EXPERIMENTAL WIRELESS & The WIRELESS ENGINEER

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Editorial Views.

New Editorial Appointments.

WITH this issue we not only commence a new volume of E.W. & W.E. but are able to announce an important change in the editorial management of the journal.

Our readers will be interested to learn that Prof. G. W. O. Howe, D.Sc., M.I.E.E., has undertaken to act as Technical Editor, whilst the Editorship passes to Mr. H. S. Pocock, who is also Editor of the sister journal *The Wireless World*, with which he has been associated in that capacity for many years.

With the appointment of Prof. Howe an old association is renewed, for he acted as Editor of the *Radio Review* from its first publication until its amalgamation with *The Wireless World*.

Prof. Howe, who was for many years Assistant Professor of Electrical Engineering at South Kensington, and later Head of the Department of Electrical Measurements, including Radio Telegraphy, at the National Physical Laboratory, is now Professor of Electrical Engineering at Glasgow University. He was Chairman of the Wireless Section of the Institution of Electrical Engineers from 1921 to 1923. He has been a Vice-President of the Radio Society of Great Britain from its inception and is a member of the Radio Research Board of the Department of Scientific and Industrial Research.

Our readers will see in these appointments a proof of the determination of the publishers to maintain the high standard which has always been one of the outstanding features of E.W. & W.E.

We have recently received several letters from readers suggesting that articles on various subjects would be very acceptable. Our readers may rest assured that we welcome such suggestions and that every effort will be made to meet their expressed wishes by publishing authoritative but simple articles on the subjects suggested.

We trust that every reader will do what he can to make E.W. & W.E. known to other wireless workers.

Common Logarithms or Natural Logarithms?

IN the article entitled "Curves and Tables for Short Wave Calculations" contributed by Mr. A. P. Castellain, he works out several examples of the inductance of coils. The formulæ involve logarithms and these logarithms are the so-called natural or Naperian logarithms to the base ϵ. Now the question which arises is this: is it preferable to work in these natural logarithms or to convert them straight away into the more familiar common logarithms to the base 10? Mr. Castellain apparently prefers the former method, but personally we always employ the latter method in such calculations. Not only are tables of common logarithms much more likely to be found at hand, but one can read them directly off any slide rule with an accuracy sufficient for almost every application apart from the class of work which is done at such institutions as the National Physical Laboratory. Not only so, but our whole system of numbers is based on the decimal system and the common system of logarithms is specially designed to facilitate calculations. One need only look at Mr. Castellain's calculation of $\log_\epsilon 1\,970$ to appreciate the point, for everyone knows that $\log_{10} 100$ is 2, but who could say at once that $\log_\epsilon 100$ is 4.605? When we have to calculate $\log_\epsilon 8a/\rho$ we therefore prefer to call it $2.3 \log_{10} 8a/\rho$, and having divided $8a$ by ρ on the slide rule, to read off the logarithm of the quotient and multiply it by 2.3 without writing a single figure.

The Inductance of Straight Wires.

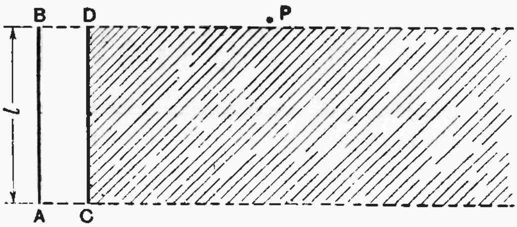
IT is generally stated that the inductance of a straight wire of length l cms. and small radius ρ cms. is for high frequencies given by the formula

$$L=2l\,(\log_\epsilon 2l/\rho - 1) \text{ cms.}$$

This is the formula given by Mr. Castellain in his article in this number, but let us look a little more closely into the meaning of the term the " inductance " of a piece of straight wire.

The formula given refers only to that part of the magnetic flux which lies between two parallel planes perpendicular to the wire and passing through its extremities. The current in the wire of length l produces a greater magnetic flux outside these planes than between them—the total flux is indeed infinite, as one can prove by simple integration—and however useful the above expression may be in subsequent calculations, there appears to be no justification for calling this the self inductance of the piece of conductor.

Similarly the formula usually given for the mutual inductance between two parallel conductors of length l is really a formula for the magnetic flux due to unit current in the wire AB, which passes through the rectangular strip shown shaded which must be assumed to stretch away to infinity. Now this is a very useful thing to know, but it is not at all clear why one should call it the mutual inductance between the two wires.



This is generally defined as the lines due to unit current in AB which cut the wire CD. Now who will say that the line of force due to AB which passes down through the paper at P got there without cutting the wire CD? The application of the terms self and mutual inductance to straight pieces of wire without any reference to the rest of the circuit is bound to lead to such difficulties.

Esperanto and the Reader.

FOR some time past a good deal of space has been devoted in E.W. & W.E., month by month, to the international language, Esperanto. With the commencement of a new volume it is natural that the question of the relative importance of various sections of the Journal should receive the special attention of the editors. To guide us in our decision as to whether or not the space and attention which has been devoted to Esperanto in the past has met with the approval of our readers, we invite those readers who appreciate the section to send us a post-card expressing their views, and our decision regarding the allocation of space to Esperanto in the future will be largely influenced by the response received to this invitation.

Notes on the Laws of Variable Air Condensers.

By W. H. F. Griffiths. [R381·4

AMONG the most important components of a modern wireless receiving set are its variable condensers, and care should therefore be exercised in the selection or design of these units for any particular purpose. If the maximum capacity of a condenser is too great, tuning by its means may become too critical due to its having too great a capacity change for a given angular movement, more particularly at the commencement of its scale. This effect may be minimised by the fitting of a worm gear or other form of fine adjustment gearing to enable very fine angular movement to be smoothly performed, but again it must be remembered that in most wireless circuits employing potential-operated detectors and amplifiers, such as crystals and thermionic valves, the capacity of oscillatory circuits at resonance should be kept within limits, as the oscillatory potential available across these circuits is proportional to the reactance of that capacity, which is inversely proportional to that capacity.

If, on the other hand, a variable condenser has too small a maximum capacity value, there is a probability that it will have a far too limited *range* of capacity variation, due to the fact that its minimum or "zero" capacity cannot possibly be reduced *proportionately* to its maximum capacity, especially when it is augmented by the distributed capacity of the inductance coil with which it is paralleled and by various lead capacities, inter-electrode valve capacities, etc. If the condenser is fitted with an electrostatic screen which is connected electrically to its moving plate system, its minimum capacity is even more seriously augmented because of the large surfaces of fixed plate system and screen (between which the full potential difference exists), which are of necessity *constantly* in fairly close proximity unless the size of the screen is made impossibly large.

When a variable condenser of the correct value has been chosen, some idea as to the "law" connecting its capacity variation with angular movement must be known.

Assuming that the mechanical imperfections of a condenser have been removed (*i.e.*, that each moving plate rotates truly parallel with, and exactly midway between, the pair of fixed plates with which it interleaves) the capacity change, if semi-circular plates are employed, should follow the straight line law

$$C = a\theta + b \quad \ldots \quad \ldots \quad (1)$$

in which C = capacity, θ = degree scale reading and a and b are constants, "a" determining the "slope" $dC/d\theta$ of the curve (or $\tan \alpha$) and "b" determining the position of its intersection with the "C" ordinate as shown in Fig. 1.

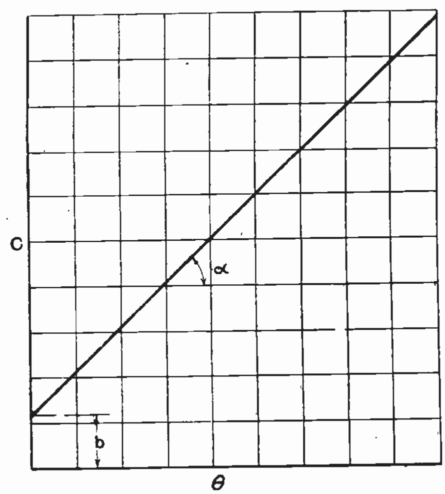


Fig. 1.

Actually, however, as is well known, the curve only obeys this straight line law between certain limits of capacity, such as those of θ=20 degrees and θ=160 degrees of Fig. 2. Outside these limits the curve bends owing to the absence of uniformity of field at the edges of both plate systems and to the 5 degrees cut-away portions of the moving plates in some makes of condensers.

If the capacity values of the condenser be measured at, say, 20 degrees and 160 degrees, a pair of simultaneous equations may be formed, the solution of which will give the constants of the law to the curve so :—

$$\text{When } \theta=20^\circ \qquad C=72\mu\mu F$$
$$\text{and when } \theta=160^\circ \qquad C=460\mu\mu F$$
$$\therefore\ 460=160a+b$$
$$\text{and } \ 72=\ 20a+b$$
$$388=140a \qquad \therefore\ a=2.77$$
$$\text{and } b=72-55.4$$
$$=16.6\mu\mu F$$

The complete equation to the capacity curve

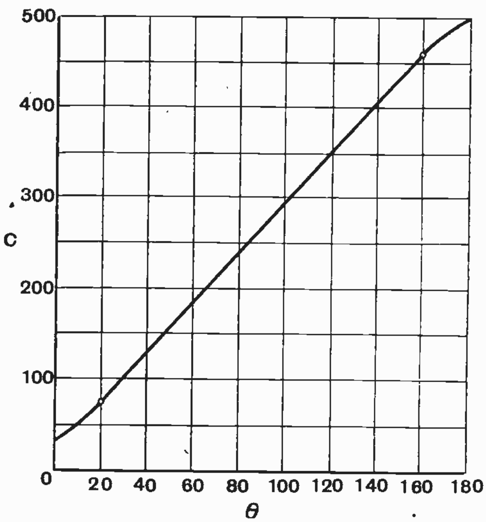


Fig. 2.

of Fig. 2 between the limits $\theta=20^\circ$ and $\theta=160^\circ$ is therefore

$$C=2.77\theta+16.6\mu\mu F$$

It will be observed that the two ends of the curve are bent to about the same extent ; this shows that the moving plates are symmetrically spaced relative to the fixed plates when the condenser is set at zero, as

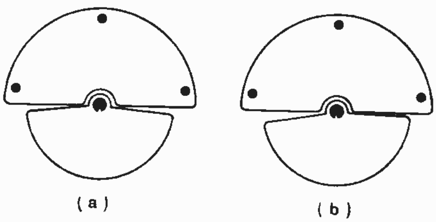


Fig. 3.

shown in Fig. 3 (*a*). If they were not symmetrically set as, for instance, is shown in Fig. 3 (*b*), the curve itself would also be unsymmetrical about the 90° point as shown in Fig. 4, with a consequent increase in the constant " *b* " of the curve and in the residual capacity value at 0°.

The reason for limiting the moving plates to about 170 degrees as shown in Fig. 3 is, of course, merely to effect a reduction of this residual minimum capacity value.

It has been stated above that each moving plate should rotate exactly midway between the pair of fixed plates with which it interleaves.

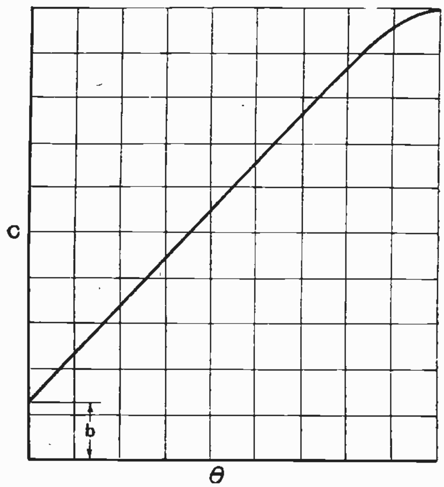


Fig. 4.

The reason for this is that since the *capacity* between the adjacent moving and fixed plates is connected with the *distance* between them by an inverse law, it follows that the percentage change of capacity (for a fixed scale setting) due to a given change of position of one bank of plates, axially relative to the other, will be a minimum when the distance between *all* adjacent plates is a maximum. This can only occur when the distances between all adjacent plates are

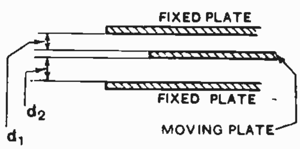


Fig. 5.

equal, and in this condition the capacity value of the condenser is, of course, a minimum for any given degree scale reading.

Let d_1 and d_2 be the distances of the dielectric gaps shown in Fig. 5 then the capacity of the condenser is proportional to $1/d_1+1/d_2$.

$\therefore$ Capacity is proportional to d_1+d_2/d_1d_2, but d_1+d_2 is constant.

$\therefore$ Capacity is proportional to $1/d_1d_2$.

In order to show that this exact "mid setting" of plates is far from being unimportant, a curve (Fig. 6) has been plotted giving, for any *initial* percentage axial displacement of one set of plates from the correct "mid position," the percentage capacity variation of the condenser, for any fixed scale setting, when a given small axial displacement of one set of plates occurs due to some mechanical defect happening subsequent to calibration.

From a glance at this curve it will be seen that the calibration constancy of a variable condenser is very largely due to the careful equalisation of *all* the dielectric gaps. Further, it will be seen that the closeness with which a condenser follows its law of capacity variation also depends very largely upon this adjustment, since the effect of any want of parallel movement of the moving plates will be less evident after the gap equalisation has been effected.

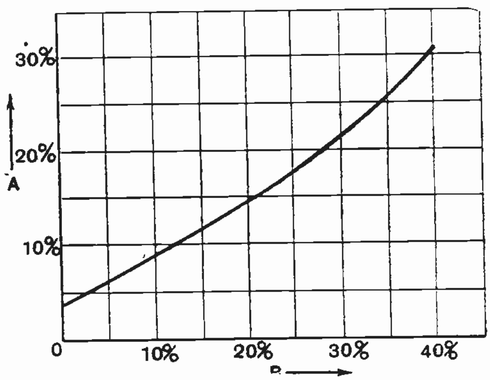


Fig. 6.

(A) *Percentage variation of capacity for a displacement of one set of plates axially relative to the other, equal to 10% of the two gaps $d_1 \times d_2$.*
(B) *Initial percentage displacement of one set of plates from the "mid position."*

If the capacity curve of a condenser is known to be a straight line between limits, then the law of the curve connecting its degree scale reading with its wave-length for any given inductance may be very simply found, as

$$\lambda = k_1\sqrt{C} \quad \ldots \quad \ldots \quad (2)$$

and $$C = a\theta + b \text{ from (1),}$$

whence $$\lambda = k_1\sqrt{a\theta+b} \quad \ldots \quad \ldots \quad (3)$$

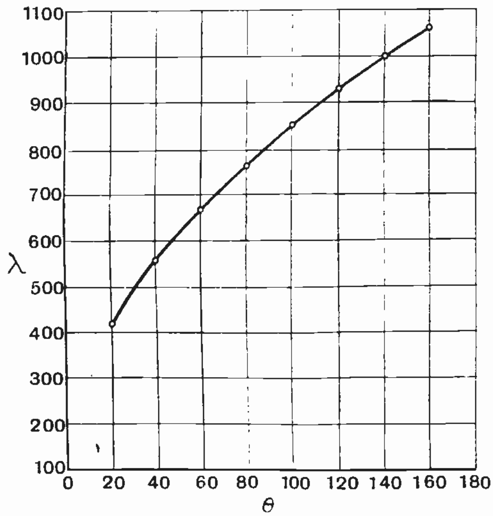


Fig. 7.

The constants "a" and "b" have already been found and if, for a given inductance, the constant k_1 (which is $1\,885\sqrt{L}$) is assumed to be 50, then

$$\lambda = 50\sqrt{2.77\theta + 16.6} \text{ metres,}$$

and the curve to this equation can be plotted between the angular limits of the straight line law of capacity. This curve is shown in Fig. 7 and it should be noted that the distributed capacity of the inductance coil has been neglected in its calculation.

In passing it may be of some interest to note the best-known method of determining the distributed capacity of an inductance coil of an oscillatory circuit when plotting the wave-length curve of the latter.

As the wave-length of an oscillatory circuit is proportional to the square-root of the capacity, if, instead of plotting wave-length against capacity, the *square* of the wave-length be plotted against capacity, a straight line as shown in Fig. 8 will be obtained. If now the line be continued beyond the point where $C=O$ it will cut the axis of C at a point representing the *true* zero of capacity of the oscillatory circuit and the distance "C_s" from this point to the zero of *added* capacity will be a measure of the distributed capacity of the inductance coil and circuit generally.

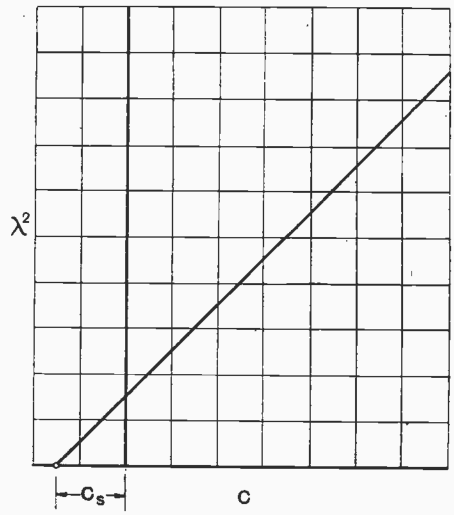


Fig. 8.

