vibrations of the crystal is obtained by Miller's method, on the basis of an assumed electrically equivalent crystal circuit. The electrical equivalent of the crystal is then considered as the grid circuit of an oscillating valve circuit, and the equations for the frequency and condition for oscillation derived. The effects of the valve and of the circuit upon the frequency of a crystal-controlled oscillator are then shown. The former effect is evidenced by different frequencies given by the same crystal when controlling different types of valve: this is believed to be due to the difference in input capacity, and could be predicted from some of the equations arrived at earlier in the paper. It is mentioned finally that a crystal can be used to control the output frequency of an oscillator of the "relaxation" type, so that crystal-controlled oscillations which are subharmonics of the fundamental crystal frequency can be obtained.

VISUAL OBSERVATION OF PIEZO-ELECTRICAL OSCILLATIONS.—(*German Patent*, 467,629, Radiofrequenz, pub. 26th October, 1928.)

By suitable adjustment of the gap between upper electrode and crystal, optical phenomena render the oscillations visible. Observation is improved by enclosing in a more or less evacuated glass vessel.

PIEZO-ELECTRIC CRYSTAL PREPARATION.—(*German Patent*, 467,594, Telefunken, pub. 26th October, 1928.)

A crystal cut from a mother-crystal is sometimes imperfect because some silicon molecules remain sticking to the surfaces. It is here specified that the piezo-crystal should be washed with hydrofluoric acid.

PROTECTION AGAINST OVERLOADING A PIEZO-CRYSTAL.—(*German Patent*, 466,765, Telefunken, pub. 11th October, 1928.)

The use of a limiting tube (glow discharge ?) is specified, to protect the crystal from too violent oscillations.

AN AUXILIARY FREQUENCY CONTROL FOR R.F. OSCILLATORS.—G. F. Lampkin. (*Proc. Inst. Rad. Eng.*, January, 1929, V. 17, pp. 115–117.)

The usual oscillator employs a variable condenser as a means of covering the frequency range. For greater precision, a small semi-circular plate condenser is often used in parallel as a vernier control. But even so, the value of cycle change per vernier-dial division will vary widely over the oscillator range, owing to the shape of the frequency-capacity curve. In the arrangement here suggested, the auxiliary (vernier) control operates on the element of the circuit which is *fixed*: *i.e.*, in the above case, the auxiliary control would be a variometer; while if the main control were a variometer and the condenser were a fixed one, the auxiliary control would be a small variable condenser. The frequency-change calibrations of the auxiliary control, for various settings of the main control, then become straight lines: the ratio of the slopes of these lines at 1,400 kc. and 625 kc. (in the example taken) is only about 2. Thus the value of cycles change per division of auxiliary control can be determined for each main control setting, and the resulting curve plotted and used. If the auxiliary control were made a small variometer, and the main control a straight-line-frequency condenser, the calibrations of both the main and auxiliary controls would be linear.

A DIRECT READING RADIO-FREQUENCY METER.—R. C. Hitchcock. (*Proc. Inst. Rad. Eng.*, January, 1929, V. 17, pp. 24–34.)

A well-made tuned-circuit absorption type of wavemeter with a single variable condenser is reliable to about 2.5 kc. per sec. in the present (U.S.A.) broadcast band. The Bureau of Standards type, in which a small variable condenser shunted the large main fixed one, the coils being adjusted so that the waves to be measured came near the middle of the variable condenser, gave an increased accuracy. Recently an American firm has brought out an instrument which is guaranteed for six months to give a precision of 500 cycles p.s. when kept within ±5 deg. F. of the calibration temperature. The instrument here described is of another type—measuring the beat note produced with a calibrated crystal oscillator—and its scale divisions are 0.1 kc. apart, the accuracy (under reasonable conditions) being of this order. A new type of direct-reading audio-frequency meter having a useful scale of 2.0 to 4.5 kc. per sec., makes the device automatic. Like others of the beat-note type, it has the advantage that it can be operated at some distance from the radio source—several miles, if suitable audio amplification is provided. In cases where the circuit to be checked is liable to vary so much that it might give the correct beat note on the wrong side of the zero point, two standard crystal circuits are used, of slightly different frequency (either one above and one below the standard, or both on the same side), the combined behaviour indicating clearly on which side of zero beat the beat note lies. Warning devices can be operated by the note-frequency meter, through a grid-glow relay. As an indicating device a parallel resonant circuit loosely coupled to a milliammeter circuit can be used in place of the note-frequency meter. The special form of the latter instrument, referred to throughout the paper, is only described as of the tuned circuit type, with a useful scale spread over an arc of 90 deg.

L'ÉTALONNEMENT DES DIAPASONS SERVANT DE BASE AUX MESURES DES FRÉQUENCES RADIOTÉLÉGRAPHIQUES (The Calibration of Tuning Forks used for Radiotelegraphic Frequency Measurements).—B. Decaux. (*Comptes Rendus*, 21st January, 1929, V. 188, 316–317.)

Describes the frequency determination of an electrically driven fork by measuring a submultiple frequency (about 1/35); using Van der Pol's discovery (that relaxation oscillations can be synchronised by a frequency higher than their natural frequency) to obtain this demultiplication. An A.C. of the fork's frequency was obtained by a microphone (not by using the driving current, as such use is liable to introduce complications) and after amplification was applied, in the form of a small P.D. at the terminals of a transformer, to the feed circuit of a neon tube. The capacity across the tube was varied till the frequency of the relaxation oscillations was near that of a submultiple of the fork frequency: synchronisation then took place. (This was confirmed by examination of the Lissajous figures produced in a cathode ray oscillograph, which also enabled the order of the submultiple to be determined if this could not be deduced by a knowledge of the approximate frequency of the fork.) The synchronised neon tube oscillations were registered and compared with the record of a wireless-controlled chronometer. The measurement was taken over a period of 5 minutes, and the accuracy was found to be 3 in 100,000.

VIBRATIONSRELAIS UND PHONISCHES RAD MIT UNTERBRECHER (Vibration Relay and Phonic Wheel with Interrupter.)—R. Skancke. (*Zeitschr. f. Instrkde*, No. 9, 1928, V. 48, pp. 432–438.)

In a paper on the Maxwell-Thomson method of absolute capacity measurement, the writer describes two pieces of apparatus which he has designed and used in place of the usually employed (and much more costly and complicated) rotating commutator and governor of Giebe.

AN ELECTRICALLY MAINTAINED TUNING FORK WITH A CALIBRATED SPEED ADJUSTMENT.—D. C. Gall. (*Journ. Scient. Instr.*, January, 1929, V. 6, pp. 18–19.)

A calibrated frequency scale reading from 48.5 to 51.5 cycles is provided upon the fork: an accuracy of setting of 0.1 per cent. can be relied on. The balance and damping is not affected by such adjustment, owing to the form of construction: an auxiliary fork, of much lighter construction, having the same length of limb but a much longer natural period, is coupled to the main fork only at the centre of the bobs; the two forks vibrate in unison, the frequency of the main fork being modified by the additional weight of the auxiliary bobs. The auxiliary fork is moved backwards and forwards by a screw adjustment, and this alters the centre of gravity of the weights and varies the frequency of the combination. The scale can be calibrated in temperature if it is desired to provide compensation for such change.

A PHONIC MOTOR AND SLAVE FORK.—D. C. Gall, (*Journ. Scient. Instr.*, January, 1929, V. 6, pp. 19–21.)

Description and curves of a Tinsley phonic motor: output available on shaft is about 10 W. with the best D.C. supply voltage 20 v., for fork speeds 20–50 cycles. It will run on voltages down to 5 v., but with decreased output. Large tungsten contacts are needed on the fork, easily renewed by the user. To prevent such a renewal from changing the frequency, a slave fork is used with a special adjustment to balance the limbs after re-setting the contacts: this slave fork is controlled by a standard fork with small contacts.

A BRIDGE CIRCUIT FOR MEASURING THE INDUCTANCE OF COILS WHILE PASSING DIRECT CURRENT.—V. D. Landon. (*Proc. Inst. Rad. Eng.*, December, 1928, V. 16, pp. 1771–1775.)

A bridge circuit is described in which the inductance of an iron core coil carrying D.C. is compared with resistances and a capacitance. In this way the trouble encountered in obtaining a satisfactory standard inductance is avoided. The voltage drop across the inductance is balanced against the drop across a resistance. The phase is corrected by the impedances in the other two legs. By reversing the positions of R_1 and the unknown, the bridge becomes the conventional one for measuring an impedance having resistance and capacity components. The paper concludes by comparing the bridge with those of Maxwell and Anderson. The writer considers the advantages of the Anderson bridge over the Maxwell to be very dubious, and prefers his own circuit which eliminates the divided D.C. path.

THERMO-COUPLE MILLIAMMETER AND AMMETER.—(*Journ. Scient. Instr.*, January, 1928, V. 6, p. 22.)

A Ferranti instrument primarily for radio frequencies, in moulded insulating case. Lowest range is to 25 mA. (also used for voltmeters), upper range to 5 A., all in the 2½-inch diameter size, with 2½-inch scale. The couples are insulated from the heater, so that there is no capacitance effect of the movement to earth and no reversal error on D.C. Consumption for the 25 mA. is about 20 mW. Successfully used on a 3-metre wavelength, but equally suited to commercial A.C. frequencies or D.C. Temperature compensation less than 0.1 per cent. per deg. C.

RECTIFIER VOLTMETERS, ETC.—(*Journ. Scient. Instr.*, January, 1929, V. 6, p. 23.)

Standard Ferranti 2½-inch radio-instrument movements combined with Westinghouse Copper-oxide rectifiers to produce A.C. instruments having high torque (equal to that of moving-coil instruments), efficient damping, very small current consumption which is constant for all ranges (unlike other A.C. voltmeters), and improved scale shape. Correct on all power-supply frequencies and wave-forms, not on peaked or other distorted wave-forms. Temperature error very small.

MEASUREMENT OF VERY SMALL D.C. CURRENTS.—J. Zenneck. (*Proc. Inst. Rad. Eng.*, January, 1929, V. 17, p. 102.)

In his paper on "the Importance of Radiotelegraphy in Science," the author mentions that in the photometry of stars by means of the photoelectric cell, direct currents of the order of 10^{-14}A have to be dealt with. According to Rosenberg it is possible, without appreciably affecting proportionality between light intensity and current, to amplify these currents about 100,000 times so as to measure them by a moving-coil galvanometer.

ELEKTRONENZÄHLROHR ZUR MESSUNG SCHWÄCHSTER AKTIVITÄTEN (Electron Counter for the Measurement of Very Small Energies).—H. Geiger and W. Müller. (*Naturwissen.*, No. 31, 1928, V. 16, pp. 617–618.)

A device of astonishing sensitivity which when unshielded in a room will register hundreds of deflections per minute from cosmic radiations, radiations from the walls, etc. Shielded by iron 25 cm. thick, it indicates about 50 impulses per minute. It consists of a thin wire stretched axially inside a metal tube. A voltage between tube and wire is prevented from causing a spark by a thin, very uniform insulating skin covering the wire. The arrival of an electron ray causes an ionisation current, which breaks off owing to the charging up of the skin. Each individual impulse is made evident on a string electrometer.

EXPERIMENTAL METHODS FOR DETERMINING THE DISTRIBUTION OF ELECTRIC AND MAGNETIC FIELDS.—B. Hague. (*Electrician*, 15th February, 1929, V. 102, pp. 185–187.)

"Problems demanding new methods of calculation; scope of mathematical methods; the graphical process; use of the magnetic potentiometer; the electrostatic probe." The magnetic potentiometer consists of a flexible non-magnetic core wound uniformly and closely with a coil of fine wire connected to a ballistic galvanometer; one end of the coil is kept fixed and the other moved suddenly from one point to another, the throw of the galvanometer being proportional to the difference of magnetic potential at the two points. The electrostatic probe depends on a telephone null method using a potentiometer. Du Bois' use of the iron filings method as a guide or check in accurate work (*e.g.*, on magnetic shielding), and the analogous fine powder method for electric fields, are discussed; the latter has been used successfully by Deutsch for investigating the field in three-core cables. The paper is to be continued.

ENREGISTREMENT PHOTOGRAPHIQUE D'UNE VITESSE ANGULAIRE. APPLICATION AUX MESURES BALISTIQUES (Photographic Recording of an Angular Velocity: Application to Ballistic Measurements).—A. Guillet. (*Comptes Rendus*, 14th January, 1929, V. 188, pp. 240–242.)

In a ballistic galvanometer, the source of light, instead of illuminating the slit continuously, illuminates it for very short periods at a frequency N. This is done by the use of a tuning fork, of frequency $N/2$, each of whose prongs carries a disc pierced at the centre with a very small hole, these holes being opposite when the fork is at rest. On development of the photographic film, a succession of points at intervals s measure the displacement of the spot during equal intervals $\frac{1}{N}$: the angular velocities of the moving systems are given by $\omega = \frac{sN}{2R}$ where R is the radius of the optical system. The film carrier can be moved by a micrometer adjustment, so that the same film can take a large number of measurements, either of ω (with the tuning fork in action) or of θ (tuning fork at rest).

USEFUL DATA CHARTS (No. 21). RATIO OF H.F. RESISTANCE TO D.C. RESISTANCE OF A COIL.—(*Wireless World*, 30th January, 1929, V. 24, pp. 120–122.)

One section of the text shows the effect of winding the same coil with different types of wire (solid, 9-strand Litz and 27-strand Litz). For coils for short waves, where Litz stranding is worse than useless, S. Ward's proposal is mentioned—to split up the solid wire into a series of adjoining strands connected in parallel and wound on like tape; thus giving a truly single-layer winding with uniform spacing.

METHODS FOR THE DERIVATION AND EXPANSION OF FORMULAS FOR THE MUTUAL INDUCTANCE OF COAXIAL CIRCLES AND FOR THE INDUCTANCE OF SINGLE-LAYER SOLENOIDS.—F. W. Grover. (*Bur. of Stds. Journ. of Res.*, October, 1928, V. 1, pp. 487–511.)

A paper giving a classification of existing inductance formulæ for the general cases mentioned. A number of new ones are developed which can be used to advantage in certain cases. It is shown by examples that in any given case the inductance can be calculated by more than one formula and to a precision far beyond practical requirements. A long bibliography is added.

ALTERNATING CURRENT BRIDGE METHODS: THEIR APPLICATION TO ELECTRICAL ENGINEERING PROBLEMS, WITH SPECIAL REFERENCE TO THE TESTING OF SYNCHRONOUS CONDENSERS. PART I.—R. G. Churcher. (*Electrician*, 9th November, 1928, V. 101, pp. 518–520.)

MISURA DELLE CORRENTI AD ALTA FREQUENZA CON METODO FOTOMETRICO (H.F. Current Measurement by a Photometric Method).—G. Pession and T. Gorio. (*L'Elettrotec.*, 25th November, 1928, V. 15, pp. 870–872.)

A tungsten filament is heated to incandescence by the current to be measured, and its radiation measured by a photoelectric cell and suitable adjuncts.

DEMONSTRATION STATISCHER HOCHSPANNUNGSVOLTMETER (Demonstration of a Static H.T. Voltmeter).—H. Starke. (*Vortragshandbuch* 90 Versamm. d. Ges. Deut. Nat. forsch., Hamburg, September, 1928.)

The electric field between two high-tension electrodes exerts a rotating effect on a small vane attached to a stretched thread; in its zero position the vane rests in a small slit in the one electrode, and is so small that the field distortion arising from its rotation extends only to its immediate neighbourhood. As a result the calibration is the same for all the electrode gaps used: *i.e.*, the scale remains the same for a number of ranges, and once calibrated on a low range (*e.g.*, 3–10 kV.) is correct for all the ranges up to the limit of insulation. Deflection is aperiodic, in 1.5 second.

AN ABSOLUTE CURRENT-BALANCE HAVING A SIMPLE APPROXIMATE THEORY.—L. F. Richardson and V. Stanyon. (*Proc. Physical Soc.*, 15th December, 1928, V. 41, pp. 36–42.)

The simplification of the theory is attained by making the length of the coils five or six times their diameter, instead of using narrow rings (Rayleigh and Mrs. Sidgwick) or coils having a length about 0.65 of their diameter (N. P. L., 1907).

A NEW MICROAMMETER. (*Journ. Sci. Inst.*, December, 1928, V. 5, p. 387.)

Brief description and illustration of a new Ferranti instrument serving as a portable quick-acting galvanometer for null tests, and as a calibrated microammeter (250–0–250, 10 microamperes per division: resistance 60–70 ohms).

A NEW ALTERNATING CURRENT POTENTIOMETER OF LARSEN TYPE.—A. Campbell. (*Proc. Physical Soc.*, 15th December, 1928, V. 41, Part I, pp. 94–99.)

The main object of the new system is to make the instrument read the in-phase and quadrature components of the unknown voltage *directly*. As emerges from the subsequent discussion, the new instrument should be specially useful for acoustical work in which the distribution, reflection, etc., of sound is measured by microphones, the source of sound being a loud speaker actuated by A.C. of pure wave-form. The instrument requires no phase-splitting device and uses a very small amount of power. It is particularly useful for the accurate measurement of very small voltages and current (*e.g.*, a few microamperes), for in both cases the scale does not follow the square law but gives direct proportionality, which is an enormous gain at the low readings.

A DEVICE FOR ACCURATE TIMING.—H. L. Johnston. (*Journ. Opt. Soc. Am.*, November, 1928, V. 17, pp. 381–385.)

In the particular case, astronomical time signals at second intervals were used to operate a circuit once per minute. The device includes a pawl-and-sprocket drive as used in a pedometer. The whole was calibrated on the Cornish-Eastman method (*Journ. Am. Chem. Soc.*, p. 627, 1928) by comparing a four-minute interval controlled by the device with the number of oscillations of a high frequency oscillating circuit of constant frequency: it was found to possess "an accuracy of better than 3×10^{-3} sec. for any integral number of minutes."

DIE BESTIMMUNG DER DURCHSCHLAGFESTIGKEIT VON FESTEN STOFFEN IN HOMOGENEN FELDE (Determination of Dielectric Strength of Solid Materials in Homogeneous Fields).—E. Marx. (*E.T.Z.*, 10th January, 1929, pp. 41–44.)

Methods and results of the latest measurements, taken with specially designed electrodes and test-samples, under a suitable liquid.

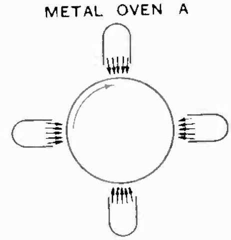
DIE BESTIMMUNG DER LICHTGESCHWINDIGKEIT UNTER VERWENDUNG DES ELEKTROOPTISCHEN KERR-EFFEKTES (Measuring the Velocity of Light by the Electro-optical Kerr Effect).—A. Karolus and O. Mittelstaedt. (*Physik. Zeitschr.*, 1st October, 1928, pp. 698–702.)