It should be noted that in this curve (Fig. 8), unlike all the previous curves, actual capacity values are plotted along the *x* axis, and *not* degree scale readings. The reason for this is obvious.

Variable condensers having semi-circular moving plates, although giving an even variation of capacity value, do not, of course, give even variations of wave-length value; and in view of this, condensers having "square law" shaped moving plates have been designed, in which attempts are made to make the curve plotted between wave-length and degree scale reading a straight line.

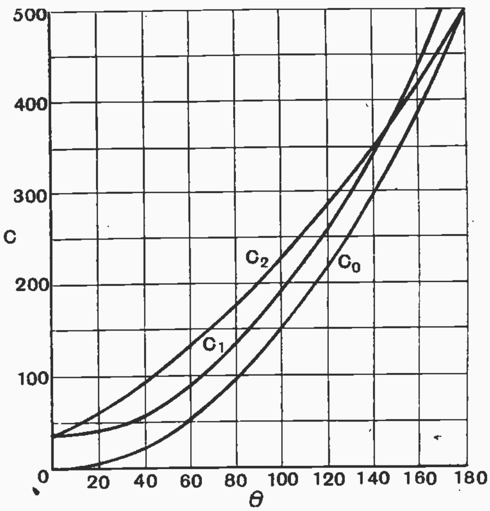


Fig. 9.

In such condensers the capacity value at any point of the scale should be proportional to the square of the degree scale reading.

As an example of method, the simple calculation for such a plate is given, though for reasons shown later it will not in practice fulfil its object.

If the residual (zero) capacity of a variable air condenser of this type, together with the distributed capacity of the inductance coil,

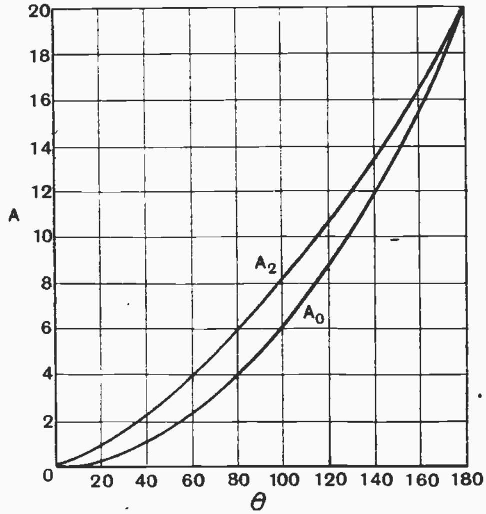


Fig. 10.

be neglected, the law connecting capacity and degree scale reading will be

$$C_0 = a\theta^2 \text{ (where a is a constant)} \quad .. \quad (4)$$

and if a condenser having a maximum value of $500\mu\mu F$ be taken as an example, when $\theta = 180°$ $C_0 = 500$

$$\therefore \quad a = \frac{C_0}{\theta^2} = \frac{500}{180^2} = 0.015\,4$$

and the equation to the capacity curve becomes

$$C_0 = 0.015\,4\theta^2 \mu\mu F.$$

This true "square law" curve is given as C_0 in Fig. 9, and to satisfy this square law of capacity increase with angular movement "θ" of moving plates, the area of moving plate "A_0" enclosed by the fixed plate system at any angular position "θ" must be proportional to $0.0154\theta^2$.

$$\therefore \ A_0=k_2(0.0154\theta^2)$$

and if the total area of the moving plate is assumed to be 20 square centimetres, then $A_0=20$ when $\theta=180$

$$\therefore \ k_2=\frac{20}{0.0154\times 180^2}=0.0399$$

and the law becomes

$$A_0=0.0399\times 0.0154\theta^2$$
$$=0.000615\theta^2 \text{ square centimetres.}$$

This curve of plate area plotted against degree scale reading is given as A_0 in Fig. 10, and the shape of plate given in Fig. 11 satisfies this curve.

The radius of this plate at any given angular position θ may be found in the following manner :—

For small angular increments $\delta\theta$ (Fig. 11) the incremental areas may be regarded as sectors of circles of radius R, and as the area of a sector of a circle is

$$\frac{a}{2\times 57.3}.R^2, \quad [\text{Radian}=57.3 \text{ degrees}]$$

the shaded area $\delta A_0=\frac{\delta\theta}{2\times 57.3}R_0^2$.

From this

$$R_0=\sqrt{\frac{114.6\,\delta A_0}{\delta\theta}}$$

and by making the angular increments $\delta\theta$ infinitely small the exact value of R_0 is obtained

$$R_0=\sqrt{114.6\frac{dA_0}{d\theta}} \quad \ldots \quad \ldots \quad (5)$$

and from $A_0=0.000615\theta^2$

$$\frac{dA_0}{d\theta}=0.00123\theta$$

$$\therefore \ R_0=\sqrt{114.6\times 0.00123\theta}$$
$$=0.376\sqrt{\theta} \text{ cms.}$$

The radii at various angles given in the following tabulation may, from this formula, be very rapidly computed, and from them the shape of the plate drawn as in Fig. 12*a*.

It should be noted that in the above formulæ for the plate area and shape no account has been taken of the semi-circular non-active centre portion of the plate.

Apart from this, such a true "square law" plate shape is of very little use, for it only gives a "square law" capacity curve (C_0 of Fig. 9), if the residual capacity of the condenser is neglected. A reasonable value for this residual capacity (*i.e.*, the capacity at 0^0), as augmented by that of the leads together with the distributed capacity of the inductance coil, would be about $36\mu\mu$F, and so the curve C_0 of Fig. 9

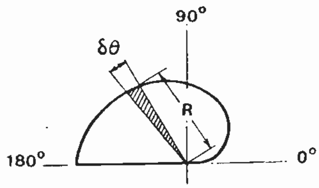


Fig. 11.

must be displaced upwards by this amount, giving the new curve of actual resultant capacity C_1 at any degree scale reading of the condenser when using plates shaped to the area curve A_0 Fig. 10 [$R_0=0.376\theta^{\frac12}$]. This new curve, it will be seen, no longer gives a "square law" variation of capacity, and will therefore not satisfy the conditions for giving the straight line law of wavelength which it was required to obtain.

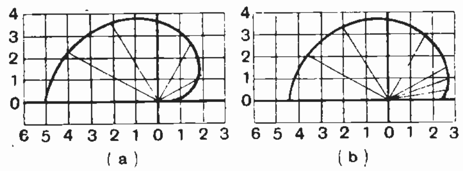


Fig. 12(a). $R_0=0.376\theta^{\frac12}$.

Fig. 12(b). $R_2=\left[114.6\left\{2ka_2(a_2\theta+b_2)+K\right\}\right]^{\frac12}$

Stated simply, the rate of increase of capacity is too great over the last quarter of the scale (tuning will be too critical) and not great enough over the first quarter of the scale (tuning will be very open).

In order to correct for this error a new law must be formed to take account of this all-important residual capacity.

θ degrees ..	0	1	2	5	10	20	30	60	90	120	150	180
R_0 centimetres..	0	0.38	0.53	0.84	1.19	1.68	2.06	2.91	3.57	4.12	4.60	5.05

Corrected Square Law Plate.

In order that the wave-length variation with angular rotation of the condenser shall be uniform (*i.e.*, that $d\lambda/d\theta$ shall be constant), λ must be proportional to $a\theta+b$, and as $\lambda \propto \sqrt{C}$,* it follows that C must be proportional to $(a\theta+b)^2$. Therefore

$$C=(a_2\theta+b_2)^2 \quad .. \quad (6)$$

where a_2 and b_2 are constants depending upon the maximum and augmented residual capacities of the condenser.

When $\theta=O$, C must obviously equal the residual capacity, and so

$$\text{Residual capacity}=b_2^2$$

from which the constant

$$b_2=\sqrt{\text{Residual capacity.}}$$

And when $\theta=180$, C must be the maximum capacity of the condenser.

$$\text{Max. cap.}=(180a_2+\sqrt{\text{Residual cap.}})^2,$$

from which the constant

$$a_2=\frac{\sqrt{\text{Max. capacity}}-\sqrt{\text{Residual capacity}}}{180} \quad (7)$$

For any desired values of maximum capacity and residual capacity therefore, the capacity at any scale position can be directly calculated from equation (6).

C is, of course, a composite capacity consisting of the residual capacity plus that due to actual plate area in operation, and the part due to the actual operative plate area is naturally equal to $C-$Residual capacity.

The plate area in operation at any degree scale reading θ will therefore have to be proportional to $C-$residual capacity.

Therefore from equation (6) the area of plate at any angle θ will be given by

$$A_2=k\{(a_2\theta+b_2)^2-\text{Residual capacity}\} \quad (8)$$

where k is a constant depending upon the total plate area. This, however, neglects to take account of that semi-circular portion of the moving plate which is rendered inoperative by the cut-away portion of the fixed plates round the spindle of the condenser. A term may be added to compensate for this error.

The inoperative area is always a sector of a circle of radius "r," and is

$$\frac{\theta}{2\times57.3}\cdot r^2$$

and this may be written $K\theta$ where the constant $K=r^2/114.6$.

The complete expression for plate area therefore becomes :—

$$A_2=k\{(a_2\theta+b_2)^2-\text{Residual cap.}\}+K\theta \quad (7)$$

When $\theta=180$, A_2 is, of course, the total plate area, and if this is given the value of the constant k may be found for—

Total plate area =

$$k\{\text{max. cap.}-\text{Residual cap.}\}+180K$$

from which the constant

$$k=\frac{\text{Total plate area}-180K}{\text{Max. cap.}-\text{Residual cap.}} \quad .. \quad (10)$$

From (5) the radius R at any point of the plate is :—

$$R=\sqrt{114.6\frac{dA_2}{d\theta}}$$

And from (7)

$$A_2=k\{(a_2\theta+b_2)^2-\text{Residual cap.}\}+K\theta$$
$$=k\{a_2^2\theta^2+2a_2b_2\theta+b_2^2-\text{Resid. cap.}\}+K\theta \quad (11)$$

Differentiating—

$$\frac{dA_2}{d\theta}=k(2a_2^2\theta+2a_2b_2)+K$$
$$=2ka_2(a_2\theta+b_2)+K \quad .. \quad (12)$$

Therefore the radius of the corrected square law plate at any angle θ is given by—

$$R_2=[114.6\{2ka_2(a_2\theta+b_2)+K\}]^{\frac{1}{2}} \quad .. \quad (13)$$

As an example a condenser having a maximum capacity of 500μμF has been taken, and it has been assumed that, in the absence of more exact data, the residual capacity, augmented as previously explained, will be of the order of 36μμF. The capacity curve for this condenser to equation (6) is given in Fig. 9 (C_2). The plate area curve to equation (9) is given in Fig. 10 (A_2), and the values of plate radius R_2 for various values of θ have been computed from equation (13) and are given in the following

θ degrees	0	5	10	20	30	60	90	120	150	180
R_2 centimetres	2.49	2.56	2.60	2.76	2.89	3.18	3.56	3.86	4.12	4.38

tabulation. As a basis for the dimensions of the plate a total plate area of 20 square centimetres has been taken for this example.

Figs. 12*b* and 13 show the shape of the plate drawn with these radii and it will be seen that it differs greatly from the "square law *area*" plate of Fig. 12*a*, although it will

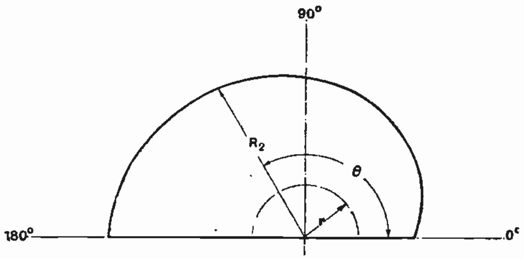


Fig. 13. $R_2[114.6\{2ka_2(a_2\theta+b_2)+K\}]^{\frac{1}{2}}$
(See also Figs. 16 and 19.)

give a true "square law *capacity*" change and a consequent *uniform scale of wave-length.*

It is of interest, perhaps, to note that the effect of ignoring the centre inoperative portion of the moving plate is to *decrease* the minimum radius from 2.49 cms. to 2.32 cms. and to *increase* the maximum radius from 4.38 cms. to 4.48 cms.

Fig. 14 shows curves of calculated wave-length ($\lambda = 50\sqrt{C}$) plotted against degree scale readings obtained by the use of plates of the three shapes discussed up to the present. The curve λ is obtained when semi-circular plates are employed, the curve λ_1 when plates of radii R_0 are employed and the curve λ_2 when plates of radii R_2 are used. The curve λ_2 is, of course, absolutely straight throughout its entire scale length whereas the curve λ_1 is far removed from this ideal.

If a variable condenser having plates shaped to give a straight line curve of wave-length is fitted with a single fine adjustment plate or "vernier," the evenness of its scale graduations, it should be noted, will depend upon the single plate being at its position of minimum capacity. If the single plate happens to be in a position of considerable capacity the wave-length curve will be bent slightly for the first few degrees of the scale. It should also be noted in connection with "vernier" plates that these should preferably be of semi-circular shape (irrespective of the shape of the plates of the main condenser unit) in order to obtain the same degree of fine tuning whatever the exact position of the single plate happens to be.

Inverse Square Law Plate.

Although the square law plate shape facilitates the "tuning-in" of stations whose wave-lengths are known and renders less critical the tuning adjustments at the lower capacity end of the scale, it is obviously not the *ideal* plate shape that should be used for C.W. work. Beat notes are governed by frequency difference. In order to obtain tuning adjustments equally critical as regards "chirp" at all parts of a tuning condenser scale, the latter should be evenly divided in *frequency* and should have a plate shape designed to give this "straight line law" of frequency variation with degree scale reading. In this case the heterodyne beat note range (*i.e.*, angular movement of the condenser scale required to vary the note of heterodyning with a station of constant wave-length from, say, 1 000 cycles per second through exact synchronism to 1 000 cycles per second on the opposite side of synchronism), will be constant for all scale readings. It should be noted also, in passing, that *frequency* tuning would facilitate supersonic

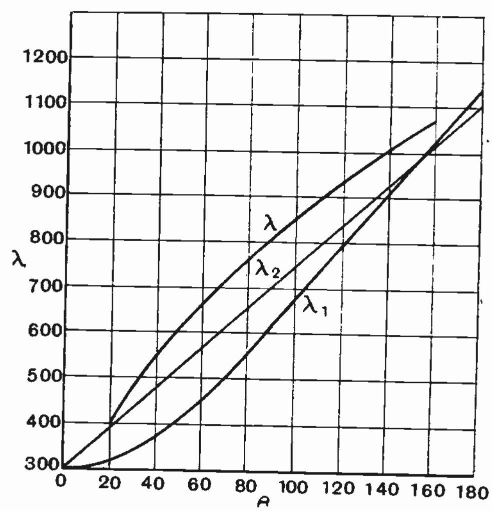


Fig. 14.

heterodyning, where constant *frequency* differences between receiver and local oscillator are required.

To proceed with the design of this uniform frequency change condenser plate, since frequency is inversely proportional to wave-length, *i.e.*,

$$f = \frac{3 \times 10^8}{k_1\sqrt{C}}$$

then in order to obtain a straight line law between frequency and degree scale reading it is at once apparent that the capacity of the condenser must vary inversely as the square of the degree scale reading. The equation to the capacity curve must be :—

$$C_3 = \frac{1}{(a_3\theta + b_3)^2} \quad \ldots \quad \ldots \quad (14)$$

where a_3 and b_3 are constants depending upon the maximum and residual capacity values of the condenser.

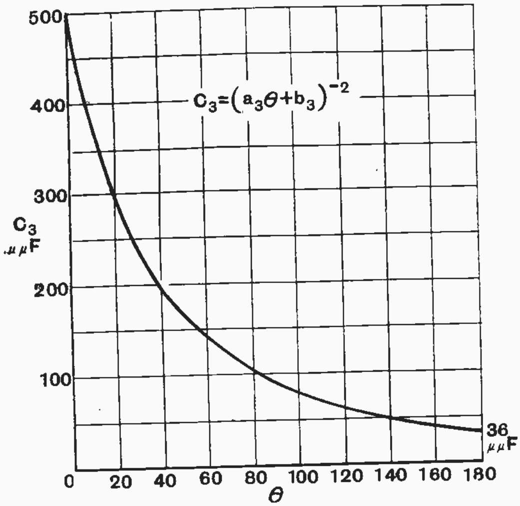


Fig. 15 (See also Fig. 9).

If the maximum capacity is known and the residual capacity is estimated, the values of these constants may be found.

When $\theta=0$, C_3 must be the maximum capacity and so

$$\text{Maximum capacity} = \frac{1}{b_3^2}$$

from which the value of the constant b_3 is

$$\sqrt{\frac{1}{\text{Max. cap.}}}$$

and when $\theta=180$, C_3 must be the value of the residual capacity.

$$\therefore \text{Residual cap.} = \frac{1}{(180a_3 + b_3)^2}$$

from which

$$a_3 = \frac{1}{180}\left\{\frac{1}{\sqrt{\text{Residual cap.}}} - b_3\right\}$$

The part of the capacity C_3 due to actual plate area is C_3— Residual Capacity, and the plate area in operation at any degree scale reading θ must therefore be proportional to this value ; that is to say :—

$$A_3 = k\left\{\frac{1}{(a_3\theta + b_3)^2} - \text{Residual Cap.}\right\} \qquad (15)$$

But, to be exact, a term must be added as before to account for the semi-circular centre portion of the plate which is rendered inoperative, and this will involve the constant K, the value of which was determined for equation (9), the term itself in this case obviously being $K(108—\theta)$, and the complete area expression becomes :—

$$A_3 = k\left\{\frac{1}{(a_3\theta + b_3)^2} - \text{Residual cap.}\right\} + K(180 - \theta) \qquad (16)$$

and for any given total plate area the value of the only remaining unknown, the constant k, can be determined. It is easily seen that this has the same value as in equation (10), in fact the values of k and K are unaffected by the law of the plate, and from (16)

$$\frac{dA_3}{d\theta} = -\left[\frac{2ka_3}{x^3} + K\right] \text{ where } x = a_3\theta + b_3 \qquad (17)$$

Therefore :—

$$R_3 = \left[114.6\left\{\frac{2ka_3}{(a_3\theta + b_3)^3} + K\right\}\right]^{\frac{1}{2}} \quad .. \quad (18)$$

The minus sign obtained when differentiating merely indicates that the area is decreasing with increasing values of θ and can be ignored in forming the expression for R_3.

As an example, in the design of a plate to this law, a condenser to give a uniform scale of frequency and having the same values of maximum and residual capacities as those of the square law example has been worked out. In order to facilitate comparison also, the total plate area has been made the same as that of the square law example. The data therefore are as follows :—

Max. cap. 500$\mu\mu$F.
Augmented residual cap. 36$\mu\mu$F.
Total plate area (at $\theta=0$) 20 square cms.

The curve of Fig. 15 has been plotted for this condenser the capacity values being obtained by the use of the equation (14).

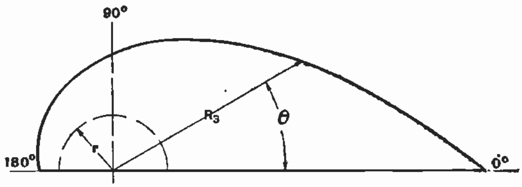


Fig. 16. $R_3 = \left[114.6\left\{\frac{2ka_3}{(a_3\theta+b_3)^3}+K\right\}\right]^{\frac{1}{2}}$
(See also Figs. 13 and 19.)

The values of plate radius R_3 for various angles θ (tabulated below) have been computed from formula (18), and Fig. 16 is a scale drawing of the plate shape constructed to these values.

$\theta°$	R_3 cms.
0	8.25
10	6.70
20	5.62
30	4.80
40	4.17
60	3.32
80	2.75
100	2.37
120	2.10
140	1.90
160	1.76
180	1.65

Fig. 17 shows the variation of frequency with degree scale reading when using this condenser in conjunction with an inductance of a value such that

$f = \frac{3 \times 10^8}{50\sqrt{C_3}}$ in order to keep the example easily comparable with that of the previously designed square law plate.

Exponential Law Plate.

There is yet another condenser law which is extremely useful in radio work for all purposes except where autodyne reception is used (for which the previous type is the best); the "exponential" or "compound interest" law.

When using a variable condenser having plates formed to suit this law in an oscillatory circuit, the same *percentage* detuning will be obtained for equal degree scale movements at all positions of the scale. That is to say, the rate of change of wave-length (or frequency) at any setting of the condenser will be proportional to the wave-length to which that setting corresponds.

$\frac{d\lambda}{d\theta}$ must be proportional to λ

or $\frac{d\lambda}{d\theta} = b\lambda$ where b is a constant.

The law which satisfies this condition is, of course, the exponential law.

$$\lambda = a\varepsilon^{b\theta} \quad .. \quad .. \quad (19)$$

At the suggestion of the Editors the present article is being extended to cover the design of a plate to give this law connecting wave-length and degree scale reading.

Since the wave-length corresponding to any condenser setting θ is given by

$$\lambda = a\varepsilon^{b\theta}$$

and $$\lambda = k_1\sqrt{C}$$

then $$k_1\sqrt{C} = a\varepsilon^{b\theta}$$

or $$C = \frac{1}{k_1^2}\left(a\varepsilon^{b\theta}\right)^2 = \frac{1}{k_1^2}a^2\varepsilon^{2b\theta}$$

The equation to the capacity curve of this condenser must therefore be

$$C = a_4\varepsilon^{b_4\theta} \quad .. \quad .. \quad .. \quad .. \quad (20)$$

where a_4 and b_4 are constants depending upon the maximum and residual capacity values of the condenser. It should be noted here that $b_4 = 2b$, as the constant b of equation (19) will be useful later.

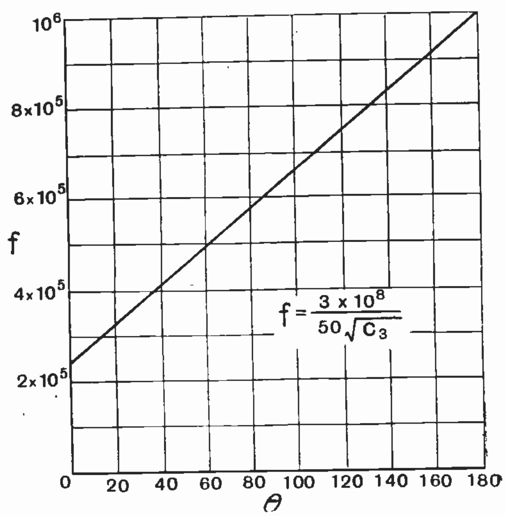


Fig. 17. (See also Fig. 14.)

The values of these constants are very easily determined from the values of maximum and residual capacity, because when $\theta = O$,

$\varepsilon^{b_4\theta}$ becomes unity and so the constant a_4

is the effective (augmented) residual capacity of the condenser.

Also, when $\theta=180$, C_4 must be the value of the maximum capacity of the condenser and so :—

$$\text{Max. cap.} = (\text{Residual cap.})\epsilon^{180b_4}$$

Equating logarithms :—

log (max. cap.) =
log (residual cap.) + $(180b_4 \, log_{10}\epsilon)$

from which

$$b_4 = \frac{log\ (\text{max. cap.}) - log\ (\text{residual cap.})}{78.174} \qquad (21)$$

As in the previous examples the part of the capacity at any angle due to actual operative plate area is

$$C_4 - \text{residual cap.},$$

and the operative plate area for any condenser setting must therefore be

$$A_4 = k\left(a_4\epsilon^{b_4\theta} - \text{residual cap.}\right) \quad .. \quad (22)$$

but the term $K\theta$ must be added to this expression to compensate for the loss of area round the condenser spindle, the complete area expression becoming :—

$$A_4 = k\left\{a_4\epsilon^{b_4\theta} - \text{Residual cap.}\right\} + K\theta \quad (23)$$

The values of the constants K and k can be determined from a knowledge of the total plate area and the radius of the centre cut-away portion of the fixed plates round the spindle ; in terms of these dimensions they will be exactly as determined for equation (9) for the plate area of the square law plate.

As the radius of the plate at any angle θ is given, as in the previous examples, by :—

$$R_4 = \sqrt{114.6 \frac{dA_4}{d\theta}}$$

the expression for plate area (13) must be differentiated, which gives

$$\therefore \frac{dA_4}{d\theta} = ka_4b_4\epsilon^{b_4\theta} + K \quad .. \quad (24)$$

The plate radius is therefore given by

$$R_4 = \left[114.6\left\{ka_4b_4\epsilon^{b_4\theta} + K\right\}\right]^{\frac{1}{2}} \quad .. \quad (25)$$

Values of capacity and plate radius for a condenser of the same value and total plate area as assumed in the other examples have been computed from these formulæ, and the results given in the capacity curve of Fig. 18 and the plate shape drawing of Fig. 19.

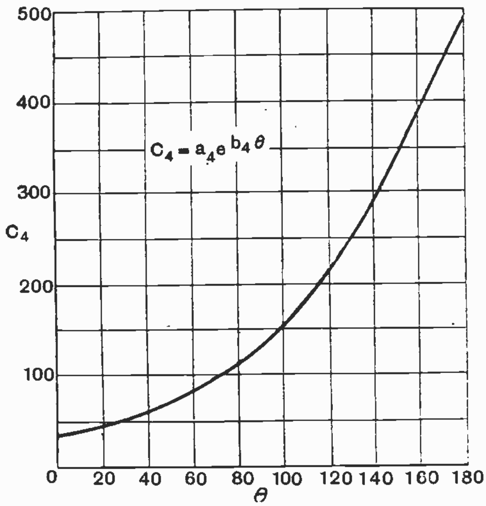


Fig. 18.

These two figures should be compared with the corresponding figures for the "square law" and "inverse square law" plates. The following tabulation gives the values of plate radius R_4 for various angles θ.

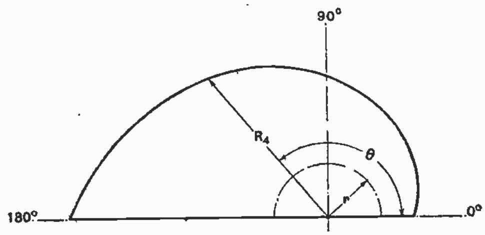


Fig. 19. $R_4 = \left[114.6\left\{ka_4b_4\epsilon^{b_4\theta} + k\right\}\right]^{\frac{1}{2}}$
(See also Figs. 13 and 16.)

Fig. 20 gives the wave-length curve obtained with the condenser of this example

θ deg.	0	10	20	30	40	60	80	100	120	140	150	160	170	180
R_4 cms.	1.93	2.02	2.13	2.24	2.36	2.64	2.98	3.38	3.85	4.40	4.71	5.04	5.40	5.80

and from it will be seen that a given angular movement of the condenser will give the same percentage change in wave-length at all points of the scale.

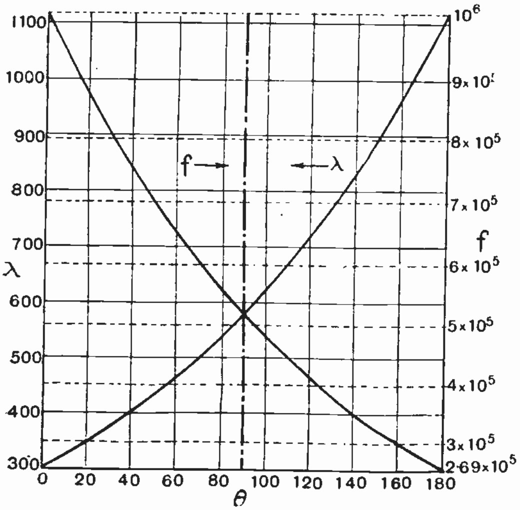


Fig. 20.

Moreover, it will be observed that the frequency curve, plotted in the same figure, follows the same law and that the two curves are perfectly symmetrical about the centre of the scale ($\theta=90°$). This fact is peculiar to the exponential law condenser and may be explained as under :—

$$\lambda = a\varepsilon^{b\theta}$$

and $$\frac{d\lambda}{d\theta} = ab\varepsilon^{b\theta} = \underline{\underline{b\lambda}}$$

but $$f = 3\times 10^8\left(\frac{1}{\lambda}\right) = 3\times 10^8\left(\frac{1}{a\varepsilon^{b\theta}}\right)$$

$$= 3\times 10^8\left(\frac{1}{a}\cdot\varepsilon^{-b\theta}\right)$$

and $$\frac{df}{d\theta} = 3\times 10^8\left(-\frac{b}{a}\cdot\varepsilon^{-b\theta}\right)$$

$$= -b\left\{3\times 10^8\left(\frac{1}{a\varepsilon^{b\theta}}\right)\right\}$$

$$= \underline{\underline{-bf}}$$

$$\therefore \frac{d\lambda}{d\theta}\cdot\frac{1}{\lambda} = -\frac{df}{d\theta}\cdot\frac{1}{f}$$

Showing that the percentage change of *wave-length* per degree of movement is exactly equal to the percentage change of *frequency* per degree and this percentage is a constant characteristic of the condenser, remaining the same whatever the value of the associated inductance (provided that the value of its distributed capacity has not varied greatly from that of the inductance for which the condenser was designed). The value of this percentage change is, of course, simply $100b$ and the constant b has already been seen to be equal to $\frac{b_4}{2}$.

The value of the constant b_4 was determined for the equation (20) to the capacity curve and is

$$b_4 = \frac{\textit{log}\text{ (max. cap.)}-\textit{log}\text{ (residual cap.)}}{78.174}$$

and so the percentage change in wave-length *or* frequency per degree is given by

$$100b = \frac{\textit{log}\text{ (max. cap.)}-\textit{log}\text{ (residual cap.)}}{1.56348} \quad (26)$$

The percentage of wave-length change in the case of the example given here is 0.7315% per degree (Fig. 20).

There is no need to remind the reader of the advantages of a condenser giving this law of wave-length variation in cases of tests and comparisons requiring equal percentages of detuning from exact resonance and these notes would not have been complete without its inclusion.

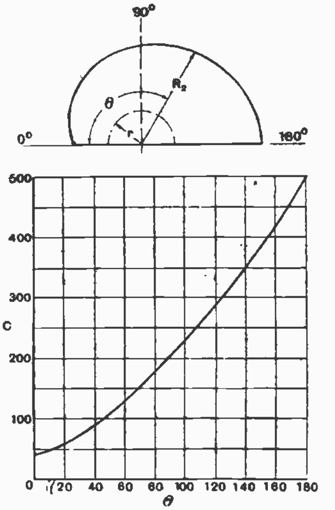
Conclusion.

In conclusion it is thought that a summary of the formulæ and their constants will prove useful and these have therefore been tabulated on the next page in a form which facilitates comparisons of the three chief laws. This tabulation is headed by true scale drawings of the plate shapes and their capacity curves and it should be noted that the three plates have the same total area.

It is hoped that this table will prove useful as a reference guide since it provides in a condensed and convenient form the information required by those concerned in condenser design.

TABLE GIVING A SUMMARY OF FORMULÆ AND THEIR CONSTANTS.

PLATE DESIGN FOR CONSTANT WAVE-LENGTH CHANGE.



$$C_2=(a_2\theta+b_2)^2$$

$$A_2=k\left\{a(_2\theta+b_2)^2-\text{Residual Capacity}\right\}+K\theta$$

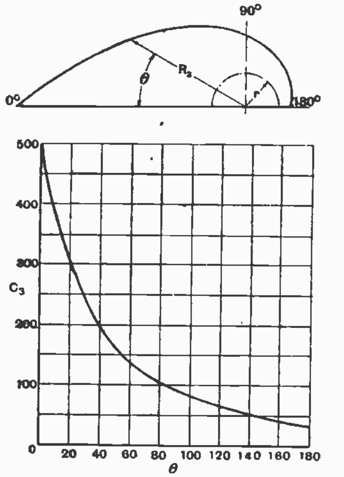
$$R_2=\left[114.6\left\{2ka_2(a_2\theta+b_2)+K\right\}\right]^{\frac{1}{2}}$$

Constants—

$$a_2=\frac{\sqrt{\text{Max. Cap.}}-\sqrt{\text{Residual Cap.}}}{180}$$

$$b_2=\sqrt{\text{Residual Capacity}}$$

PLATE DESIGN FOR CONSTANT FREQUENCY CHANGE.



$$C_3=\frac{1}{(a_3\theta+b_3)^2}$$

$$A_3=k\left\{\frac{1}{(a_3\theta+b_3)^2}-\text{Residual Capacity}\right\}+K\,(180-\theta)$$

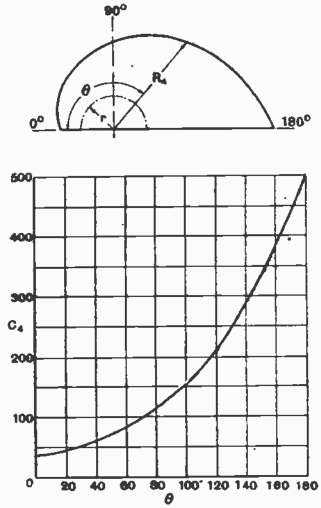
$$R_3=\left[114.6\left\{\frac{2ka_3}{(a_3\theta+b_3)^3}+K\right\}\right]^{\frac{1}{2}}$$

Constants—

$$a_3=\frac{1}{180}\left\{\frac{1}{\sqrt{\text{Residual Capacity}}}-b_3\right\}$$

$$b_3=\frac{1}{\sqrt{\text{Max. Capacity}}}$$

PLATE DESIGN FOR CONSTANT PERCENTAGE CHANGE OF WAVE-LENGTH OR FREQUENCY.



$$C_4=a_4\epsilon^{b_4\theta}$$

$$A_4=k\left\{a_4\epsilon^{b_4\theta}-\text{Residual Cap.}\right\}+K\theta$$

$$R_4=\left[114.6\left\{ka_4b_4\epsilon^{b_4\theta}+K\right\}\right]^{\frac{1}{2}}$$

Constants—

a_4 = Residual Capacity

$$b_4=\frac{\log(\text{Max. Cap.})-\log(\text{Residual Cap.})}{78.174}$$

COMMON CONSTANTS—

$$k=\frac{\text{Total Plate Area}-180K}{\text{Max. Capacity}-\text{Residual Capacity.}}$$

$$K=\frac{r^2}{114{\cdot}6}$$

The Performance of Amplifiers. [R342

Paper read by Mr. H. A. THOMAS, M.Sc., before the Wireless Section, I.E.E., on 2nd December, 1925.