A BRIDGE FOR MEASURING AUDIO-FREQUENCY TRANSFORMERS, ETC.—G. Koehler. (*See under* "Acoustics and Audio-frequencies.")

SUBSIDIARY APPARATUS AND MATERIALS.

DER WEG ZUM FARAD (The Achievement of Farad Condensers).—v. Hartel. (*Rad. f. Alle*, December, 1928, pp. 552–556.)

The writer begins by pointing out the desirability of large capacities such as one farad, if they could be obtained within reasonable dimensions, at reasonable cost, to stand useful voltages: *e.g.*, for smoothing rectified A.C. He then describes recent research on the dielectric strength of very thin dielectrics, which has shown that whereas for normal thicknesses the breakdown voltage may be, say, 100,000 v/cm., for very thin layers where ionisation by collision is enormously reduced (between .001 and .0001 mm.) the value may be 300,000,000 v/cm. He goes on to describe the method recently patented by Polanyi to make use



of this result: a method which is at present being developed and backed by a large capital, for the manufacture not only of large-capacity condensers (a farad in a volume of about 120 c. inches, with a breakdown voltage of 1,000 v.) but also of thin insulating layers for laboratory and other purposes, to withstand 50 kV. per 0.1 mm. The schematic idea of the process of manufacture is shown in the diagram.

A drum rotating at 8,000 r.p.m. is contained in a vacuum of 1/10,000 mm. mercury, and can be cooled by a liquid led in through its axis. The four electrically heated ovens contain alternately metal and insulating material, which volatilise and deposit themselves on the rotating drum. At either end, a pair of screens shut off one metal and one insulator oven, so that here the alternate metal layers overlap and form one pole of the final condenser. By adjusting the oven-temperatures and the speed of rotation, the thickness of dielectric and metal films can be adjusted, down to a molecular thickness. A one-farad condenser takes a few minutes only to manufacture.

A Unique Method of Control by Means of Sound Waves.—A. B. Du Mont. (*QST*, January, 1929, V. 13, pp. 41–42.)

A change-over switch (*e.g.*, for switching on and off a broadcast receiver, or—in testing—for switching from the standard circuit to the one under test) is operated at a distance by a low-frequency sound impulse caused by clapping the hands together, cup-shaped. The sound-operated circuit-breaker consists of a light tab of copper resting on two copper wires. This operates a simple self-setting relay whose construction is described.

Die selbstregelnden Harastate-Widerstände (Self-regulating Harastate Filament Resistances). (*Rad. f. Alle*, December, 1928, pp. 560–561.)

According to the writer, the iron-wire automatic regulating resistance has had a complete revival in America. A new German make, the "Harastate," is referred to and strongly recommended.

Suppression of Disturbing Pulsations in H.F. Generators. (*German Patent* No. 466,630, Lorenz, pub. 9th October, 1928.)

Such machines have a very small air-gap compared with the rotor diameter, so that the necessarily imperfect centering of the rotor produces current fluctuations. In the invention, these are counteracted by opposing impulses from a rotary transformer mounted on the axle: its rotating field winding is connected across the H.F. terminals, while its stator winding is in series with the H.F. output circuit.

Governor for H.F. Generators. (*German Patent* No. 465,984, Lorenz, pub. 28th September, 1928.)

A tuned circuit for the correct frequency is coupled to the generator circuit: in resonance, the voltages at the inductance and the capacity are equal; they are conveyed to the windings of a differential H.F. relay, the action of which regulates the speed of the generator.

Centrifugal Governor. (*German Patent* No. 465,964, Telefunken, pub. 28th October, 1928.)

In a centrifugal force, gravity, and spring governor much resembling those referred to in recent Abstracts, an additional adjusting force is supplied by making the weight of soft iron and providing a magnetic field to act on it as it passes.

The Diverter Pole Generator for Battery-Charging.—E. D. Smith. (*Journ. Am.I.E.E.*, January, 1929, V. 48, pp. 11–15.)

A new type of generator developed to overcome certain limitations inherent in the shunt and compound generator when used for charging batteries by the constant voltage, modified constant voltage, or floating methods. A small diverter pole spaced midway between each pair of main poles has a magnetic bridge connecting it to one of these main poles. A restricted section in this bridge (produced by a hole through it) limits the leakage from the main pole and also acts as a magnetic choke which regulates the magnetism passing to the armature from the diverter pole, which has a winding in series with the load circuit. The resultant effect, which is fully described and illustrated by flux distribution and voltage regulation curves, is to give a machine with a number of advantages for the purposes mentioned.

Tungsten Filament Vacuum Fuses. (*Gen. Elec. Review*, January, 1929, V. 32, pp. 37–38.)

One D.C. fuse mentioned (rated at 10 A. at 15,000 v.) will rupture a current of 45 A. at that voltage. Another, for the protection of instrument transformers (rated at $\frac{1}{2}$ A. at 13,200 v.) will rupture a current of 110 A. When the tungsten filament burns out, one remaining end is hot enough to emit electrons which temporarily carry the current. In the case of the D.C. fuse, the emission quickly and smoothly falls to zero as the point cools; in the case of the A.C. fuse, it ceases as the current wave passes through the zero point.

Vakuum als Isolator (A Vacuum as Insulator).—W. Malischew, N. Semenov and N. Tomaschewsky. (*Journ. Applied Phys., Moscow*, No. 3/4, 1928, V. 5, pp. 93–118.)

A new theory of the breakdown of a high vacuum is evolved. By simple outgassing of the electrodes, the writers have obtained an insulation standing up to 400 kV. with a leak of only $1–2 \times 10^{-6}$ A/cm.^{2}

Theorie van den Oscillograaf: Beweging van een Electron in een veld van hooge frequentie. Practische methode voor het bepalen van Phaseverschillen (Theory of the Oscillograph: Motion of an Electron in a H.F. Field; Practical Method for Determining Phase Displacement).—A. v. Itterbeek. (*Tijdschr. Wiss. en Natuurk*, No. 2/3, 1928, V. 4, pp. 47–59.)

In connection with his cathode ray oscillograph (500–1,000 v.) the writer investigated the mathematical theory of the instrument, depending on the behaviour of an electron in a H.F. field. For frequencies greater than 2×10^7, the time taken by an electron to pass from between the deflecting plates must be considered. A consideration of the special case where the deflecting systems are not at right angles to one another leads to a practical method of measuring phase differences.

An Optical Oscillograph.—(*Phys. Review*, No. 2, 1928, V. 32, p. 319.)

A light ray passes through a Nichols prism, which polarises it in one plane; then through a quartz plate, which rotates the plane according to the equation $\delta = A + B/\lambda^2$; then through a carbon disulphide cell surrounded by a coil through which the current under examination passes. This cell increases or decreases the rotation, according to the current fluctuations through the coil. The ray then passes through a second Nichols prism, which cuts off all wavelengths rotated through $n\pi$ (n being a whole number). The ray is now observed through a spectroscope; a spectrum consisting of light and dark bands is obtained, in which the position of the dark bands depends on the strength of the current through the coil. The use of a rotating mirror allows the current variations to be registered on a photographic film.

Über einen neuen Kohlewiderstand (A New Carbon Resistance).—Hartmann and H. Dossmann. (Abstract in *Vortragshandbuch*, 90 Versamm. d. Ges. Deut. Nat. forsch., Hamburg, September, 1928).

A resistance applicable not only to valve circuits but also to D.C. and A.C. measuring purposes, including high voltage work. It is made by depositing a very thin layer of clean crystalline carbon (from the anthracite series) on an insulating surface, in a stream of carburetted hydrogen at 900–1,000 deg. It can be made for resistance between 10 and 10^7 ohms ; it is very constant and will stand very heavy overloads beyond the normal load of half a watt per sq. cm. No further details are here given. *Cf.* Seth, Anand and Chand, under "Miscellaneous."

A High Speed Graphic Voltmeter for Recording Magnitude and Duration of System Disturbances.—A. F. Hamdi and H. D. Braley. (*Journ. Am. I.E.E.*, July, 1928, V. 47, pp. 512–515.)

Normally the record-paper moves at the rate of only 3 cm. per hour, but the arrival of a certain over-voltage speeds it up to 10 cm. per sec., with a lag of 0.28 sec.

STATIONS, DESIGN AND OPERATION.

Who's Who in the Ether : A Guide to Distant Reception, Comprising a List of European Broadcasting Stations with their Wavelengths, Call-Signs, and Identification Signals.—(*Wireless World*, 6th February, 1929, V. 24, pp. 149–151.)

Gleichwellen-Rundfunk (Common Wavelength Broadcasting).—H. Göttinger. (*Rad. f. Alle*, November, 1928, pp. 501–503.)

In spite of rumours, inside and outside Germany, no common wavelength broadcasting has made its appearance : reports show that it was unsuccessfully tried in England. The writer, however, thinks it may yet be developed, and outlines the principles, the advantages and the difficulties of such a system. The Berlin G.P.O., working with Telefunken and Lorenz, appears to have solved the problem successfully in trials. Telefunken use a fundamental frequency of 30,000 p.p.s. transmitted by overhead lines to the various stations and there stepped up by valves working on the bend of the characteristic : four frequency-doubling stages are used, resulting in a frequency of 480 kilohertz. Lorenz starts with a lower frequency, 2,500, which can be transmitted by cable : at the stations it is stepped up by the Lorenz H.F. generator, to give a final wavelength round 530 m. The final trials were with three stations round Berlin. Stettin is now to be included, so that a four station group will soon be working. The trouble of "interference zones" (due to the production of stationary waves) is described : it is thought that an increasing number of stations will diminish such zones and that they can be located in a little-populated district.

High Power Broadcasting Transmitters.—(*Gen. Elec. Review*, January, 1929, V. 32, p. 41.)

"Decided improvements in the design . . . were effected by the utilisation of recently-developed water-cooled pliotrons having a nominal rating of 100 kW. With two of these tubes in the output stage the transmitter is capable of delivering 100 kW. to the antenna and this power is modulated 100 per cent." (*Cf.* Nelson, under "Transmission.") This transmitter is regularly operated on WGY programmes at an output of 50 kW., and a high degree of frequency stability is obtained by means of quartz crystals.

Die neuen Rufzeichen (The New Call Letters).—(*Rad. f. Alle*, December, 1928, p. 568.)

A list of the new national call prefixes which came into force on 1st January, 1929.

Sydney Talks to New York : Australia's Latest Short-Wave Feat.—(*Wireless World*, 30th January, 1929, V. 24, pp. 119–120.)

An account of the November, 1928, demonstration to the Press of telephonic communication from Sydney to Bandoeng (Java : 2,000 miles) and Schenectady (New York : 10,000 miles). Sydney worked on 28.5 m. and used a 20 kW. transmitter, some details of which are given. The demonstration began at 10 p.m.

Tabelle der Wichtigsten Kurzwellensender (Table of the Most Important Short Wave Stations).—(*Rad. f. Alle*, November, 1928, p. 511.)

Wavelengths vary from 104 m. (Mailand) down to 13.6 m. (Geizers Hill, 9 CH).

Ein Blick in die Funkkabine des "Graf Zeppelin" (A Glimpse into the Wireless Cabin of the "Graf Zeppelin.")—(*Rad. f. Alle*, December, 1928, pp. 557–558. See also *Telefunk. Zeit.*, October, 1928, pp. 49–50.)

GENERAL PHYSICAL ARTICLES.

The Electromagnetic Equations in the Quantum Theory.—C. G. Darwin. (*Nature*, 9th February, 1929, V. 123, p. 203.)

By the methods of Schrödinger it is possible to express the radiation of atoms in the form of electromagnetic waves, but the formulation is quite incomplete, because it fails to give the reaction of the radiation on the emitting system. The theory of Dirac is free from this cardinal fault, but fails to show the relation of radiation to static electric force ; it is, in fact, a valid theory of light, but scarcely an electromagnetic theory. The present letter shows the outline of how we may hope that the old waves, with their Maxwellian equations, can be fitted almost without change into the new scheme, when certain difficulties (involving the idea of superposed *times*) have been solved. The direct interactions of particles according to relativity principles will probably do away with the actual need for the idea of radiation: but the latter will always remain a convenient eliminant, expressive of the effect of a number of particles on a distant one.

THE UNDERSTANDING OF RELATIVITY.—(*Nature*, 2nd February, 1929, V. 123, pp. 160–161.)

Continuation of the correspondence referred to in recent Abstracts. Lodge—as an example of "uninstructed common sense" being occasionally a bad guide—quotes the velocity of light in water flowing in the same direction: as predicted by Fresnel and found by Fizeau, it is definitely not $c/\mu + v$ (velocity in stagnant water plus velocity of water) but this sum less v/μ^2. He mentions that the Larmor-Lorentz transformation, from which this and other "queer rules of composition" follow, was invented some years before Einstein boldly applied it to actuality.

REFRACTION OF BEAMS OF MOLECULES.—I. I. Rabi. (*Nature*, 2nd February, 1929, V. 123, pp. 163–164.)

As a more precise optical analogy than the Stern-Gerlach experiment, the writer investigates (theoretically) the refraction of a beam of molecules travelling from a region of no magnetic field to another in which there is a homogeneous magnetic field. He obtains $\delta = \frac{\mu H}{2E} . \tan \theta$ (where μ is the Bohr magnetron, E the kinetic energy of the molecules, θ the angle of incidence), provided that the ratio $\mu H/E$ is small. A complete discussion, including an experimental investigation, is to appear in *Zeitschr. f. Phys.*

POSITIVE ION CURRENTS IN THE POSITIVE COLUMN OF THE GLOW-DISCHARGE IN THE NOBLE GASES.—W. Uyterhoeven. (*Proc. Nat. Acad. Sci.*, January, 1929, V. 15, pp. 32–37.)

The author's results with Ne, Ar and He present two discrepancies with Langmuir's results with mercury vapour; namely, an increase of i with decreasing collector-potential, and the difference between i_m (the measured value) and i_c (the value calculated by Langmuir's theory): i_c being only about half i_m. Various explanations are discussed: not one of them can be singled out as free from objections: one of the most probable would seem to be secondary emission from the metal plate due to the impact of metastable atoms; but even here the efficiency of the process must be assumed rather high, *e.g.*, 50 per cent. A more complete record is promised to follow.

THE ABSORPTION OF PENETRATING RADIATION.—L. H. Gray. (*Proc. Roy. Soc.*, 4th February, 1929, V. 122 A, pp. 647–668.)

Adopting the hypothesis that penetrating radiation is a type of gamma radiation, its absorption in the atmosphere is investigated from the theoretical standpoint.

SKIN EFFECT IN RECTANGULAR CONDUCTORS AT HIGH FREQUENCIES.—J. D. Cockcroft. (*Proc. Roy. Soc.*, 4th February, 1929, V. 122 A, pp. 533–542.)

A treatment by electrostatic analysis. At high frequencies the surface of the conductor becomes a stream-line in the magnetic field, and the problem of distribution of current becomes analogous to an electrostatic problem: surface current density corresponds to E.S. surface density, and depth of penetration is the same as for infinite strips.

LA DIFFRACTION DES ÉLECTRONS PAR DES POUDRES CRISTALLINES (Electron Diffraction by Crystalline Powders).—M. Ponte. (*Comptes Rendus*, 14th January, 1929, V. 188, pp. 245–246.)

The writer has obtained such diffraction by the use of an arrangement similar to that employed in the study of powders by X-rays. He points out that his results show the possibility of studying the crystal lattice of a substance by the aid of electrons without the necessity for a delicate technique such as is involved in the preparation of the thin films used by G. P. Thomson and Rupp. His method gives the analysis in a short time (1 to $1\frac{1}{2}$ hrs.) with the expenditure of little power (35 W for $V = 17$ kV.). Moreover, it lends itself to the study of positive ions and the determination whether these, like the electrons, are accompanied by an associated wave.

ACTIONS MAGNÉTIQUES LONGITUDINALES SUR DES FAISCEAUX D'ÉLECTRONS LENTS (Concentrations et Dilatations périodiques)—(Longitudinal Magnetic Effects on Rays of Slow Electrons—periodic Concentrations and Dilatations).—J. Thibaud. (*Comptes Rendus*, 2nd January, 1928, V. 188, pp. 54–56.)

The authors have experimented on rays of slow electrons, obtained in a bronze cylinder 30 cm. long and 12 cm. in diameter, very thoroughly exhausted. Such a ray can be obtained with voltage as low as 16 v., and possesses properties (comparable with those of soft X-rays) which disappear when 500 v. is reached: *e.g.*, the whole of its path is visible owing to fluorescence of the gas molecules. If a magnetising coil inside the cylinder coaxial with the ray is energised, the direction of the ray is hardly affected, though its glow is brightened. But if the magnetising current is varied continuously by a rheostat, the pencil of rays periodically dilates and contracts, varying from a wide-ended cone (diam. 100 mm. at 30 cm. from the source) to a brilliant and fine pencil (0.2 mm. diameter). The values of magnetic field producing the concentration effect are obtained by making $n = 1, 2, 3 \ldots$ in the equation $H_c = K(n - \frac{1}{2})\beta$, where K is a constant for the particular apparatus and β is the velocity of the electrons; while $H_d = Kn\beta$. The tests included the use of fields from 2–450 gauss and of electron energies of 16-1,100 v. The authors have established a theory of these phenomena, not given here. The subject is dealt with further in the next issue (7th January, pp. 158–160).

MATHEMATICAL STUDY OF A RECTIFIED ALTERNATING CURRENT.—G. Poux. (*L'Industrie Élec.*, 25th August, 1928, V. 37, pp. 365–372.)

BEMERKUNG ZUM HARMONISCHEN ANALYSE (A Note on Harmonic Analysis). — G. Duffing. (*E.T.Z.*, 25th October, 1928, p. 1592.)

Describes a mathematical procedure, first proposed by the writer in 1916, which should be useful to experts, as it allows them to entrust the work to assistants who need only be accurate computers.

HEAVISIDE'S FORMULÆ FOR ALTERNATING CURRENTS IN CYLINDRICAL WIRES.—T. J. I'a. Bromwich. (*Phil. Mag.*, November, 1928, V. 6, No. 38, pp. 842–854.)

The writer gives for the first time proofs of certain of Heaviside's formulæ and directs attention to the advantages obtained by using these Bessel-function formulæ instead of "the much less convenient solutions" obtained later by Kelvin in terms of *ber* and *bei* functions.

THE PRACTICAL APPLICATION OF THE FOURIER INTEGRAL.—G. A. Campbell. (*Bell Tech. Journ.*, October, 1928, V. 7, pp. 639–707.)

The growing practical importance of transients and other non-periodic phenomena makes it desirable to simplify the application of the Fourier integral in particular problems of this kind, and to extend the range of problems which can be solved in closed form by this method. 45 pages of tables facilitate such employment by the physicist.