Abstract.

THE paper describes work carried out for the Radio Research Board at the National Physical Laboratory.

In an introduction the term "amplifier" is specified as being applied only to a combination of components fulfilling the purpose of pure H.F. or of L.F. amplification, while an "amplification system" can be of any of the combinations: (A) H.F. with detector, (B) detector and L.F., (C) H.F., detector and L.F. stages. The performance of an amplifier must be expressed in terms of: (1) its voltage amplification, (2) its effect upon the circuit to which it is connected, (3) its distortion of wave-form. These properties are intimately related, but the amount of experimental work carried out has been insufficient for an attempt to correlate any one property with any other.

SECTION 1.

The Measurement of Voltage Amplification.

This section opens with a discussion of practical difficulties, pointing out, *inter alia*, that the determination of the amplification is of value only when the E.M.Fs. and currents are of the same order as those encountered in practical operation.

Next is described the method employed by the author in making the measurements described in the paper. The outline of the apparatus is shown in Fig. 1.*

The actual measuring instrument was a vibration galvanometer, in connection with a current transformer joined to a measuring valve. The input E.M.F. was derived from a step-down H.F. current transformer of the Dye pattern. To operate the vibration galvanometer this transformer output to the amplifier was modulated at 1 000 cycles. The condition of complete modulation was determined by the auxiliary crystal circuit shown. On over-modulation, a second harmonic is easily detectable in the telephones, the point where it just vanishes being that of complete modulation. Fig. 3 (not reproduced) illustrates the somewhat extensive switching system used to enable check of calibration, etc., and to apply the audio source alone as input for L.F. amplification measurements. In discussing the results obtained, curves of voltage amplification against wave-length are shown; additional curves obtained since the original paper was written were also illustrated by slides at

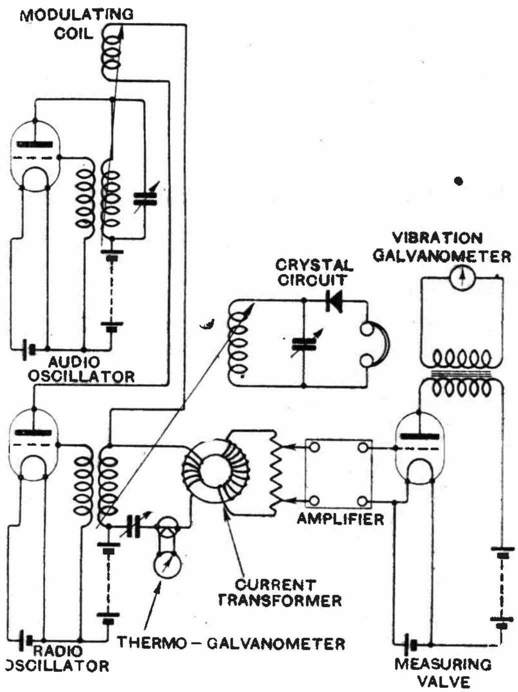


Fig. 1.

the meeting. In the curves for two apparently identical H.F. amplifiers, transformer coupled, very different amplitudes are noticeable, the factor per stage in one case actually exceeding that of the valves, due to reaction effects which were increasing while in the other case they were decreasing

* The author's original figure-numbers are used throughout this abstract.

the overall amplification. A curve for a 6-stage resistance capacity amplifier shows the known inferiority of this arrangement at shorter wave-lengths. As regards L.F. amplifiers, it is stated that several standard amplifiers were tested at 1 000 cycles, and it was found that the overall amplification of several cascade stages was less than the product of the individual stages. A special 2-stage amplifier was made up with mercury cups and links to permit ready change to either or both stages. Taken separately, the stages gave 21.9 and 19.65 respectively, these becoming 22.2 and 19.2 on cascading, or 426 for the two stages as against 433, the product of their two separated values. The gain of 1 per cent. on the first stage is attributed to reaction effects back to a weak input, the loss of 2 per cent. on the second stage to the input being no longer sinusoidal. The effect of H.T. condenser and of separate batteries is also discussed, it being stated that separate L.T. batteries produce an increase of 4 per cent.

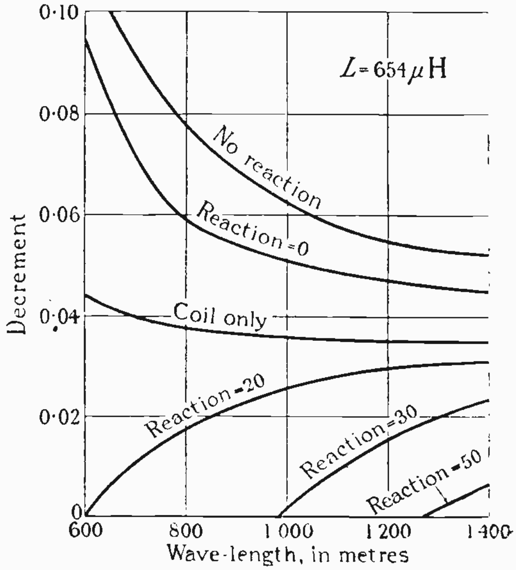


Fig. 9.

SECTION 2.

The Input Impedance of an Amplifier.

It is first pointed out that the effect of the amplifier upon the tuned input circuit is twofold :—

(A) To increase or decrease its effective resistance, due to power taken from (or delivered to) this circuit by the amplifier.

(B) To alter the tuning of the circuit due to the shunt capacity of the input circuit of the amplifier.

After discussing the difficulties of alternative systems of H.F. measurement, the use of a resonance method is described. The test circuit was kept constant and the input frequency varied, the supply oscillator being carefully calibrated and its variable condenser controlled from a distance of several feet. Expressions are given for calculation of decrement, and curves of decrement against wave-length are shown for three different values of tuned cir uit inductance 126 H, 654μH and 1930μH. Each curve shows the decrement for several different settings of reaction control, those for the 126μH coil revealing a hump about 505 metres, due, it is stated, to absorption at the natural wave-length of a very loosely-coupled aerial tuning coil which formed part of the tuner panel. The decrement of the tuned circuit alone is also shown, this having been separately determined, without the amplifier. From these curves the total effective resistance of the circuit was determined, and illustrated by curves, from which in turn the effective added resistance

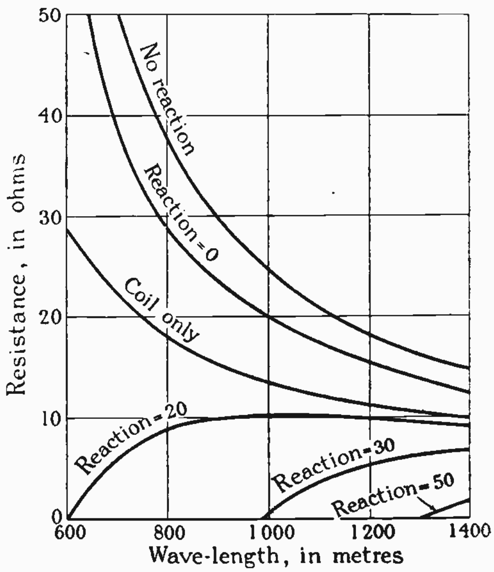


Fig. 12.

(positive or negative) due to the amplifier was ascertained. Typical curves are shown (for the 654μH coil) in Figs. 9, 12 and 15.

A theoretical treatment of these results follows. The load due to the amplifier is shown to be equivalent to a series resistance and capacity joined across the tuned circuit condenser. From a vector diagram expressions are derived for the calculation of the added resistance, tables showing theoretical and experimental values in good agreement. It is concluded that the capacity term of the amplifier load remains constant at all frequencies and values of tuning inductance, while the resistance term differs for various values of L as follows :—

L. μH.	R. ohms.
126	20 800
654	87 600
1 930	249 000

The vectorial treatment is then expanded to meet the case of reaction, and it is shown that this can be expressed in terms of the known theoretical conditions, *i.e.*, the electrical constants of the anode circuit and its mutual inductance to the input.

SECTION 3.

Distortion in Audio-Frequency Amplifiers.

It is stated that error in measurement of amplification is likely if the wave form departs from sinusoidal (as was mentioned in Section 1, in connection with the two stage L.F. amplifier). The vibration galvanometer measures the amplification of the fundamental, while an R.M.S. measurement includes the energy in harmonics that may be present. For this, and other reasons stated, it was necessary to establish the type of wave given by an amplifier under various conditions with a sinusoidal input. (The input was photographically verified to be of sinusoidal purity.) The former 2-stage amplifier was used, but distortion was found to be so great that one transformer only was used, while the author emphasised that the transformer was of the best possible make. Wave-forms at between 130 and 300 cycles were obtained with an Einthoven galvanometer and high-

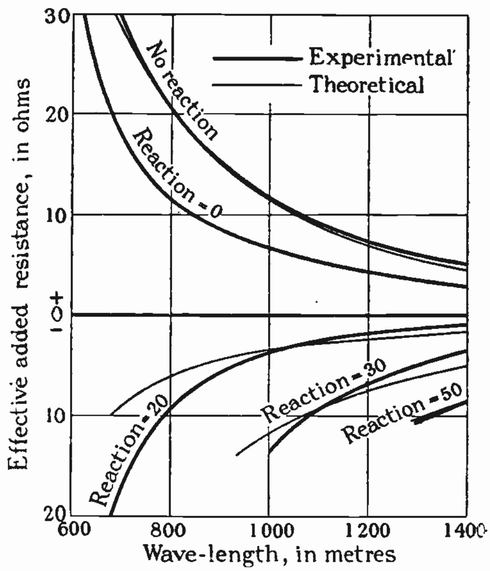


Fig. 15.

speed paper camera. For the higher frequency of 1 000 cycles (as used in the amplification determinations), a cathode ray oscillograph was employed. The exciting source was also used to supply the time scale to the oscillograph, the resultant Lissajou figures being photographically recorded on bromide paper and analysed into simple wave-form figures. The most important curves of wave-form at both 130 and 1 000 cycles are illustrated, and details of the Fourier analysis of the forms illustrated are given in a table.

Many of the forms show severe distortion due to harmonics, even with —4 volts grid bias, although it is stated that with —2 or —4 volts grid bias the output was never great enough to give a grid current. Although more experimental work is still necessary to confirm the general conclusions so far obtained, these can be stated. (i.) Increasing output modifies wave-form seriously. In general harmonics increase in magnitude far more rapidly than the fundamental. (ii.) As frequency is lowered, distortion becomes much more serious. At 150 cycles the fundamental may be almost completely eclipsed. (iii.) The effect of negative grid bias is to reduce the magnitude of the second and third harmonics and to introduce small harmonics of a higher order. From consideration of the ratios of the actual peak to the peak of the fundamental component and to the peak of a pure sine wave of the same R.M.S. value, it is shown that there is a definite distortion leading to an error of 18 per cent. which apparently cannot be removed by reducing the signal amplitude. It is suggested that this is probably due to the normal D.C. anode current component in the transformer primary. The author finally concludes that the general observations point to peak values giving the chief measure of output sound effect upon the human ear, which may lead to modification in our measurements of signal intensity.

Discussion.

A lengthy discussion followed the reading of the paper. The discussion was opened by Prof. C. L. Fortescue, who thought that difficulty might arise from the extensive switching used (as stated in the paper) for check of calibration. He also doubted the efficiency of the screening arrangements described and questioned the amount of distortion quoted by the author.

Mr. L. B. Turner doubted the wisdom of the vibration galvanometer, which he agreed to be sound for L.F. measurements but not for H.F., for which purpose he expressed preference for a valve voltmeter (*e.g.*, Moullin). He also questioned the amount of distortion, which he attributed to grid current or to unsuitable voltages.

Mr. Willans contributed remarks which were rather by way of a separate communication than a criticism of the author's paper. He described a bridge method of measurement, which permitted determination of both amplification and phase. Two diagram slides were shown (with formulæ for calculation), and several result curves. At the end of the meeting Mr. Willans gave a demonstration of his method.

Mr. J. Hollingworth outlined the origin of the method described in the paper, and referred to the N.P.L's. need for a method of standardising amplifier measurements. The vibration galvanometer he regarded as the most suitable arrangement available, while admitting it was not perfect.

Major A. G. Lee dealt with the measurement of decrement, with relation to the determination of input impedance.

Col. Edgeworth spoke on distortion, suggesting that experiment was necessary to find out how much distortion was due to the transformer.

Mr. P. K. Turner dealt with H.F. measurement and input impedance. He also spoke of the distortion quoted in the paper, which he suggested might be due to inadequacy of valve characteristic.

Dr. R. L. Smith-Rose referred to the need for a method of testing the overall characteristics of a wireless receiver to bring such measurements into line with those which the N.P.L. already performed for other branches of industry.

The author briefly replied to the main points raised in the discussion. In particular, he defended the use of the vibration galvanometer, and pointed out that the switching arrangements were only in use for the measurement of amplification not for input impedance. The connections made were such that the grid and filament were always connected to the same points for all the tests. He also emphasised that in the cases of negative grid bias quoted, no grid current flowed to account for the distortion shown in his wave-form curves.

On the motion of the Chairman (Major B. Binyon), the author was cordially thanked for the paper.

Experimental Radio Station G2DX.

By W. K. Alford.

[R625

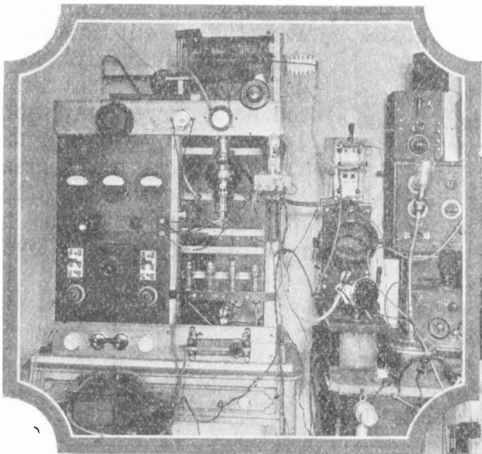


Fig. 1. *The 90-metre transmitter.*

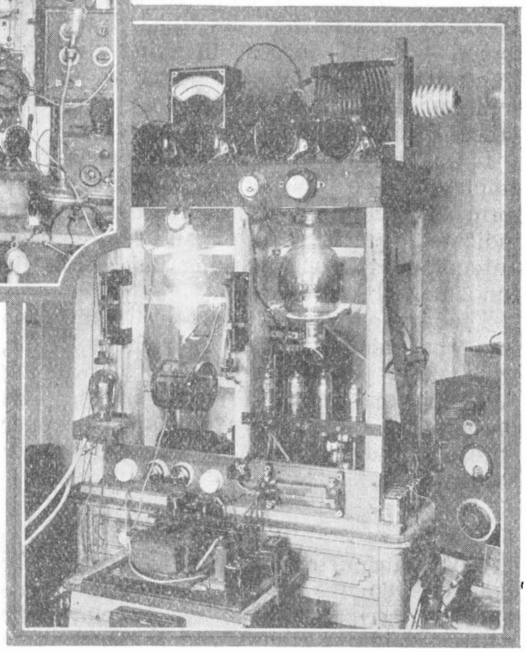


Fig. 2. *General view of the 35-metre transmitter.*

Short-wave Transmitting and Receiving Work.

THE earliest investigations of the possibilities of short-wave transmission were carried out by the writer in the winter of 1920-21, when the first of a series of transmitters was built and operated on a wave-length of 30 metres.

An exceedingly useful amount of data was obtained which has proved invaluable in later days, although, of course, it was not possible to collect any information on the signals from long-distance sources, as the Atlantic remained unconquered in the wireless sense at this date.

It is interesting to note that in these early experiments harmonic excitation of a large aerial was used and the receiver employed a single valve loosely coupled regenerative circuit much on the lines of the present arrangements. The greatest distance at which short-wave signals were observed was about 15 miles, and owing to their extreme weakness at this distance compared with 1 000 and 440 metre signals [*sic*], the opinion was formed that the utility of these short waves was confined to the laboratory. This is interesting and even humorous in the light of present events.

A non-technical description of the present receiver and various transmitters, which have been developed during the last twelve months, is appended, together with illustrations.

Power Supply for Transmitters.

Power for all purposes is derived from supply mains at 250 volts 50~ of particularly poor sine form. This is stepped up to 3 000 volts through a Zenith transformer for anode supply and stepped down to 30 and 15 volts by other transformers for filament lighting. Full-wave rectification of the high-tension output is obtained through the now famous Amrad "S" tubes—two in series operating on each side of the centre tap of the transformer. This is necessary owing to the unfortunate limitation of the tubes to 1 000 volts.

The rectified output is then smoothed by two Igranic I/C chokes of 2H in each lead and bridged by two condensers, banks of 13 and 4μF being connected across the input and output respectively of the chokes.

The 90-metre Transmitter.

This transmitter (shown in Fig. 1) has now been dismantled to make way for the 45-metre transmitter described later. It served a useful purpose in being the first transmitter built by the writer to enable communication to be maintained over distances of many thousands of miles.

It was originally of the simplest character, employing the well-known coupled Hartley form of oscillator, and delivered about 2 indicated amperes into an 8-wire cage antenna 70 ft. long working just below its fundamental wave-length.

The large valve is a Marconi-Osram T250 and the smaller one at the right a DET1, which later performed the feat of reaching Australia on an input of 66 watts. The inductances are wound with 6 s.w.g. copper wire and the various other items are easily recognisable.