ÜBER DIE URSACHE, WARUM EIN ELEKTRISCHES ELEMENTARQUANTUM NICHT IN TEILE VON NOCH KLEINEREN LADUNGEN ZERFALLEN KANN (The Reason why an elementary Quantum of Electricity cannot disintegrate into still smaller charges).—W. Anderson. (*Ann. der Physik*, No. 20, V. 87, pp. 536–542.)

THE STRUCTURE OF MOLECULES. — F. Hand. (*Nature*, 29th December, 1928, V. 122, p. 1010.)

Summary of the fourth paper on the significance of molecular spectra (*Zeitschr. f. Phys.*, 12th November, 1928).

SCHRÖDINGER DYNAMICS.—A. Bramley. (*Journ. Franklin Inst.*, November, 1928, V. 206, pp. 605–621.)

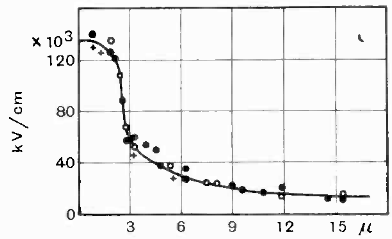
AN UPPER LIMIT FOR ENERGY-DENSITY: THE STRUCTURE OF TIME.—G. I. Pokrowski. (*Zeitschr. f. Phys.*, 2nd November, 1928, V. 51, pp. 730–739.)

Two papers, in the first of which various ways of treating the subject lead to 3×10^{12} deg. as the maximum possible temperature, 10^{13} g./cm.^{3} as the highest probable energy-density, and n as the maximum frequency for radiation, where $\log n = 24$ approx.; in the second paper a time of the order of 4.5×10^{-24} is proposed as the ultimate element.

MISCELLANEOUS.

DIE ELEKTRISCHE FESTIGKEIT DÜNNER SCHICHTEN (The Electrical Strength of Thin Films).—A. Joffe. (*Summary in E.T.Z.*, 31st January, 1929, pp. 169–170.)

The writer, investigating the effect of decreasing the possible ionisation by collision by decreasing the path from one electrode to the other, has worked on glass films down to 0.014μ in thickness and on mica down to 0.05μ, while with oil, benzol, pizein and colophonium he has tested from thicknesses of 15μ down to about 1μ. With all these materials, as the thickness is reduced below 5μ the dielectric strength rapidly mounts (*see* curve).



Tests on the still thinner glass and mica, however, showed that though the breakdown voltage rose to about 150,000 kV/cm. for a thickness of 0.2μ, a further diminution of thickness produced no further rise. This steady value is, he considers, the "true" dielectric strength of the material. *Cf.*, v. Hartel, under "Subsidiary Apparatus."

VELOCITY OF PARTICLES SPUTTERED BY DISRUPTIVE DISCHARGE.—H. Nagaoka and T. Futagami. (*Proc. Imp. Acad. Tokyo*, No. 5, 1928, V. 4, pp. 201–204.)

Rotating film records indicate speeds varying from 10–130 metres per sec.

INSULATION: THE OPPORTUNITY FOR RESEARCH.—J. B. Whitehead. (*Journ. Am. I.E.E.*, January, 1929, V. 48, pp. 27–31.)

A short survey of our present knowledge, pointing out the need for research on the size, motion and other characteristics of the mobile ions, their accumulation as space charges, and their relation to the chemical constitution, origin and subsequent states of the dielectric material. Results of physicists such as Debye and his followers (associating S.I.C. with inherent molecular dissymmetry) and Euguchi (with his "electrets" with permanent electrification similar to permanent magnetism) are important and stimulating but throw little light, for example, on the nature of dielectric absorption and loss.

DIE ELEKTRISCHE LEITFÄHIGKEIT DES SILIZIUSM (The Electrical Conductivity of Silicon).—H. J. Seemann. (*Summary in E.T.Z.*, 24th January, 1929, p. 134.)

Silicon, like Carbon, Titanium, etc., has a negative temperature-characteristic. Ryschkewitsch has shown that single graphite crystals have a positive coefficient (and a conductivity exceeding that of mercury). The writer has now found that single silicon crystals, also, have a positive coefficient. It looks, therefore, as if in all these cases the negative coefficient is a result of polycrystalline structure and consequent oxidised surface-layers.

Sur la Rectification par les Mauvais Contacts purement Métalliques (Rectification by Purely Metallic Imperfect Contacts).—H. Pélabon. (*Comptes Rendus*, 28th January, 1929, V. 188, pp. 382–384.)

An apparently perfectly symmetrical arrangement of one steel cylinder standing on another, identical, cylinder, with a few grains of lycopodium or cork powder separating them, presents curious properties. When brought to a condition of fatigued coherence (by the regular application, at 30 sec. intervals, of electromagnetic impulses) it shows equal conductivity in the two directions, and yet when an alternating current is applied, a rectifying action appears, always in the direction of the upper cylinder. The only lack of symmetry is that the upper cylinder is free to move while the lower, standing on a hard surface, is fixed. If now the lower cylinder is placed on a "giving" surface such as a piece of woollen material, the rectifying action vanishes. The force of "electrostatic pressure," invoked by Blanc for the explanation of coherer-action, is evidently involved. The paper concludes by a consideration of the rectifying action of two steel spheres, suspended by wires of equal length and touching each other.

"The Transmitting Station actually sends out Waves of One Definite Frequency, but of Varying Amplitude."—A. B. Howe. (*E.W. & W.E.*, February, 1929, V. 6, pp. 95–96.)

A continuation of the argument referred to in February Abstracts. One particular point here dealt with is the reason why, if we listen to the second harmonic of a modulated radio-frequency wave, we do not observe all the tones of the modulation to have been raised in pitch by one octave. The mathematical treatment given shows that we shall hear the original modulation and not the octave, but that a certain amount of harmonics of the original modulation frequencies will always be present, introducing more or less distortion—as is found in practice.

A Filter for Street Car Noises.—(*QST*, January, 1929, V. 13, p. 45.)

Summary of a report by an official of the San Diego Electric Railway Company. A suitable filter, between trolley-wheel and motors, was found very effective so far as commutator-generated interference was concerned, but not very useful as regards trolley-wheel spark interference, which could only be minimised by care in the maintenance of the contact-parts.

The Physical Society's Exhibition: Matters of Wireless and Laboratory Interest.—(*E.W. & W.E.*, February, 1929, V. 6, pp. 81–85.)

Humours of the Market Survey: Ourselves as Others See Us: Foreign Impressions of the British Wireless Position.—(*Electrician*, 9th November, 1928, V. 101, p. 525.)

Weitere Mitteilungen zum Kristalldetektorproblem (Further Information on the Subject of the Crystal Detector).—P. Beck. (*Physik. Zeitschr.*, No. 13, 1928, V. 29, pp. 436–437.)

As an extension of Reissaus' contribution to the problem, the author describes experiments, on various galena contacts, in which the electrical measurements were taken simultaneously with microscopical observations of the active spot.

Sur l'Étude des Contacts Imparfaits en Courants Continus (The Study of Imperfect Contacts with Continuous Currents).—R. Audubert and M. Quintin. (*Comptes Rendus*, 26th November, 1928, V. 187, pp. 972–974.)

Most imperfect contacts give rectification through a combination of various phenomena—electronic, thermoelectric and electrolytic. This paper deals with the Silicon-Carbon contact: here the effects are instantaneous, reversible and stable: the thermoelectric effect is opposed to the rectifying effect: the hypothesis of solid electrolysis cannot be invoked. The action depends on a skin of oxide: when this skin is gradually thickened the dissymmetry of the two parabolic branches of the current-voltage curve increases, passes through an optimum, and then decreases. But the critical voltage, beyond which the unilateral conductivity disappears, increases regularly with the thickness of the skin. Increase of pressure diminishes the dissymmetry, the characteristic tending towards a straight line. Increase of temperature gives a similar effect. Curves are given showing this, and the conclusion is that this combination is particularly well suited to the study of the mechanism of rectification.

Sur le Mécanisme de la Conductibilité dissymétrique des Contacts imparfaits (The Mechanism of Unsymmetrical Conductivity in Imperfect Contacts).—R. Audubert and M. Quintin. (*Comptes Rendus*, 2nd January, 1929, V. 188, pp. 52–54.)

Referring to the above paper, the writers say: "If one considers the conductivity as due to a pure electronic displacement, such a régime should be represented by Maxwell's law, *i.e.*, by the first part of the saturation curve of thermionic emission before the intervention of the space charge. Experiment does not confirm this idea, since the intensity (of current) varies as the square of the P.D." They go on to show that experiment and theory fit in well together for the silicon-carbon contact if it is supposed that ionisation intervenes—as is probable in view of the presence of absorbed or occluded gases in the carbon; and conclude that for this contact and also, probably, for silver and lead sulphide contacts, the mechanism is electronic emission accompanied by ionisation.

ÜBER KONTAKTWIDERSTÄNDE (Contact Resistances).—R. Holm. (*Vortragshandbuch*, 90 Versammlung der Gesell. Deutscher. Nat. Forsch., Hamburg, September, 1928; also shorter abstract, *E.T.Z.*, 13th December, 1928, p. 1814.)

Conduction between technically clean pieces of metal is principally metallic: the contact has a selective resistance. The proof of this lies particularly in the voltage-resistance characteristics. These can be plotted with electric and thermal specific conductivities as parameters. Experimental results conform very well with the theory, which shows a uniform proportion of temperature at the contact to contact voltage. Recrystallisation temperature shows a first resistance-drop, melting point a second. A cohering contact surface is only obtained at specific pressures. So-called "smooth" surfaces for the most part touch each other only in individual spots, where they display contact resistance which, like the friction, depends only on the total pressure and not on the magnitude of the apparent surfaces of contact.