The 45-metre Transmitter.

This transmitter evolved itself from the skeleton remains of the 90-metre transmitter described above. It employs the master oscillator circuit, which seems to be only little investigated by amateur workers. The circuit is given in Fig. 3, and a general view in Figs. 1 and 2.

The power amplifier is a Marconi-Osram T450A, the filament of which consumes 5 amperes at 17 volts; while the drive, or master, oscillator is a T250 of the same make. The inductances, other than that in the drive circuit, are wound with phosphor-bronze strip of heavy gauge, and the variable condensers tuning the various circuits are made by the Igranic Co., and are all mounted on plate glass—a feature of which the necessity was not fully realised until it was tried.

It may appear that the 250-watt valve, acting as the master oscillator, is unduly large but it seems that on these short wave-lengths plenty of "drive" is an absolute necessity.

The question of "blanking" stray H.F. currents at these frequencies by means of air-cored chokes cannot be overstressed. These chokes must be inserted in all filament leads and in the actual supply mains themselves.

A series of experiments is being carried out at the present time with this transmitter using crystal control of frequency. The DET1A valve seen at the right is actually used as a power amplifying stage for this purpose. Up to the time of writing considerable success and a great deal of interest have been derived from these experiments, but great difficulty has been encountered in controlling powers of over 50 watts input.

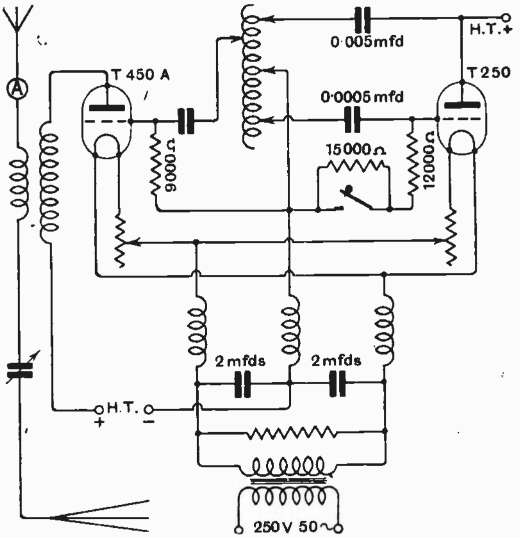


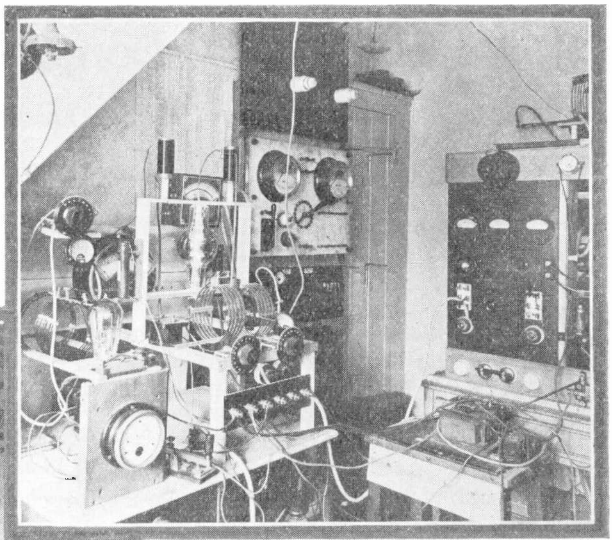
Fig. 3.
The circuit arrangement of the 45-metre transmitter.

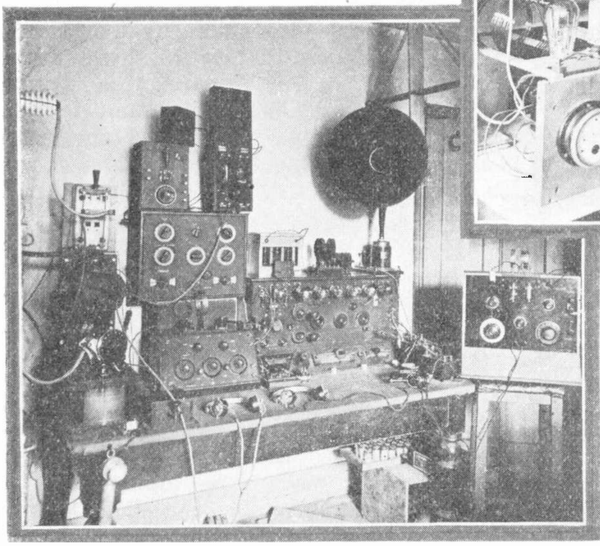
It is hoped to give details of these experiments at a later date, when the matter has been more fully investigated.

No trouble has yet been experienced owing to the failure of valves at these high frequencies. It is, of course, essential in valves where the anode lead comes up from the pinch through a re-entrant tubular space to keep this lead well clear of the glass, and I believe that in certain professional circles an "electrostatic balancing ring" surrounds the top of the valve. This, being connected to the anode, avoids any serious concentration of the field, which is the chief factor causing puncturing of the glass of the valve.

The 20-metre Set.

A general view of the 23-metre transmitter is shown in Fig. 4 and as will be seen is in a state of extreme experimental untidiness. At the time the photograph was taken work was being done on the application of the master oscillator to this wave-length, this valve being a DET1 and the amplifier a T250. The DET1 is rated at 40 watts and is too small to control the normal input to the





(*Above.*) Fig. 4. *The 23-metre transmitter.*
(*Left.*) Fig. 6. *The receivers at 2DX.*

T250; but in the case in point the power input to the amplifier was well under 100 watts.

Considerable interest was attached to a circuit attributed to Reinartz which functioned extremely well on this set using 12 ft. of copper tape above the set for an antenna and a similar length of heavy rubber-covered cable across the floor as a counterpoise.

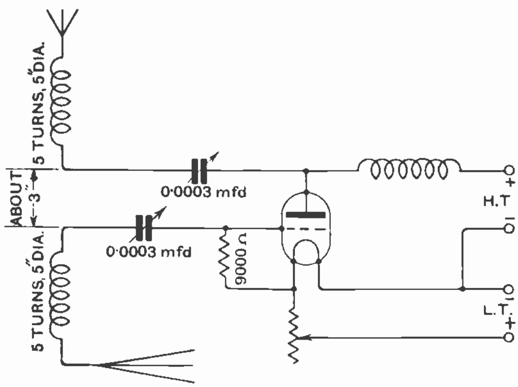


Fig. 5. *Circuit of 20-metre transmitter.*

The circuit is quite well known and is given in Fig. 5. It will be noticed that the circuit is simplicity itself, and it is interesting to observe that the inter-electrode capacity of the valve is used as a series antenna-counterpoise capacity.

This set gives an indicated antenna current of 2.2 amperes on 23 metres on the antenna described, and has been reported as giving good signals at 4 000 miles.

The Receiver.

A general view of the receiving equipment is shown in Fig. 6. The 2-valve instrument on the right was built when the difficulties of producing supersonic reception were encountered first and has a range of 5-70 metres. The main receiver is a 10-valve supersonic which now functions perfectly down to 17 metres and gives very remarkable results on the 20-40 metre range. Loud-speaker signals of great strength have been obtained from New Zealand using a 2 ft. loop of 2 turns. Such results are not at all exceptional and any supersonic will repeat them if patience is used to overcome the apparent unwillingness of the instrument to perform on the first trial.

Short Waves for Long Ranges: A Review.

By Capt. W. G. H. Miles, R.M. [R401·24

A Lecture delivered before the Radio Society of Great Britain on Wednesday, 25th November, 1925.

WHEN your Society honoured me with an invitation to lecture to-night, I had intended to give you some rambling reminiscences of the various uses to which wireless has been put in the Navy since the days of Trafalgar.

I was told however that you would prefer something more up to date.

I am therefore attempting to give a broad review of the progress made in the use of short waves for long range working since the war, together with an account of the reasons for their astonishing success.

I do not profess to be an expert on the subject, and speak subject to correction.

In his play, *Back to Methuselah,* Bernard Shaw says: "It's only the politicians who improve the world so gradually that nobody can see the improvement. The notion that Nature does not proceed by jumps is only one of the budget of plausible lies that we call classical education. Nature always proceeds by jumps."

If Nature proceeds by jumps, so does wireless. The progress of wireless may be divided into three eras: (1) The Spark Era; (2) The Valve Era; (3) The Short Wave Era.

In the first, the detecting apparatus—coherer, magnetic detector, crystal detector—was crude and insensitive.

In order to get the ranges required, spark transmitting plants of increasing power were installed, working on wave-lengths from 300m. upwards.

Such apparatus was wasteful of power, and caused much interference with similar installations trying to work on adjacent wave-lengths.

The second era dates from about 1914. The valve, invented by Fleming and developed by de Forest, Round, Langmuir, Lieben, Reiss, etc., worked a revolutionary change.

By its use one could employ more scientific methods in reception—amplification and re-action. Consequently receiving gear could be made more selective, receiving aerials could be reduced in size, transmitting power could be reduced, and full use could be made of C.W. transmitters—Poulsen arc, high frequency alternator, transmitting valve—which are more economical in power and permit of closer spacing of transmitting wave-lengths. Wireless direction finding became a practical proposition—a great boon to navigation. A perfect transmitter was made available for speech and music, so opening the way for the modern broadcasting.

The third era—that of short waves—dates from about 1922.

By short waves I mean those below 100m. These short waves have four outstanding advantages for long range working:—

The first is in economy of power. The new G.P.O. long-wave station at Rugby, which is designed to work to Australia, requires about 1 000 kW, whereas the short wave beam station now being erected by the Marconi Company for the G.P.O., and intended for the same purpose, will require about 40kW, *i.e.*, 4 per cent. of Rugby's power.

The second advantage is the possible utilisation of a totally virgin field of wave-lengths.

Before the advent of short waves it was becoming most difficult to fit in any new channel of communication in Europe or America; most of the available wave-lengths between 300 and 30 000m. were fully employed.

It is now possible to open up new services in the unrestricted field below 100m. This field is *not* as narrow as it might appear at first sight. The necessary spacing between two waves depends, not on their wave-length, but on their frequency, and the shorter the wave the higher its frequency and *vice versa* —"the higher the fewer!"

There is actually the same frequency difference between 9 and 10m. as between 90 and 30 000m.

If therefore the use of short waves proves as successful as we anticipate, and if the band of really useful short waves is not too narrow, there should be enough for everyone for a good long time.

It is as if a man living in an overcrowded house were to dig down through the floor of his cellar and find below another house of greater dimensions than his own.

The third advantage of short waves is that they can be concentrated in a given direction by the use of a reflecting screen.

In order to reflect any ether wave, the reflector must have dimensions of the same order as that of the wave being reflected. This process is, therefore, only applicable to short waves, as long waves are put out of court by the *size* of the reflector they would require.

The fourth advantage is that atmospherics, the world over, are far weaker on short waves than long ones.

A property of short waves when directed upwards—of leaving the surface of the earth near the transmitter and coming down again very much farther off—is an advantage when you know the position of the receiving station—since you can avoid interfering with intermediate stations—and a disadvantage when you don't, as in the case of communication to a mobile station.

Very short waves, of the order of centimetres, were used by Hertz in his pioneer experiments, and he also used a reflector to polarise them.

After that they were neglected for signalling purposes till 1918. Military authorities of a foreign country were testing them for the purpose of giving communication over a range of about 20 miles while being inaudible at 40 miles. This purpose they achieved, but to the astonishment of everyone they were picked up again in a country 2 000 miles away.

After the war the amateur comes into the picture, and, in my opinion, all wireless engineers owe a tremendous debt to him.

When bands of waves were being parcelled out for various services, the professional users were allocated all those thought to be of any value, while the amateur—at the end of the queue—was given the band below 220m. which no one else wanted.

As a great concession, he was also given 1 000m. for a time, as being the only one he could possibly get any range with.

It was thought possible that he might work from Balham to Peckham Rye, or even from Caterham to Gerrard's Cross. Instead, he promptly starts signalling across the Atlantic.

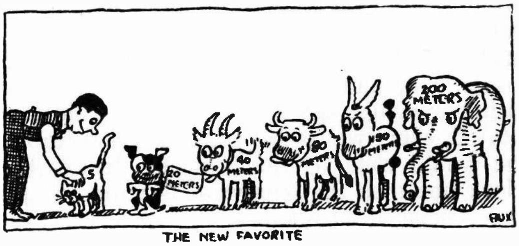
The sequence of affairs is roughly as follows: In December, 1921, an elaborate programme of transmission on 200m. by American amateurs was arranged, and read successfully in England at night only. The best reception was by an American, Mr. P. F. Godley, who erected a Beverage aerial specially for the purpose, in Scotland.

In 1923 two-way night communication was established between U.S.A. and France and U.S.A. and England on 100m.

In May, 1924, two-way night communication between Buenos Aires (using 120m.) and New Zealand (using 190m.).

In October, 1924, two-way night communication between England and New Zealand on 90m.

In May, 1925, two-way *daylight* communication between England and U.S.A. on 23m.



THE NEW FAVORITE

Fig. 1.*

Fig. 1 shows pictorially the reduction in wave-length that has taken and is taking place.

The foregoing is only a very brief summary, and to do justice to all the pioneer experimenters would take me all night.

It does, however, illustrate my point—namely, that of the rapid progress in invention and technique which has brought us to the present position when practically every range on the earth's surface has been bridged in daylight, with power less than a kilowatt.

I will now turn to professional developments.

After the war it was considered desirable to link up the Empire by wireless telegraphy to provide a service supplementary to the cables.

The first proposal was that of the Government Committee presided over by Sir Henry

* Reproduced by courtesy of *QST*.

Norman in 1922: that was to link up the Empire in 2 000 mile stages, using long-wave high power stations, with stations in England, Egypt, Nairobi, South Africa, India, Singapore, Hong Kong, Australia, Canada. This meant that a message for Australia would be relayed via Egypt, India and Singapore.

The Dominions replied that they would prefer to have larger stations and work direct.

A Parliamentary Commission in 1924, under Mr. Robert Donald, agreed to this, and the G.P.O. commenced the construction of Rugby, which will be opened before the end of the year; this station uses 1 000kW, has 12 masts 800 feet high, works on a wave of about 18 000m., and costs about £350 000.

Meanwhile Australia, South Africa, Canada and India entered into contracts with subsidiary companies of the Marconi Company for the erection of corresponding high power stations.

Suddenly, in July, 1924, Senatore Marconi announced that his short-wave experiments from Poldhu on a wave of 92m. had given him excellent communication with Australia, while darkness extended over the whole route, and had led him to believe that by using ultra high speed signalling, for which, he stated, short waves are particularly suitable, he would clear as much traffic during the dark hours as the long-wave stations would have done in 24 hours.

The waves would be directed on the required bearing by means of a reflecting screen, so giving great economy in power and freedom from interference.

In December, 1924, he further announced that using a wave of 30m. he had communicated to Montreal, Rio, Buenos Aires and Sydney *entirely during daylight* and without using a reflector.

His most recent experiments (September, 1925) showed that a wave of 15m. gave excellent communication with Rio by daylight, but that this wave failed during darkness.

As a result of these experiments, all the Dominion contracts for high power stations were cancelled, and substituted by ones for short-wave beam stations.

At the present moment beam stations are nearing completion in England as follows: At Bodmin a double transmitter for working to Canada and South Africa, with a double receiving station at Bridgwater; at Dorchester with reception at Somerton for working New York and South America; at Grimsby with a double receiving station at Skegness for working India and Australia. All these stations are being paid for if successful by the G.P.O., and will be controlled by land line from London.

It is interesting to note the cost of Rugby in comparison with the double stations at Bodmin and Bridgwater—the former costs £350 000 and the latter £55 000 per transmitter and receiver, or about one-sixth of the cost, and this would be lower still if all-round transmission were used instead of beam.

The results of trials of these stations will be awaited with much interest.

Numerous other long range services are springing up; for example: Paris to Djibouti—Madagascar to South America—Germany to South America—Holland to Java.

Nauen has three transmitters: POR13 and 18m.; POW 28m., 50kW; AGA 26m., 10kW.

A contrast to the optimism of the Marconi Company is found in an article by a French engineer in *Radio Electricité*, 10th May, 1925. He says:—

"From the different results obtained in France and abroad we can affirm that short-wave stations of powers from 10 to 20kW are capable of handling traffic at great distances, but only during certain strictly limited periods.

"Moreover, the possible duration of the traffic, as also the quality of the reception, itself vary from day to day and from season to season. It has even been noticed already that results vary from one year to another on corresponding dates, doubtless on account of differing atmospheric conditions.

"Progress will certainly be made. The most recent trials on short waves of the *order of* 30*m*. allow one to hope that the daily duration of use will be increased by reducing the wave-length. Perhaps one may be driven to the use of short waves of different lengths according to the conditions of the time and atmosphere. However that may be, one cannot hope that this new development will allow in the near future of a permanent long range traffic during 24 hours a day throughout the year."

The above article was however written six months ago, which is a long time in these days of short wave development, but

I believe this view that short waves will only be useful to supplement the service provided by long range high power stations, is shared by American radio engineers. Time and trial alone can show whether their eccentricities will prevent their use in entire substitution of long waves for long range working.

The next question to be considered is: In what way is the technique of short waves different from that of long ones?