EFFET DU CHAMP MAGNÉTIQUE SUR LA RÉSISTANCE ÉLECTRIQUE D'UN CONTACT (Effect of a Magnetic Field on the Electrical Resistance of a Contact).—J. Cayrel. (*Comptes Rendus*, 26th December, 1928, V. 187, pp. 1287–1288.)

For a field of about 20,000 gauss, results were negative for all the contacts tried except the contact Bismuth-Bismuth, where it was positive, though much less marked than for bismuth wire; and it increased as the contact resistance decreased, *i.e.*, as the contact became more intimate and therefore more like a homogeneous metal.

SINGLE SIDE-BAND CARRIER FOR INTER-STATION COMMUNICATION.—R. Wilkins and F. I. Lawson. (*Elec. World*, 3rd November, 1928, V. 92, pp. 877–881.)

The suppressed-carrier system adopted by the Pacific Gas & Electric Company for communication over its 110–220 kV. network.

RESONANT CONTROL FOR MULTIPLE STREET LAMPS.—W. W. Edson. (*Elec. World*, 10th November, 1928, V. 92, pp. 929–932.)

Frequencies of 720 and 480 p.p.s. are used, travelling along the 4,000 v. circuit, through the distribution transformers and to the various street lamps, each of which has two tuned relays in the base of the post.

THE GEOMETRY OF RESONANCE DIAGRAMS.—J. K. Catterson-Smith. (*Engineering*, 5th October, 1928, V. 126, pp. 415–416.)

A description, with examples, of the use of a graphical method of solving resonance problems, the determination of decrement, H.F. resistance, etc.

MATHEMATICAL SYMBOLS. (*E.T.Z.*, 1st November, 1928, p. 1625–1627.)

Tables recently issued by the German Committee for Units and Dimensions.

LICHTENBERG FIGURES.—C. E. Magnusson. (*Journ. Am.I.E.E.*, November, 1928, V. 47, pp. 828–835.)

TESTING INSTALLATION FOR 500,000 VOLTS AT THE ELECTROTECHNICAL LABORATORY, ITALY. (*Génie Civil*, 20th October, 1928, V. 93, p. 389.)

The plant was supplied by a Dresden firm and operates on the plan of charging blocks of condensers in parallel and connecting in series.

BEITRAG ZUR ALLGEMEINEN THEORIE DER ELEKTROSTATISCHEN UND ELEKTROMAGNETISCHEN KOPPLUNG ZWISCHEN STARKSTROM—HOCHSPANNUNGS — UND FERNMELDELEITUNGEN IM STATIONÄREN ZUSTAND (Contribution to the general theory of e.s. and e.m. coupling between power—H.T.—lines and telephone-lines, in the stationary condition).—G. Eggeling. (*E.N.T.*, August, 1928, V. 5, pp. 312–333.)

A mathematical treatment in which the e.m. and e.s. couplings are dealt with simultaneously instead of separately as has been done by previous writers. A bibliography of 18 items is appended, and in addition the author particularly mentions the report of the Railroad Commission of the State of California entitled "Inductive Interference between Power and Communication Circuits." No special mention is made in the present paper of the importance of the question from the point of view of radio communication.

STÖRUNGEN VON RUNDFUNKEMPFANG DURCH QUECKSILBERDAMPF-GLEICHRICHTER (Interference with Broadcast Reception due to Mercury-vapour Rectifiers).—K. Heinrich, (*E.T.Z.*, 30th August, 1928, pp. 1296–1297.)

The interference complained of was of two kinds—a strong hum and a weaker whistling noise—the latter unconnected with the frequency of the current being rectified. Research led to the conclusion that the rectifier, in the production of this latter noise, was functioning as an arc generator. A 90,000 cm. capacity across the overhead lines removed this interference, but two microfarads were needed to abolish the hum.

THE DETERIORATION OF QUARTZ MERCURY VAPOUR LAMPS AND THE LUMINESCENCE OF TRANSPARENT FUSED QUARTZ.—A. E. Gillam and R. A. Morton. (*Phil. Mag.*, December, 1928, V. 6, pp. 1123–1132.)

The conclusions are that there are two factors: a shortening of the spectrum confined to the extreme ultra violet, and a non-selective loss in transmission. The first preponderates for the first 150–200 hours and shows itself as a rapid fall in output. During the subsequent life of the lamp the second plays an increasingly important part. It is suggested that the first effect may be due to the formation of silicon monoxide vapour inside the lamp, and the second may arise from the gradual deposition of a film of opaque elementary silicon. Three types of luminescence phenomena have been observed, but have little or no connection with the deterioration.

ACTIONS DES RAYONS LUMINEUX SUR LE CHLORURE DE POTASSIUM (Action of Light Rays on Chloride of Potassium).—J. Risler and F. de Courmelles. (*Génie Civil*, 1st December, 1928, V. 93, p. 535.)

The specific rôle played by potassium in the automatism of cardiac action has been studied by Zwardemaker, who showed for the first time the variations of this element with the seasons. Looking for the causes of these variations, the writers have found that the microradioactivity of potassium chloride is increased by light, which also explains the particularly active part played by the element in the growth of plants.

AN ATTEMPT TO ADD AN ELECTRON TO THE NUCLEUS OF AN ATOM.—W. D. Harkins and W. B. Kay. (*Phys. Review*, June, 1928, V. 31, pp. 940–945.)

Electrons with a velocity corresponding to 138–145 kV. were made to strike the surface of liquid mercury; after a time, this mercury was tested for traces of gold. The absence of positive result suggests that either less than one in a billion of the electrons attached itself to an atom nucleus, or else all or a part of the nuclei produced were not sufficiently stable to endure for the 24–28 hours of the test.

ON NUCLEAR DERIVATIVES AND THE LETHAL ACTION OF ULTRA-VIOLET LIGHT.—F. L. Gates. (*Science*, 16th November, 1928, V. 68, pp. 479–480.)

A letter, from the Rockefeller Medical Research Institute, on the mechanism of the bactericidal action of ultra-violet light.

IMPULSE CHARACTERISTICS OF DRIVEN GROUNDS.—H. M. Towne. (*Gen. Elec. Review*, November, 1928, V. 31, pp. 605–609.)

Cathode-ray oscillograph tests of the behaviour of galvanised iron pipes driven into the soil to form lightning conductor earths.

SPARK IGNITION.—E. Taylor Jones. (*Phil. Mag.*, December, 1928, V. 6, pp. 1090–1103.)

"In the opinion of the writer the thermal theory is the only theory which is capable of accounting for the known facts of spark ignition, and it is hoped that the evidence produced in the present communication will tend to renew confidence in it."

L'ENERGIE THERMIQUE DE L'EAU DES RÉGIONS POLAIRES (The Thermal Energy of the Water of the Polar Regions).—H. Barjot. (*Génie Civil*, 15th December, 1928, V. 93, p. 590.)

The writer proposes to use the difference in temperature between the water beneath the ice (which, protected by up to 5 metres of ice, remains round about zero) and the air, which may be as low as −40 deg., to drive an engine using as fluid one of the volatile hydrocarbons: thus doing for cold regions what Claude and Boucherot propose to do for tropical regions (*cf.* Abstracts, 1928, V. 5, p. 471).

PROTECTION OF ELECTRICAL APPARATUS AGAINST INTERNAL SHORT CIRCUIT. (French Patent No. 646,196, *Comp. Gén. d'Élec.*, published 8th November, 1928.)

The observed fact, that an appreciable time before the breakdown there occurs a diminution of insulation enough to be detected by a suitable arrangement, is here used to give warning or to put the machine automatically out of action.

ZUM UHRVERGLEICH AUF DRAHTLOSEM WEGE NACH DER KOINZIDENZHÖRMETHODE (Time Checking by Wireless on the Aural Method of Coincidence).—H. Martin. (*Zeitschr. f. Geophys.*, No. 2, 1928, V. 4, pp. 53–58.)

For use where recording methods are impracticable, the writer describes a telephonic method accurate to a few thousandths of a second.

THE CIRCULATION OF SEISMOLOGICAL INFORMATION BY WIRELESS TELEGRAPHY. (*Nature*, 26th January, 1929, V. 123, pp. 148–149.)

Supplementing an article (*ibid.*, 22nd December, 1928, p. 968) on the arrangements for broadcasting early information, this article shows the successful correlation, for the large earthquake of 13th January, of data supplied by Kew, Helwan, Bombay, Stonyhurst (by post), Georgetown, Honolulu and Strasbourg. The intersections of the various arcs almost met at a point in the Sea of Okhotsk. The initial impulse measured by the Kew seismographs (three components) indicated a point close to this.

THE EFFECT OF MOIST AIR ON THE RESISTANCE OF PENCIL LINES.—J. B. Seth, C. Anand and G. Chand. (*Proc. Physical Soc.*, 15th December, 1928, V. 41, pp. 29–35.)

The resistance of a pencil line is found to increase when it is kept in a moist atmosphere. In the discussion following the paper, it was pointed out that this effect of humidity on carbon granules is closely connected with their tendency to packing in microphones, particularly those used in certain aural aids for the deaf, which are extremely sensitive to changes of humidity.

NOTE SUR L'ÉLIMINATION DES PERTURBATIONS CAUSÉES PAR LES LIGNES EXPLOITÉES AU MOYEN DE L'APPAREIL BAUDOT (Note on the Elimination of the Disturbances caused by Lines using the Baudot System).—E. Boyer. (*Ann. des P.T.T.*, October, 1928, V. 17, pp. 864–872.)