In the transmitting circuit every precaution must be taken to keep the wave-length constant, and to avoid undesired capacity effects. All connections must be rigid and well spaced. A master-oscillator circuit of some sort must be provided, as the valve cannot be allowed to oscillate the aerial direct. Fig. 2 shows a typical circuit.

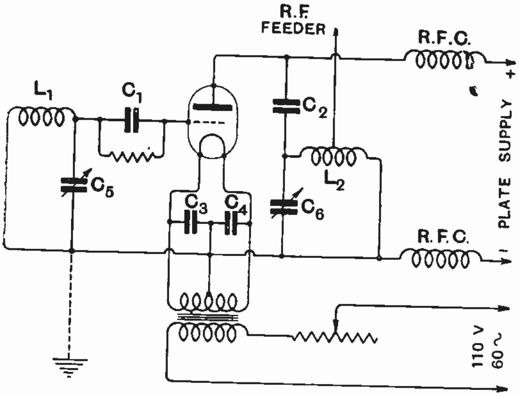


Fig. 2.* *A typical short wave transmitter.*

C_1 C_2 grid and anode stopping condensers; C_3 C_4 filament by-pass condensers; C_5 grid tuning condenser; C_6 anode tuning condenser; L_1 L_2 grid and anode coils; *R.F.C.* radio-frequency chokes.

The *aerial* itself is treated in a different way, in that account is taken of its length in proportion to the wave-length it is desired to transmit.

In the case of long waves, one hangs up an aerial, as high and as long as one can, ascertains its natural wave-length, and then loads it up with inductance till it is tuned to the desired wave-length.

In the case of short waves, however, the aerial is carefully measured and cut till it is some sub-multiple, *e.g.*, $\frac{1}{4}$, $\frac{1}{3}$, $\frac{1}{2}$, etc.—of the transmitted wave-length.

Very often the aerial is a rigid metal rod, as in the case of the American broadcasting station KDKA.*

Fig. 3 illustrates one aerial that was described in the American journal *Q.S.T.*

The "driver" circuit is the one illustrated in Fig. 2.

The length of the horizontal portion of the aerial is exactly $\frac{1}{2}\lambda$, and the aerial will oscillate as shown with a potential node and current antinode in the centre.

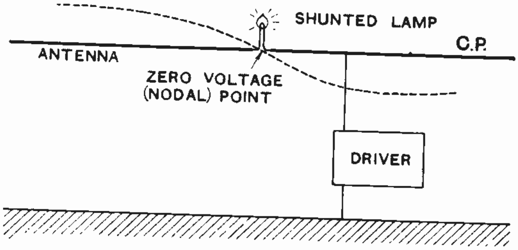


Fig. 3.*

The lamp in the middle, being at an antinode of current, will light up and is a convenient means of indicating resonance.

Receiving circuits may be of the simple type—having a valve detector and note magnifier as in Fig. 4.

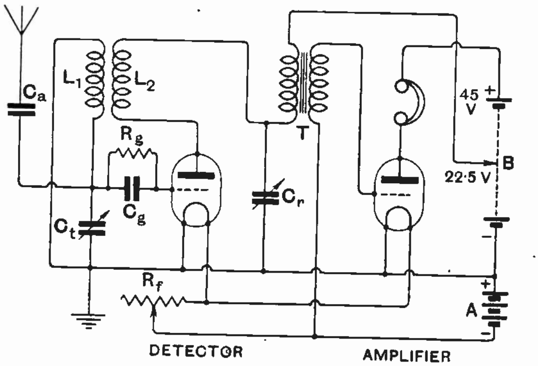


Fig. 4.† *A short wave receiver.*

C_a coupling condenser—two $\frac{3}{4}$ in. discs; C_t tuning condenser; C_r reaction control condenser; L_1 $2\frac{1}{2}$ turns 3in. dia.; L_2 $3\frac{1}{2}$ turns 3in. dia. for 20m; R_g 2—10 megohms.

* H. W. Williams, *Q.S.T.*, July, 1925.

* H. W. Williams, *Q.S.T.*, July, 1925.
† Circuit by Burgess Battery Co.

I will now turn to the question of why these remarkable results are achieved by short waves and not by long ones, and why such differences exist between the behaviour of various short waves.

The reasons appear to me to be threefold.

(*a*) The wave is directed upwards, and so travels round the world without expending energy in heating up the mountains, trees and clouds it would otherwise encounter.

(*b*) The short wave is reflected from the Heaviside layer at a flatter angle than the long wave.

(*c*) The short wave aerial is a better radiator of energy than the long wave one.

These statements require explanation.

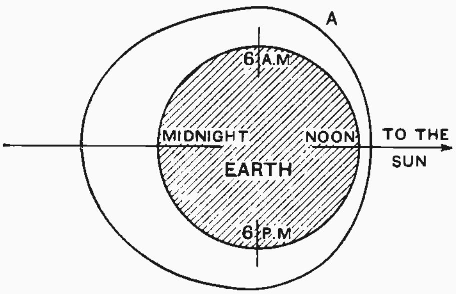


Fig. 5.

The fact that wireless waves get round the earth at all, instead of shooting off into space, is because they are partly guided round, following the surface of the earth and partly reflected round by the "Heaviside" layer.

The "Heaviside" layer is a layer of gases about 100km. above the surface of the earth, kept so ionised (*i.e.*, rendered conductive) by electrons and ultra-violet rays arriving from the sun, that they form a mirror to wireless waves and will not allow them to pass through.

You will notice that the distance of the layer from the earth (Fig. 5) is irregular, being farther away from the earth on the dark side, and nearer on the sunny side.

The existence of this layer is denied by some authorities. In my opinion, if it does not exist, there must be a similar layer with a different pet name if we are to account for 90 per cent. of the phenomena of long range wireless transmission!

Now in the case of the ordinary aerial where the wave-length is long in comparison to its height, the majority of the energy is directed along the ground, and only a comparatively small component upwards.

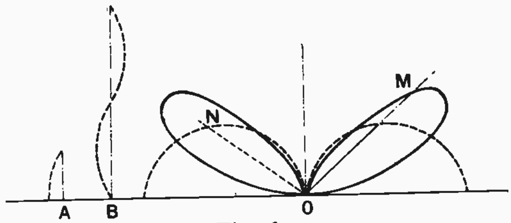


Fig. 6.

The "earth-bound" portion loses energy in every conductor it encounters, such as mountains, trees, ionised patches of air, etc., and generally gets very badly treated.

The "free" (upward) wave is reflected back to earth again, and has a very much better path for its travel than the ground wave.

Incidentally, at the point where it meets the ground wave again, one gets interference effects, which account for the well-known phenomena of "Fading."

The short waves, however, can be made to bear a definite relation to the actual length of the aerial and when they do, it is found that the radiation is directed upwards at some angle, instead of horizontally. Figs. 6 to 11 show the manner in which,

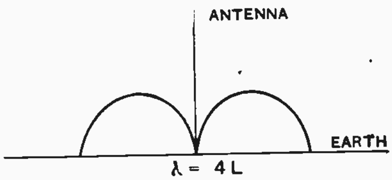


Fig. 7.

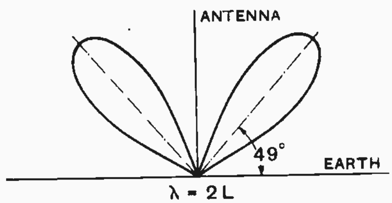


Fig. 8.

according to theory, energy is radiated from a vertical aerial on a perfectly conducting earth, at angles varying according to the relation the length of the aerial bears to the transmitted wave.

The theory that energy is reflected in an upward direction from a short-wave aerial is borne out by the fact that there is always (in all other cases except that of the quarter

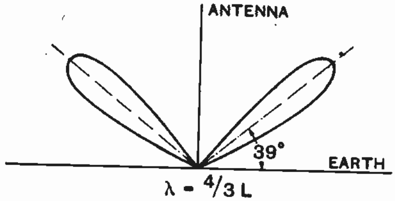


Fig. 9.

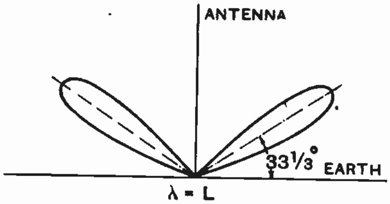


Fig. 10.

wave-length aerial) a zone in the neighbourhood of the transmitter in which signals cannot be heard, which is presumably because they are passing overhead.

This theory, shown in Fig. 8, leads one to wonder whether there is a best angle for the energy to be radiated according to the time of day and range required and whether the ratio

$$\frac{\text{wave length}}{\text{aerial length}}$$

should be arranged to give this angle.

Moreover, in theory, the energy radiated at this optimum angle can reach a high value compared to the energy emitted by a vertical aerial energised on its fundamental wave-length.

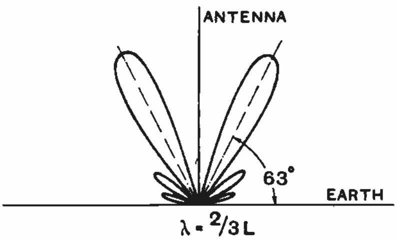


Fig. 11.

Thus, on the third harmonic, the energy radiated at an angle of 47° is one and a-half times that radiated horizontally by a vertical aerial oscillating at a ¼ wave-length; on the fifteenth harmonic, the energy, radiated at an angle of 72°, is four and a-half times greater than the radiation on the fundamental wave.

My statement that the Heaviside layer forms a reflector requires some qualification.

It is not a sharp clear-cut conductor, but a gas whose conductivity at any point depends on the number of electrons momentarily free of an atom.

The difference between a conductor and dielectric is a matter of degree, depending on the number of free electrons present.

This is particularly the case with a gaseous conductor.

Mr. Reinartz' theory is that while a long wave will be sharply reflected off it and attain only a short range, another shorter wave may penetrate a little way and go off at a different angle, or be only refracted (bent

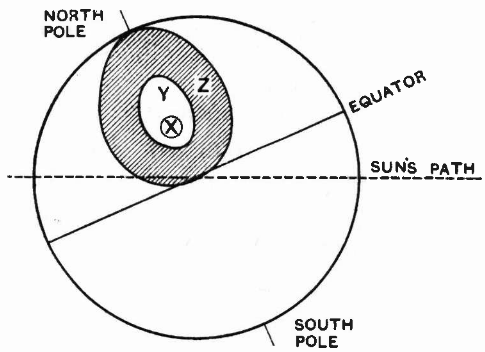


Fig. 12.

Signals can be heard in areas *X* and *Z*, not in area *Y*.

from its course) a little, and thus come back to earth farther off than the longer wave.

A useful, though not quite accurate analogy for the varying penetration of different wave-lengths into the Heaviside layer, is a spinning bicycle wheel: if you throw a tennis ball at it, the ball will glance off, whereas if you fire a bullet at it the bullet may pass through without touching a spoke.

In Fig. 13 we have a ray of light leaving water vertically and entering air. It does this without being bent: If the light starts at some slight angle, such as that of *B* in Fig. 13, it is refracted or bent as it leaves.

If it comes up through the water at a still flatter angle as *D* in Fig. 9, we shall get complete *reflection*, in which the angles I and R are alike.

Well, it may be that the shorter waves by penetrating farther into the Heaviside layer are either reflected or refracted on at a flatter angle than the longer waves.

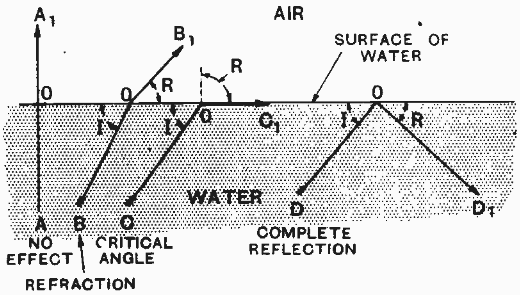


Fig. 13.

The third point deals with the radiation efficiency of an aerial.

Of the energy put into a transmitting aerial, some is expended in useful radiation, and the remainder in warming up the aerial and earth systems, neighbouring conductors, and poor dielectrics.

The higher we can make the ratio

$$\frac{\text{energy radiated}}{\text{total energy supplied}}$$

the more efficient is our aerial as a radiator and the less the power required.

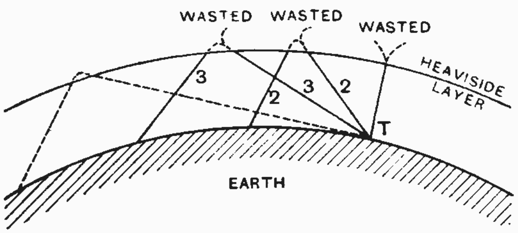


Fig. 14.

In other words, we want a high "radiation resistance"—a term denoting the ability of the aerial to radiate energy—and a low "loss" resistance due to aerial and earth conductors, etc., etc.

The radiation resistance of an aerial emitting a wave (λ) much longer than its height (h) is given by the expression

$$R_{rad} = 1600 \left(\frac{h}{\lambda}\right)^2$$

Thus an aerial 20m. high working on a 450m. wave-length would have a radiation resistance of 3.1 ohms, while if it were tuned to 800m. it would only have a resistance of 1 ohm.

In the case however of aerials whose height is of the same order as the wave-length employed, the radiation resistance increases enormously: *e.g.*, an aerial of height 15m. tuned to transmit a wave-length of 30m. would have a radiation resistance of 160 ohms, and a radiation efficiency of about 80 per cent.

You therefore get much better value for your money.

One would have thought that even before the merits of short waves were known, there would have been an ugly scramble for the shorter waves, on account of their greater efficiency of radiation, as shown by the above formula.

Against this must be set the fact that in the case of waves, the majority of whose energy is directed horizontally, the daylight losses are much greater on short wave-lengths than long ones.

Again, before the merits of short waves for easy communication over long ranges were realised, it was thought that the greater the range, the greater must be the power put into the aerial, whereas it now would seem to be much more important to choose one's wave-length correctly.

Big powers mean big aerials to handle the power; and big aerials mean long wave-lengths. Hence the wave of 18 000m. used by Rugby and that of 18 940m. used by Bordeaux.

The whole trend of wireless practice up to last year was in the direction of high powers, long wave-lengths, and elaborate measures to keep down resistance losses.

Since we hear so much nowadays about the beam system, I will now turn to the means used to focus short waves into a beam.

Any ether wave can be focused into a beam if the right sort of reflector is used.

In the case of the wireless beam the reflector takes the form of a number of wires hung up behind the transmitting aerial.

The shape of the reflector in plan may be either parabolic or straight.

The wires constituting the reflector are each separately tuned to the transmitting wave.

When the transmitting aerial is energised it sets all the wires of the reflector in oscillation, and the resultant radiation from them reinforces that of the transmitting aerial in the required direction, while behind the reflector and to the sides there is a little radiation.

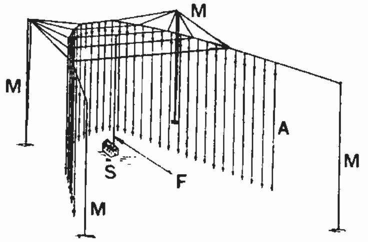


Fig. 15.

A parabolic reflector is not very convenient for long range working, in that it is hard to get into one short aerial all the energy one wants.

It is more convenient to put up a number of aerials in a row, Fig. 18, feed them in parallel, and give each a rear rank man to act as a reflector.

These reflector wires concentrate energy in one direction at right angles to the plane of the aerial—and annul it in the opposite direction.

The aerial wires have no tendency to radiate in a direction in line with themselves, by reason of the way in which they are spaced.

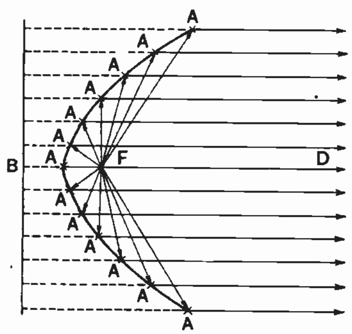


Fig. 16.

This is the form of aerial being adopted by the Marconi Co., both at their transmitting and receiving stations.

I will now drop theory, and turn to two most dramatic instances of the uses to which short wave can be put.

The first is that of the Rice Expedition.

This was an expedition led by Mr. Hamilton Rice, an American explorer, up the River Amazon at the beginning of this year. They took with them two wireless experts—Mr. J. W. Swanson and Mr. MacCaleb and a complete wireless telegraphy outfit.

To quote from *The Geographical Journal* for March, 1925:—

"About the middle of January Mr. Gerald Marcuse of Caterham began to pick up morse signals from the Expedition in the early morning, and learned from an amateur in New York that Mr. Swanson was receiving his signals from Caterham. At 6 a.m., on the morning of 19th January, Mr. Marcuse was called up by WJS and got into easy communication: at that date Mr. MacCaleb reported that they were also in touch with New Zealand.

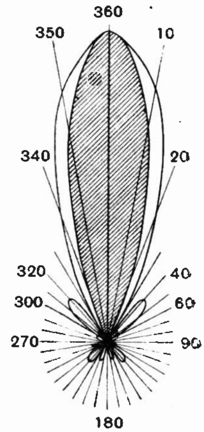


Fig. 17.

"On 6th February, we received, by the kindness of Mr. Marcuse, the following message:—

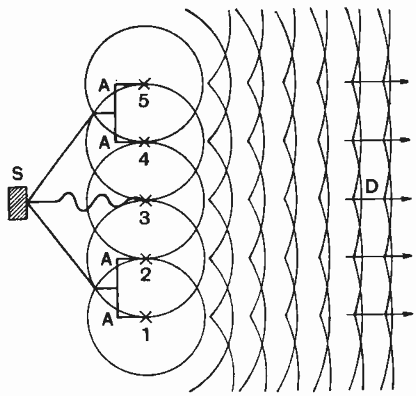


Fig. 18.

"'No. 1 words 68 via WJS and 2 NM. Main party arrived at junction URARI and URARICAPARA rivers 19th January, lat. 3° 22′ N. 61° 55′ W. progress slow, owing to extremely difficult physical conditions.

"'Personnel expedition numbers over fifty, good food, and cargo-relay transport working efficiently. Unable use hydroplane at present due low water, objects expedition being attained. All well. This message sent by expedition's own wireless.—RICE.'

"Mr. Marcuse kindly undertook to transmit a reply, and after a failure on 7th February, owing to atmospherics, was able to get through at 6.30 a.m., on 8th February. . . .

"The station WJS. at Boa Vista is using a Delco lighting set of gas-engine, dynamo and accumulators, from which they run a motor-generator. The wave-length was 81m.

"Thanks therefore to the skill and energy of Mr. Marcuse on this side it was established that an expedition 5 000 miles away in difficult conditions can from time to time report to us its progress in the field. . . ."

I may point out that had this expedition been in trouble it would have been possible to organise a relief expedition, on receipt of a request for help, by this route: and that not only would a long wave outfit have failed to get through at this range, but probably would not have got through to the nearest civilised town—at any rate using a long wave set light enough to be taken with the expedition.

A parallel instance is that of the wireless communication which has been maintained on short wave with the American Macmillan Polar Expedition ships *Bowdoin* and *Peary*. These ships off Greenland, have been read in the U.S.A., Mexico, Canada, England, France and Holland. On 37m. traffic was handled and Government messages passed by night. Daylight communication has also been effected on 20m., 16m., and 8.7m.

Traffic has actually been exchanged between the *Peary* and the U.S. fleet when off New Zealand.

A perfect channel of communciation has thus been provided by short wave, and this could not have been done in any other way.

In concluding I wish to state that the fighting services take a very keen interest in what you amateurs are achieving, especially when you record, analyse and publish your results.

All wireless engineers are trying to find out the possibilities of these short waves, and also their limitations.

It is only by numerous observations and accurate analysis of results that the laws governing their behaviour will be learnt. Accurate reports are needed, not only of when you do get through but also when you expect to get through and don't.

I know that when you have sat up all night trying to get someone in Kamschatka or One Horseville, Slosh, and at last succeed, you don't feel like sitting down and writing a long account to your Secretary about it. Unless that is done, however, half your work is wasted.

Try and evolve a theory of your own of what these short waves are doing and then set in and prove it.

The work of your Society and of its kindred societies in other countries, is something unique in the history of the world.

Men of different races are speaking to one another in a common jargon across half the circumference of the earth.

Who knows but that it may be one step towards promoting a better mutual understanding between nations, and towards the universal peace which we all—even we professional "hired assassins"—desire.

DISCUSSION.

Admiral Sir Henry Jackson: We are very much indebted to the author for his very instructive, historical and entertaining lecture. Certainly its delivery was almost perfect. He has not only given us the historical side of the progress of waves of different length but he has also given us a comparison between the obsolete or long wave high power transmission and the modern short wave low power transmission, and he has shown the advantages and disadvantages of each. I should like to criticise one point, because I do not think it is quite fair not to state that the long wave has not got those blind spots which at present exist in short wave transmission, and that is an important point. The long wave is not affected so much by its refraction at the Heaviside layer as the short wave is. Captain Miles has also given us a very clear description of the Heaviside theory, which is generally accepted now, I think, by the majority of scientists and certainly by practical men, although there is a minority which does not agree. The Radio Research Board, of which I am Chairman, have really set themselves systematically to study this question and to try and find out more about the Heaviside layer, whether it is refraction or reflection, etc., and if the height varies at different times with different wave-lengths. The Radio Research Board have set out to do this systematically, *i.e.*, we have got the best instruments we can get; photographic records are to be taken so that there can be no human error due to the ear to vitiate the results. Therefore you can imagine that I have listened to this lecture with very great pleasure and interest. We have heard of these blind spots jumping hundreds of miles here and thousands of miles there, and to have observers at all these places would mean two or three hundred and the Government would be rather against providing money for that purpose. We are therefore limiting ourselves to one thing at a time. We have done directional work and we have done long distance transmission. We are now doing broadcast wave-lengths and doing this work systematically, but we want to work down to the short wave-lengths. That will take some time and it will mean more observers. The author has mentioned the organisation in America and has given us some of the results they have obtained there. I was hoping, and I do hope, that the amateurs in England will give us some help. I have just been speaking to Mr. Marcuse and he tells me he is getting out some results, and if we have other results we shall be able to put them all down and deal with them at the same time and have them most carefully studied. In that way, we hope to get a good deal of information and that will be like having a very large increase in our staff. Therefore, I appeal to those who systematically receive short waves to send us in their results giving the different distances and times and whether the signals can be relied upon when they are being sent. That is the important point, to find out if there is much fading of the signals and also whether there are blind spots and whether they are at distances of 40 or 50 miles or distances of 3 200 or 300 miles. Information of that sort will be very useful. I will not worry you with my own experiments. I have been gradually working down to these short waves from waves of 200 or 300 metres during the past 18 months and it is very interesting work. I have found that the length of the aerial has a great deal to do with the reception as also has the type of valve, but the four-pin valve is all right. In conclusion, I would again say that we are very grateful to Captain Miles for his valuable paper.

Mr. L. F. Fogarty: The lecture, although it has been extremely interesting, is not of a very contentious nature. At the same time, one is entitled to feel very proud of the work of amateurs, as the author has said. I am afraid I cannot contribute anything useful by way of discussion and can only thank the author for his paper.

Mr. Gerald Marcuse: I am sure it has been very interesting listening to Captain Miles' description of short waves, what they do, how they go and how we get them. I am afraid none of us know very much about them yet and probably before 12 months are gone what we have been doing will all be obsolete. That is by the way. It is not many years ago that I was delighted when I was able to communicate five miles. That was with the old spark. Now I am very disappointed if I cannot do 14 000 miles. There is one very important point which the author did not touch upon which seems to me characteristic of short wave work. By that I mean waves below 90 metres, and that is what I may call the concentration of energy or focus point of these short waves or high frequency oscillations. We have definitely established the fact that there is a concentration of energy or focus point somewhere near the Antipodes and within a 600-mile radius of Sydney, and one curious thing is that although the signal strength seems to reach its maximum at that point these signals seem to transmit and to be received best when there is bright sunshine in both spots. We have all imagined that the 45-metre wave—taking that figure as it is the one with which we have been working most—travels best at night and that in daylight we have to drop down to a lower wave-length. That is not quite the case when transmitting to the Antipodes and the best results I have obtained have been when there has been bright sunshine both at the Antipodes and at the transmitting station. Which way the signals go round I am sorry I cannot prove, but it is evident that they travel for the greater part in daylight and penetrate a certain amount of the dark belt. I think we have pretty well conclusively proved that it is a reflected wave. Whether it is off the Heaviside layer or another layer which is beyond, none of us have been there to see (laughter). We have arranged for stations to listen for our signals in America, and they report them very weak, whereas Australia reports them as being very strong, so that that proves they do jump and radiate vertically and then reflect off the layer at a suitable angle for Australia which is there over the heads of intermediate listeners. There is another point which we must not lose sight of, and that is that not many years ago we were warned off a wave-length of 1 000 metres and then off 440 metres, and it was said that the amateurs could have 200 metres which was no use commercially and never would be. Times have changed since then, and I am afraid that some of the large power stations will be obsolete before they are completed. But there is another more important subject, and that is the effect of weather conditions on short waves. The cloud effect seems to be very pronounced. You will find at one moment that the atmosphere seems absolutely dead and then all of a sudden it will come live again. During the past two or three Sundays at midday you could communicate with any part of England but at six o'clock and afterwards everything disappeared and you could not hear an English signal at all on 45 metres. On the other hand, the signals from Australia could be heard as loud as possible. That is a matter which no doubt we shall find out something about. Evidently the one fact well established is that you will not find a short wave below 90 which will effectively communicate over long distances day and night. We shall have to have two wave-lengths for the two purposes. There is one rather curious phenomenon at the moment, and that is that at 3 o'clock in the afternoon you can hear Phillipine Island's amateur and China morse loudly and during the winter months you can listen to distant amateurs all day long. Last year on 90 metres there was a distinct variety of audibility of amateur stations in the Antipodes and on 90 metres it was impossible to communicate with Australia in the morning and with New Zealand in the evening. Now you can do both morning and evening to Australia on 45 metres. Atmospherics do not affect us much in this country, I am glad to say. Sometimes they are bad but generally, taking the whole year through, we find ourselves fairly free from interference in this way. The author touched upon the subject of organisation of amateurs. I think the International Amateur Radio Union is a wonderful organisation. Language forms no barrier at all, and although one may speak Hindu and the other English, we have a language of our own which we can communicate in and understand one another perfectly. I do not say that we can by word of mouth but by word of the key we can.

Major A. G. Lee: I would like to say a few words on the closing portion of the paper in which the author made the suggestion that amateurs should record their results in a more methodical fashion. If we want to know what these short waves do, we evidently want to know more than the mere fact that communication has been established for a few moments between, say, South America and England; we also want to know something about the wave-length, the mode of excitation of the aerial, the amount of power used, the readability of the signal, the amount of fading, etc. There are a number of variables and, if anything is to be sorted out of the results we get, all those factors which influence the result will have to be recorded and the observations tabulated. I do not know whether the Radio Society is undertaking such a work, but it seems to me that a really methodical investigation of the results obtained so far would be a very suitable cap to crown the work already done by the amateurs in showing the possibilities of short waves. The author's explanation of the Heaviside layer is very interesting, but there are some further points which might perhaps be added. The latest modern theories on the subject indicate that the magnetic field of the earth may have an effect on the propagation of short waves It has been found, for example, even with long waves, that magnetic storms have a very pronounced influence upon propagation. The earth's magnetic field enters into the mathematical expressions for propagation of short waves and it has a different effect upon propagation in east and west and north and south directions. This is another variable which might enter into the records of the short wave results. Another point which has been suggested to me is that the amount of power used in the transmitter may affect the path taken by the wave. One of the modern theories is that the wave gets on to the top part of the atmosphere, as the author has described, and there it can affect the free electrons or ions in the atmosphere—more probably free electrons—and therefore if the power in the wave is different in two cases the effect on the electrons will probably be different and the resulting effect on the absorption of the wave in the two cases may be different. This suggestion has not yet been proved, but it is one of the points upon which observation is needed.

Mr. G. G. Blake: Whilst listening to the lecturer a somewhat terrifying thought passed through my mind. Up to a few years ago while we amateurs have been conducting our experiments in transmitting we have had no idea that we had any control over the angle of projection. We have been sending these waves out at random and have got through. In the early days we were sending out long waves and there were no blind spots. The author referred to himself of a "professional hired assassin," and it occurred to me that if he and the "other hired assassins" had taken their gun practice in the early days of gunnery in the same way, not knowing at what angle they were projecting their projectiles, it would have been a somewhat similar sort of thing but the results would have been disastrous. To get back to the paper, there is one thing which I should be very much obliged to the author if he would tell us. He showed us diagrams of transmitting and receiving connections for short wave work, but he did not give us any indication of what wave-length one could get down to with these connections. What is the lowest wave-length for which we can hope to use them?

Mr. F. L. Hogg: On the question of fading, the author suggests that this is due to interference between reflected and direct rays. I should like to suggest that in connection with short waves this cause cannot alone be responsible for all the effects we get, for it seems fairly definitely established that the direct ray is non-existent, in many cases, when we get fading. More likely fading is due to the fact, as the beam theory suggests, that the surface of the Heaviside layer is not necessarily uniform and therefore one would get portions of the same beam reflected at somewhat different angles, and you therefore get varying interference in the receiver. The question of dead spots has been referred to. I know many will disagree, but personally I feel confident that a dead point on short waves does not exist. If we can get our aerials oscillating in such a manner that we get an almost vertical component on some short wave, say 20 metres, we can get our signals good at say 20 miles, whereas if we have not got such a great angle of projection there will be a dead spot up to about 400 miles radius. The reason the dead point is usually found is that when we are wanting to communicate with long distance stations, the best arrangements for long distance are quite useless for short distance, and we have to alter the distribution of current in our aerials to get a signal at a nearer point. I conducted a series of tests on 20 metres at the end of 1924 and I received a very large number of reports, considering the time I was testing. At that time I was working on a very low aerial harmonic, and there was a considerable amount of vertical radiation and not so much in the horizontal direction, relatively speaking. I think the author is hardly fair to physicists such as Heaviside, because it seems to me that we have in his and other theories an almost complete explanation of short wave phenomenon. I am not at the moment considering the effect of weather conditions. If one likes to examine the exact polar curve in the vertical direction of one's aerial, it is possible to predict to a very great extent at what points it will be audible and one can get a check reading of what height the Heaviside layer should be at any particular time. Certain tests which have been conducted bear this out. If you put up a quarter wave aerial surrounded by houses and masts you cannot expect to get a single vertical polar loop. The question of an alteration of power making a difference to the receiving end is, I think, one which will bear investigation. But when one alters the power one also alters, almost invariably, the distribution current in the aerial and when one is making such measurements as these it is necessary to be careful that the distribution current in the aerial is exactly the same as it was before.

Mr. H. Bevan Swift: I think that one of the greatest troubles we are going to have with short waves is on the reception side and not so much with the transmitting side. The waves are so sharp to tune that unless we know the whereabouts of the transmitting station we shall miss it and it is really up to the Radio Society rather than the Transmitter Section to try and perfect reception on the short wave band. A lot has been said about the Heaviside layer and no doubt that is one of the most complicated problems we have before us. When the late Dr. Heaviside discovered that layer he unfortunately failed to organise it so that we could know exactly where the ether waves strike and where they will rebound. That is a point we have to deal with and the fickleness of the Heaviside layer is going to be a great drawback to short wave work. There will be other problems coming in, the problem of telephony and the modulation of short waves. All these things indicate the very large field which is open to experimenters to look into. I think the amateurs and experimenters of this country are highly to be congratulated on the very active part they have played in short wave transmission and reception.

Mr. P. R. Coursey: I cannot add much to what has already been said. We are all very much indebted to the author for his paper and the excellent way he has summarised the work that has been done on short waves, and it is very interesting to have one's mind drawn back again to the early transatlantic tests which at the time were such a struggle but which now seem such a commonplace matter. I should be glad if the author could elucidate one point, and that is the much-debated question of the angle of projection of radiation. In the figures that angle was apparently referred to the ratio of L/λ. I believe it has also been referred to the ratio of capacity to inductance in the aerial and attributed to the presence, or otherwise, of a series condenser at the base of the aerial and the proportion which that capacity bears to the effective capacity of the aerial. If the author can tell us anything more about that or elucidate the point a little further, I am sure we shall all be grateful to him.

Captain Miles, replying to the discussion, said: We have had a most interesting discussion to-night, especially from men who have probably forgotten more about short waves than I have ever known. I entirely agree with Admiral Jackson that the long wave at present has a great advantage in not having any blind spots. On the other hand, the long wave has never really achieved the reliable communication that the short wave promises. We have never had a really reliable long wave service to the Antipodes. It has always faded out for some part of the 24 hours, and if short waves do not enable us to effect this continuous communication, it does not seem that anything will. This criticism of the short wave and blind spots may be got over by changing your frequency according to your range, as Mr. Hogg suggested. With regard to Mr. Marcuse and concentration near the Antipodes, I think his statement that the best signalling conditions for communication with the Antipodes is when both stations are in daylight shows distinctly that that is exactly the time when you have darkness on the way across. Undoubtedly, I should say that communication on the waves used is effected round the dark side of the earth. Mr. Blake asked what wave-length the receiver connections which I showed would go down to. I just took those connections as an example of good engineering practice. That receiver worked comfortably from 20 to 80 metres by just changing the coupling coils. The two coils were 2½ turns and 3½ turns, 3-inch former, 16 D.C.C. wire, for 20 metres and you have more turns for the higher wave-lengths. I think you get uncommon difficulties when you go down to 5 metres. Both the transmitter and the receiver circuits are comparatively simple until you get down to about 12 metres and then you have to go in for a rather cunning device of push-pull circuits as described by M. Mesny in *l'Onde Electrique*. Down to 12 metres any ordinary circuit does quite well provided you are careful to keep your wave stable. I should be very sorry to enter into a discussion with Mr. Hogg about fading. There are many theories about it and I am prepared to accept his alternative theory. I do not think I have been unfair to the early workers. I have given Van der Pohl's diagram and the Heaviside layer theory and I have not been seriously criticised about them by the practitioners, such as Mr. Marcuse, and I think the scientists have been surprisingly accurate. I should like to call attention to one thing which rather shakes the faith of the practical engineer in pure theory. According to the empirical Austen-Cohen formula, which has been argued about in detail for years, the shorter the wave the worse it goes whereas I have been talking to you for an hour to prove that the shorter the wave the better it goes. No scientist ever suggested the possibility that waves below 100 m. could cover useful ranges until this was demonstrated practically. I agree with Mr. Bevan Swift about the difficulties in reception. We are rather light-hearted in designing the short wave receiver when experimenting, but when it comes down to making a commercial instrument we shall have to go into the matter very cautiously and make receivers which cover a very small range of wave-length. The difference between 9 and 10 metres is the same frequency spacing as between 100 and 30 000 and no one would dream of designing a single receiver to cover 30 000 metres. You will have to split your receivers up in something like this order: 9 to 9.5 metres, 9.5 to 10 metres and so on, and calibrate very carefully or you will miss the signal.