Disturbances on telephone and radio-telephone circuits were produced by very highly damped H.F. currents caused by the Baudot apparatus. They were cured by the use of suitable filters on the Baudot lines.

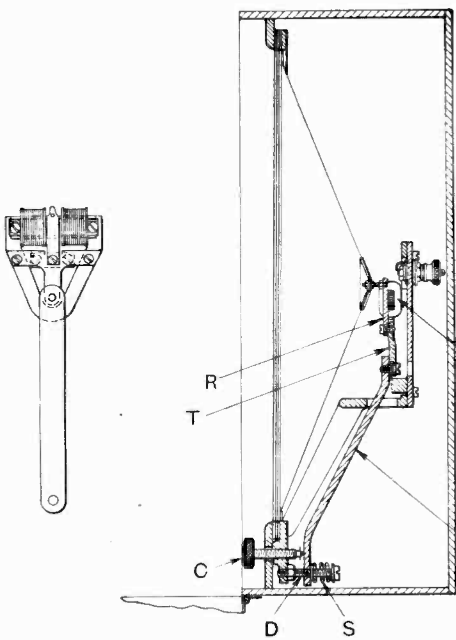
Some Recent Patents.

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 1s. each.

CONE LOUD SPEAKERS.

(*Application date, 19th October,* 1927. *No.* 300761.)

The adjustment screw for controlling the air-gap between the magnet and its armature or reed is arranged to be operated from the front of the speaker instead of from behind the instrument as usual. The reed R is supported between the magnet pole pieces P (only one of which is shown) by an adjustable T-shaped member T. Attached to the vertical limb of the member T is the adjusting lever L, which is brought forward, roughly parallel to the conical surface of the diaphragm, and anchored to a pin D rigidly fixed to the rim mounting. The lever L is moved to and fro against the action of a spiral spring S by a thumbscrew C,



thereby adjusting the effective air-gap between the magnet and the reed driving the conical diaphragm.

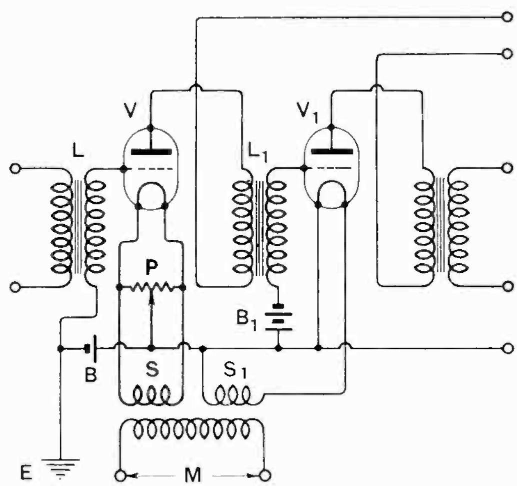
Patent issued to S. G. Brown, F.R.S.

A.C. FILAMENT SUPPLY.

(*Application date, 4th August,* 1927. No. 299908.)

The filament supply is taken direct from a raw A.C. supply so that the filament voltage fluctuates with that of the mains, but the resultant hum from one valve stage is balanced against that due to a preceding or succeeding stage in such a manner that all disturbance in the final output from the amplifier is substantially eliminated.

The mains transformer M has two secondary



windings S, S_1 supplying the filaments of two successive valve stages V, V_1. The input winding L of the first valve is earthed at E, the grid circuit being completed through a biasing battery B to an adjustable tapping P on a potentiometer shunted across the filament terminals of that valve. The input winding L_1 of the second valve V_1 is connected through a biasing battery B_1 directly to the filament as shown. By suitably adjusting the tapping point P, the hum produced by the first valve is fed to the second valve in such phase and magnitude as to neutralise the effect of the direct hum produced by the latter valve, leaving the final output free from noise.

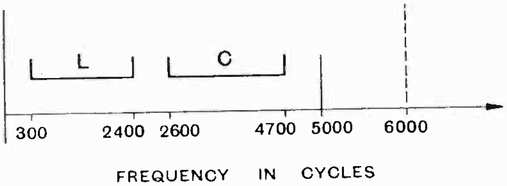
Patent issued to De W. Clinton Tanner.

WIRED WIRELESS WORKING.

Convention date (*Germany*), *27th May,* 1927, *No.* 291110.

In wired-wireless working, different messages are transmitted simultaneously over the same wire by modulating two or more sub-frequencies. The present invention relates to a method of simultaneously combining an ordinary or low-frequency telephone message with a high-frequency or modulated carrier message. In the ordinary way this is not possible, because for high-frequency or carrier-wave working the line is pupinized or loaded to prevent attenuation. The cut-off frequency is then so high as to make the line practically useless for ordinary telephonic speech.

According to the invention this difficulty is overcome by taking a lightly-loaded line having a limiting frequency of say 6,000 cycles per second, utilising a carrier-frequency some 20 per cent. below the cut-off say 5,000 a second, and, after modulation, eliminating the upper side-bands, and preferably the carrier-frequency also, so that the effective message-carrying frequencies are spaced apart as shown in the Figure. Ordinary speech is



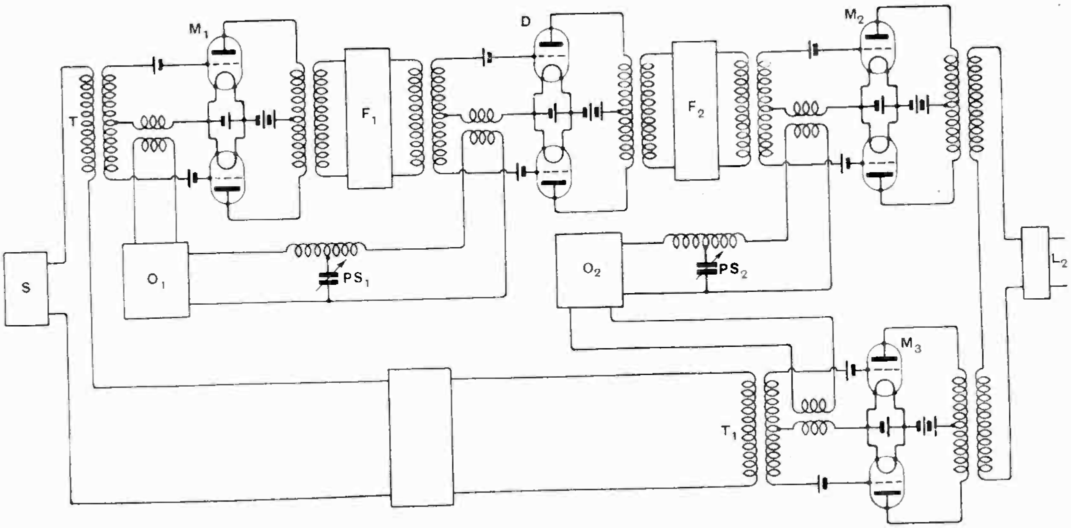
represented by the band L extending between 300 and 2,400 cycles, whilst the lower side-bands C of the high-frequency message range between 2,600 and 4,700 cycles. The original carrier is shown at 5,000 cycles, whilst the dotted line represents the cut-off frequency of the loaded line.

Patent issued to Siemens & Halske A.G.

SINGLE SIDE-BAND SIGNALLING.

(*Application date, 27th August*, 1927. *No.* 301352.)

The difficulty of separating-out one side-band from a modulated carrier wave by filtering-means increases with the frequency of the carrier. For instance to produce single side-band transmission with a carrier of 1,000 kilocycles, it is usual to build up the frequency in two or more stages of modulation, and to use filters at each stage to eliminate the unwanted side-bands.



The invention provides an improved system in which the modulating current is split into two components, differing in phase by 90 degrees. These are then impressed along separate channels on balanced modulating-valves in such a way that the undesired side-bands produced in each instance by modulation are of opposite phase and therefore cancel out, whilst the desired side-bands are combined additively.

As shown, signals from a source S are fed to a balanced modulator M_1 through a transformer T, and simultaneously through a transformer T_1 to a second modulator M_3 located in a parallel channel to the first. An intermediate carrier frequency is supplied to modulator M_1 from a source o_1, which also supplies current of the same frequency, but dephased 90 degrees by a phase-shifter PS_1, to a demodulator D. A filter F_1 passes one side-band of the modulated carrier, whilst the rectified output passes through a low-pass filter F_2 to a subsequent balanced modulator M_2. Currents of the final carrier frequency are supplied from a source o_2, (a) through a 90 degree phase-shifter PS_2 to the modulator M_2, and (*b*) directly to the modulator M_3 in the parallel channel. The final output, which is fed to a line L_2 or to a transmitting aerial, contains only the desired side-band and signal components.

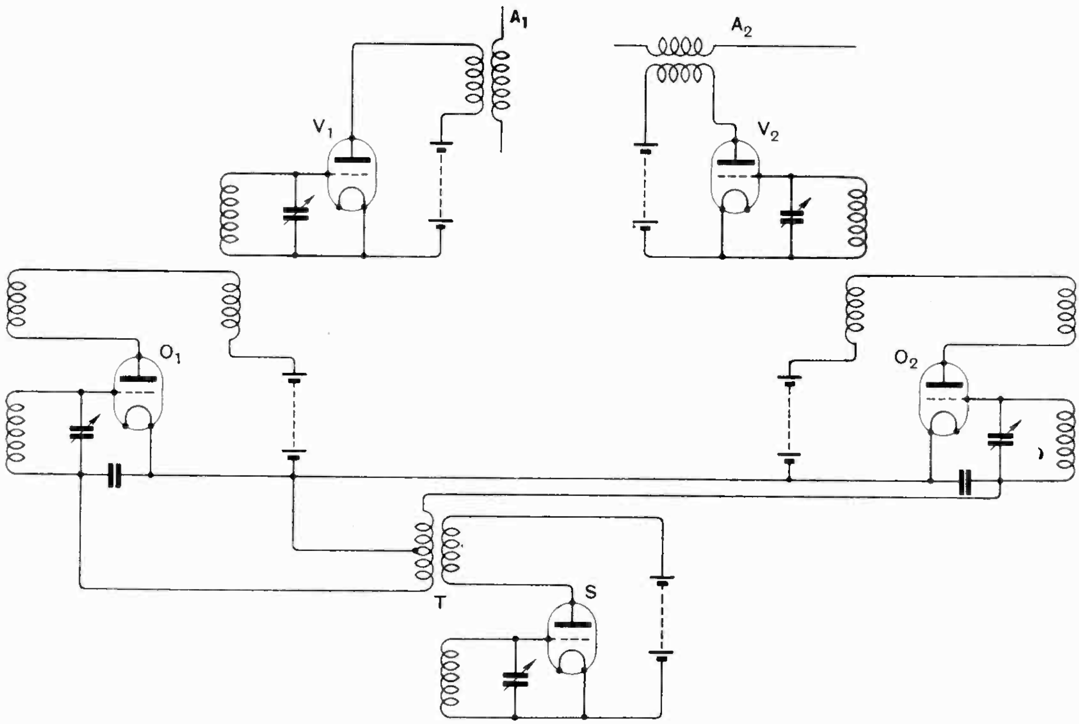
Patent issued to Standard Telephones and Cables, Ltd.

"DOVETAILED" WIRELESS TRANSMISSION.

(*Application date, 27th May*, 1927. *No.* 301436.)

Two or more sets of waves, or modulations, are used, differing either in frequency or in some other characteristic. Transmission is effected by shifting from one wave or modulation to the other at a definite frequency. For instance, the oscillator o_1 generates waves of one frequency, which are amplified by a valve V_1 coupled to the aerial A_1. A second oscillator o_2 generates waves at another frequency, these being fed to an amplifier V_2 coupled to aerial A_2 set in a different plane to the first.

A "shift" valve S oscillates at a relatively low frequency, and is so coupled to the grids of the oscillators o_1, o_2 through a tapped transformer T that it throws them into and out of action alternately.



In reception two aerials are used, each tuned to one of the transmission frequencies. These feed separate valves, the outputs from which are fed to a final combining-circuit in such fashion that signal effects occurring simultaneously in both aerials are balanced out. However by tuning the "combining" circuit to the "shift" frequency of the valve S, the final response can be made dependent solely upon the signal effects occurring alternately in the separately-tuned aerials. In this way the dove-tailed transmission is analysed into its original components. Single or multiplex signalling can be similarly effected, reception being free from either mutual or extraneous interference.

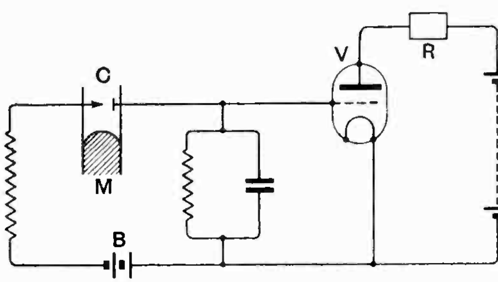
Patent issued to J. Robinson.

TIMING-DEVICES FOR PICTURE-TRANSMISSION SYSTEMS.

(*Application date, 27th July,* 1927. *No.* 301414.)

Timing-devices used in picture telegraphy usually depend upon the action of a master control, such as a tuning-fork, the periodicity of which is liable to be affected by variations of temperature. It is therefore enclosed in a casing which is maintained at a constant temperature by means of a suitable thermostat.

The invention is directed to this object. A mercury-toluene thermometer is used, the expansion of the toluene forcing the mercury column M up along the tube until it bridges a pair of contacts C inserted in the grid circuit of the valve V. Under normal conditions, a relay R in the plate circuit of the valve is kept closed to energise the heating-coil for the casing containing the master frequency-control (not shown). Should the temperature rise too high, the mercury M closes the gap C. This applies a high negative grid bias from the battery B, and so cuts down the plate current



whereupon the relay R opens and cuts off the current supply to the heating-coil. As the temperature falls again to its normal value, the contacts C are broken and the heating coil is replaced in circuit.

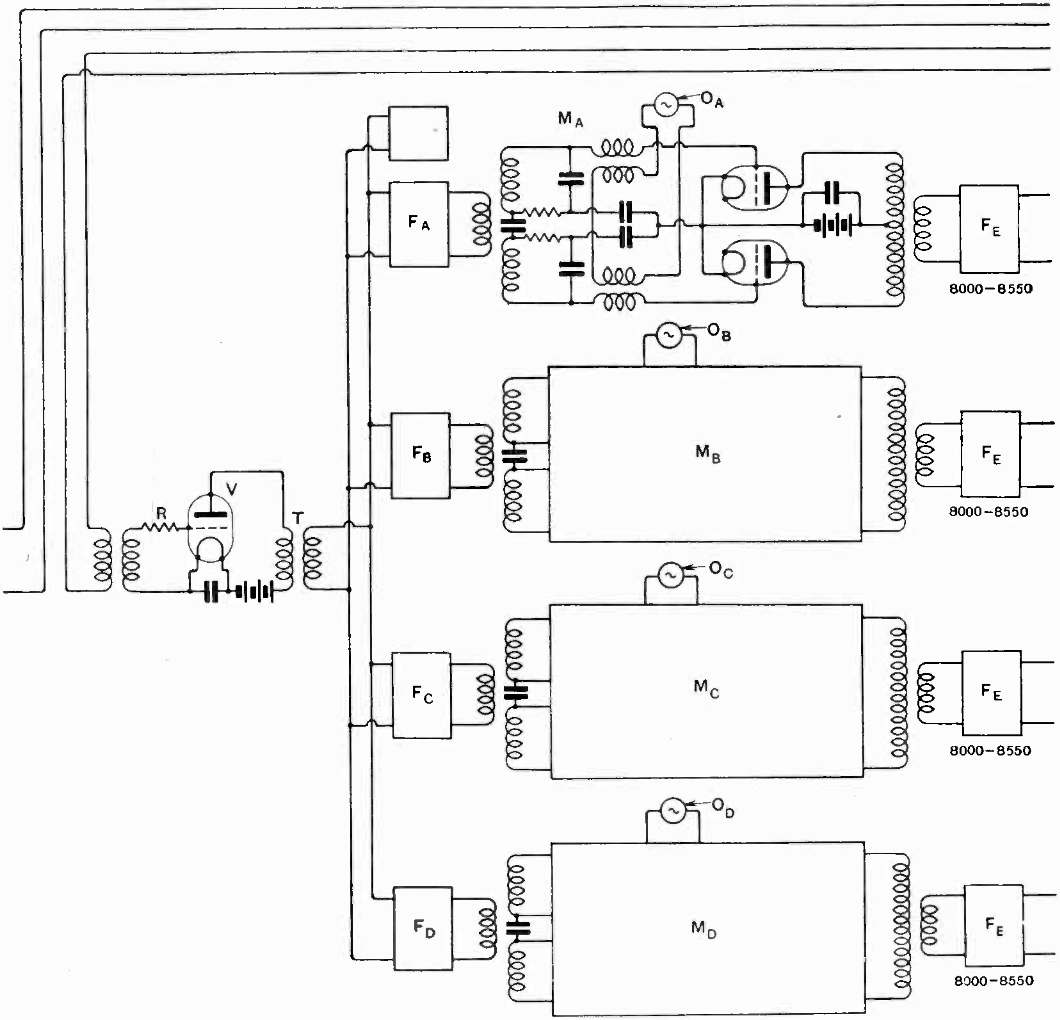
Patent issued to G. M. Wright.

SECRET TELEPHONY SYSTEMS.

(*Application date, 5th August*, 1927. *No.* 299915.)

Signals are applied to an amplifier *V* having a high resistance *R* in the grid circuit to serve as a voltage limiting device. The output is connected through a transformer *T* to band filters *F*A, *F*B, *F*C, *F*D which divide the speech band into four equal frequency ranges, viz., 400–950, 950–1,500, 1,500–2,050, and 2,050–2,600 cycles. Balanced modulators *M*A, *M*B, *M*C, *M*D, co-operating with local oscillators *O*A, *O*B, *O*C, *O*D having frequencies of 7,600, 7,050, 6,500 and 5,950 cycles respectively, (*a*) eliminate the carrier frequency, and (*b*) reduce the sub-bands to the same frequency level, and pass the output through the filter circuits *F*E as shown.

The output from the last filters are then connected to the armatures of a number of relays, preferably four for each channel, which are in turn controlled by a number of keys (not shown) in such a way as to reorganise the original frequencies, either by changing their relative position, or by inverting the frequencies within the sub-bands, or by performing both operations, prior to recombining them on the outgoing line for radiation. The secrecy circuit is essentially a one-way device, so that when used for a complete transmission channel or two-way service, it is necessary to employ either two identical secrecy circuits. Alternatively transmission in both directions can be effected by transferring a single secrecy circuit from one line to another by suitable voice-operated or similar relays.



Patent issued to Standard Telephone and Cables, Ltd.