Replying to Mr. Coursey, the diagrams I have shown, due to Van der Pol, are for a vertical aerial on a perfectly conducting earth. Under practical conditions, with asymmetrical capacity conditions or a roof aerial, the angle of emission will vary somewhat differently with the ratio L/λ. I must thank you for a very patient hearing and I hope, speaking from a selfish rather than a professional point of view, that this meeting will have the effect of getting men, say, like Mr. Marcuse, who know so much about it, to give us the benefit of their experience.

On the motion of Mr. Carpenter, seconded by Mr. Marcuse, a hearty vote of thanks was accorded the author at the conclusion of the discussion.

The Rectification of Small Radio-Frequency Potential Differences by means of Triode Valves.—Part III. [R134

By F. M. Colebrook, B.Sc., A.C.G.I., D.I.C.

B.—Rectification by means of the curvature of the foot of the anode current—grid voltage characteristic.

The general type of circuit to be considered is that illustrated in Fig. 24. It is assumed that the applied negative grid potential is of suitable magnitude to bring the "state-point" of the valve into the lower curved part of the anode current characteristic.

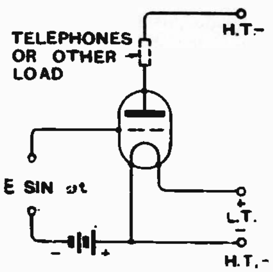


Fig. 24.

The nature of the signal E.M.F. and of the anode circuit load will be specified as each individual case is considered.

16. *General theory of the anode rectification of a continuous wave signal.*

In many applications of the thermionic valve the relationship between the anode current, the anode voltage, and the grid voltage can be expressed in the form of a simple straight line law. This is obviously not the case in the present application. There are, however, very good grounds, both theoretical and experimental, for expressing the more general relationship in the form

$$i_a = f(\epsilon + v_a + \mu v_g) \quad .. \quad (16.1)$$

For the justification of this statement the reader is referred to *The Thermionic Vacuum Tube*, by Van Der Bijl, p. 42 *et seq.* In the above ϵ is a small constant quantity (not, in this case, the base of Napierian logarithms), v_a and v_g are respectively the anode and grid potential differences with respect to the negative end of the filament, and μ is a constant for a given valve. It will be convenient for abbreviation to put

$$(\epsilon + v_a + \mu v_g) = E_s \quad .. \quad (16.2).$$

Putting i for the change in i_a due to a change δE_s in E_s,

$$i = \delta E_s f'(E_s) + \frac{\delta E_s^2}{2!} f''(E_s) + \frac{\delta E_s^3}{3!} f'''(E_s) \; .... \text{etc. } ad\ inf. \quad .. \quad (16.3)$$

where

$$f'(x) = \frac{df(x)}{dx} \quad \text{etc., etc.} \quad (16.4)$$

It will be shown later that under the conditions of anode rectification and for values of δE_s not exceeding 1½ to 2 volts only the first two terms of the above series are really significant, and it will therefore be legitimate to adopt as the fundamental equation for the present analysis

$$i = a_1 \delta E_s + a_2 \delta E_s^2 \quad .. \quad (16.5)$$

where $a_1 = f'(E_s)$ .. .. (16.6)

and $a_2 = \frac{1}{2} f''(E_s)$ .. .. (16.7)

It should be noted that for given initial conditions both a_1 and a_2 are constant co-efficients, the magnitude of which can be determined from the static characteristic of the valve. The application of the above general equation will be found to make the analysis of the rectification process in any given case a comparatively simple matter.

As the fundamental case we will consider the effect of a continuous wave signal E.M.F. represented by

$$e = E \sin \omega t \quad .. \quad .. \quad (16.8)$$

with no additional load in the anode circuit, *i.e.*,

$$\delta E_s = \mu E \sin \omega t \quad .. \quad .. \quad (16.9)$$

By inserting this value in equation (16.5) and taking the mean value of i over one high-frequency period it can easily be shown that the continuous or rectified component of i is given by

$$i_c = a_2\mu^2\frac{E^2}{2} \quad .. \quad (16.10)$$

The change of mean anode current is therefore proportional to the square of the signal E.M.F.

We must now consider the effect of inserting in the anode circuit a pure resistance load of magnitude R, the load being short-circuited by a condenser of sufficient magnitude to provide a path of negligible impedance for the high-frequency components of i. In the first place, before the signal E.M.F. is introduced in the grid circuit, there will be a small change of mean anode current the magnitude of which can be determined from equation (16.5) above. If i_a be the magnitude of the anode current before the resistance R is introduced in the circuit, and i_a' the magnitude of the anode current after the resistance is introduced, then, since δE_s is given by

$$\delta E_s = -i_a' R \quad .. \quad (16.11)$$

$$i = \delta i_a = i_a' - i_a = -a_1 i_a' R + a_2 i'^2_a R^2 \quad (16.12)$$

The exact solution of this equation can be found in the ordinary way, but in practice the effect of the square term on the solution is exceedingly small, so that

$$i_a' \doteqdot \frac{i_a}{1 + a_1 R} \quad .. \quad (16.13)$$

When the continuous wave signal E.M.F. acts on the grid,

$$\delta E_s = (\mu E \sin \omega t - i_a' R - i_c R) \quad (16.14)$$

Inserting this value in equation (16.5) and taking the mean value of i over a period will give

$$\delta i_a + i_c = -a_1 R(i_c + i_a') + a_2\mu^2\frac{E^2}{2} + a_2 R^2(i_c + i_a')^2 \quad (16.15)$$

and, from equation (16.12),

$$i_c = -a_1 R i_c + a_2\mu^2\frac{E^2}{2} + 2 i_c a_2 R i_a' \quad (16.16)$$

(The term containing the square of i_c has been omitted, as it will be found to be negligibly small.) It is easily seen from equation (16.16) that the expression for i_c can now be reduced to the standard form

$$i = \frac{E_c}{R_c + R} \quad .. \quad (16.17)$$

where

$$R_c = \frac{1}{a_1 - 2a_2 R i_a'} \quad .. \quad (16.18)$$

and

$$E_c = a_2\mu^2\frac{E^2}{2} R_c \quad .. \quad (16.19)$$

It should be noted that R_c is independent of the signal amplitude, but varies with the load R, increasing as R increases. The limiting or no-load values are clearly

$$R_c = \frac{1}{a_1} \quad .. \quad (16.20)$$

$$E_c = \frac{a_2\mu^2 E^2}{2a_1} \quad .. \quad (16.21)$$

Before proceeding to the other applications of anode rectification it will be well to describe the experimental confirmation of the foregoing analysis and indicate the order of the magnitudes involved.

17. *Experimental confirmation.*

(*a*) Determination of the static characteristic.

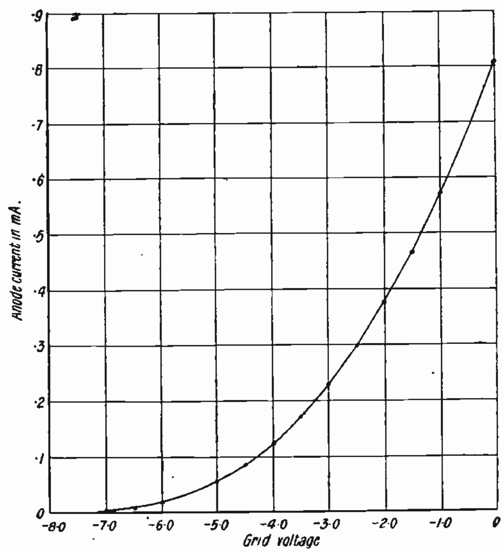


Fig. 25.

This is a very simple matter, and need not be described in detail. The curve of Fig. 25, which refers to a dull-emitter valve, with an anode voltage of 50 and a filament voltage 1.8, is typical of the results obtained for a number of small receiving valves.

It would seem from an inspection of this curve that a negative grid voltage of 5 or 6 volts would give the greatest rectification sensitivity. By actual measurement it was found that a negative grid voltage of 3 volts gave a considerably greater sensitivity. This, therefore, was taken as the fixed initial condition.

(*b*) Determination of the rectification characteristic.

The rectification characteristics for the above initial conditions were measured by means of a circuit almost identical with that described in Section 8 (Fig. 11), the grid-circuit resistance being short-circuited and the grid maintained at a constant negative potential of 3 volts. The high-frequency E.M.Fs. (wave-length about 400 metres) were applied in the same manner as for the grid rectification measurements. The values of i_c were determined for a range of signal amplitudes up to about 1.8 volts, with no load in the anode circuit, and also with various loads up to 50 000 ohms. The results are exhibited in the curves of Fig. 26.

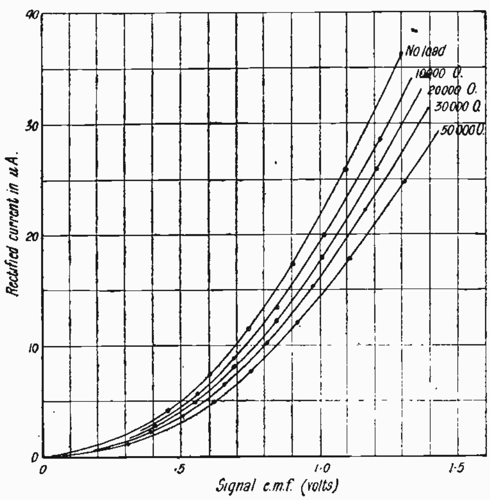


Fig. 26.

(*c*) Analysis of experimental results.

Unfortunately, the static values of

$$\frac{\delta i_a}{\delta e_a} \text{ and } \frac{\delta^2 i_a}{\delta e_a^2}$$

were not determined for the above valve

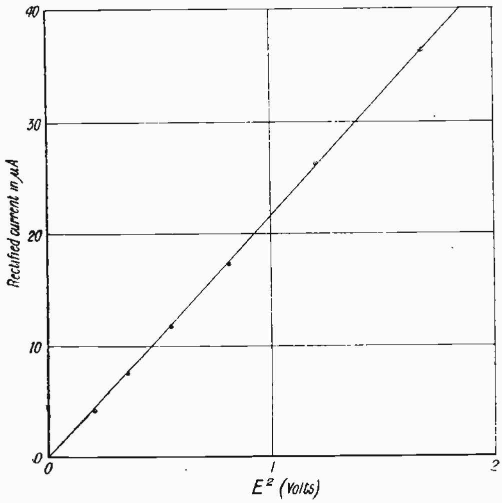


Fig. 27.

at the time of the measurements. To this extent the measurements must be regarded as incomplete. It will be shown, however, that the no-load rectificaton characteristic agrees with that predicted from the i_c, e_g static characteristic. Further, that from the no-load value of R_c the rectification characteristic for any other load can be predetermined.

(*d*) The static values of

$$\frac{\delta i_a}{\delta e_g} \text{ and } \frac{\delta^2 i_a}{\delta e_g^2}$$

For small changes from the intial values, equation (16.5) takes the form

$$i = \frac{\delta i_a}{\delta e_g}\delta e_g + \frac{1}{2}\frac{\delta^2 i_a}{\delta e_g^2}\delta e_g^2 \quad .. \quad (17.1)$$

i.e.,

$$\frac{i}{\delta e_g} = \frac{\delta i_a}{\delta e_g} + \frac{1}{2}\frac{\delta^2 i_a}{\delta e_g^2}\delta e_g \quad .. \quad (17.2)$$

Thus the first and second derivatives can be found by plotting $i/\delta e_g$ against δe_g and measuring the constants of the straight line so obtained. In the present case it was found that for a range of 2 volts on either side of -3,

$$\frac{\delta i_a}{\delta e_g} = 1.25 \times 10^{-4}$$

$$\frac{\delta^2 i_a}{\delta e_g^2} = 39.76 \times 10^{-6}$$

(*e*) No-load rectification characteristic.

In Fig. 27 is shown the result of plotting i_c against E^2 with no load in the anode circuit, E being the R.M.S. signal voltage. As indicated in the foregoing analysis, the result is a straight line. The measured slope of the line is

$$\frac{1}{2}\frac{\delta^2 i_a}{\delta e_g^2} = 21.3\times 10^{-6}$$

which agrees within the limits of experimental error with the value $\frac{1}{2}$ $39.76\times 10^{-6} = 19.88\times 10^{-6}$ predicted from the static characteristic.

(*f*) The no-load value of R_c.

From equation (16.18) it can easily be shown that

$$a_1 = \frac{a_2\mu^2 E^2}{2}\left(\frac{\delta}{\delta R}\cdot\frac{1}{i_c}\right)_{R=0} \quad (17.3)$$

Also, from equations (16.2), (16.6) and (16.7),

$$a_1 = \frac{1}{\mu}\frac{\delta i_a}{\delta e_g} \quad .. \quad .. \quad (17.4)$$

$$a_2 = \frac{1}{2\mu^2}\frac{\delta^2 i_a}{\delta e_g^2} \quad .. \quad .. \quad (17.5)$$

Therefore,

$$a_1 = \frac{1}{4}\frac{\delta^2 i_a}{\delta e_g^2}\left(\frac{\delta}{\delta R}\frac{1}{i_c}\right)_{R=0}$$

and since $\delta^2 i_a/\delta e_g^2$ is known, the value of a_1 can be determined by plotting $1/i_c$ against R and measuring the slope of the curve at $R=0$. The magnitude of $1/a_1 = (R_c)_{R=0}$ was thus found from the rectification characteristics to be

$$\frac{1}{a_1} = 8.41\times 10^4$$

which, from (17.4) above, gives

$$\mu = 10.5$$

From the above constants the value of E_c and R_c corresponding to any given signal amplitude and load resistance can be calculated as shown above, and i_c can therefore be calculated. The following table gives the values corresponding to a signal amplitude of 1.77 volts, calculated and measured values being given for comparison.

R	R_c	E_c	i_c calc.	i_c measured.
0	8.41×10^4	2.79	33.2×10^{-6}	33.3×10^{-6}
10 000	9.00×10^4	2.99	29.9×10^{-6}	29.8×10^{-6}
20 000	9.55×10^4	3.17	27.4×10^{-6}	27.3×10^{-6}
30 000	10.05×10^4	3.34	25.6×10^{-6}	25.2×10^{-6}
40 000	10.50×10^4	3.49	24.0×10^{-6}	23.7×10^{-6}
50 000	10.98×10^4	3.64	22.8×10^{-6}	22.5×10^{-6}

The agreement between the observed and calculated values is very satisfactory. The comparatively high values of E_c should be noted. They are actually greater than the signal amplitude, which appears to indicate very perfect potential rectification. It must not be forgotten, however, that the magnification factor of the valve enters into these values. The corresponding rectified potentials in the grid circuit will only be about 1/10 of these values, or, better, the effective signal E.M.F. in the anode circuit is about ten times the actual signal amplitude. In spite of this fact, anode rectification is in general very much less sensitive than grid rectification. This will be considered more fully later on. For certain purposes, however, the approximate square law behaviour, and the very high input impedance compared with grid rectification, have considerable practical advantages.

Having thus established the validity of the general theory as presented in Section 16, we are now in a position to analyse the remaining and more important practical cases of anode rectification.

18. *The anode rectification of a modulated continuous wave.*

As in the corresponding case of grid rectification, it will be convenient to confine the analysis to an E.M.F. modulated with a single pure tone, *i.e.*,

$$e = (E + M \sin nt) \sin \omega t \quad .. \quad (18.1)$$

The rectification of this E.M.F. will give rise to certain low frequency currents, and if the anode circuit contains a telephone load or a transformer winding these low frequency currents will give rise to low frequency back E.M.Fs. of which the instantaneous value will be represented by the general symbol v_m. The total change of potential will therefore be

$$E_s = \mu(E + M \sin nt) \sin \omega t - i_a' R - i_c R - V_m \quad (18.2)$$

To determine the magnitudes of the various components of i, the change of anode current, it is only necessary to insert this value of δE_s in equation (16.5) and then equate separately the components of equal frequency. The process is quite straightforward and need not be given in detail. It will be found that the continuous component is

$$i_c = \frac{E\left(1 + \dfrac{M^2}{4E^2}\right)}{R_c + R} \quad .. \quad (18.3)$$

i.e., the percentage change in the rectified E.M.F. due to the modulation is $25\frac{M^2}{E^2}$

In nearly all cases of practical telephony the ratio of M to E is small. The modulation will therefore produce no appreciable change in the magnitude of the continuous rectified current. This fact can be verified experimentally as already described in connection with grid rectification.

The fundamental modulation frequency component of the current is given by

$$i_n = \mu^2 a_2 EM - v_n(a_1 - 2a_2 i_a' R - 2a_2 i_c R) \quad (18.4)$$

and since i_c will be small compared with i_a',

$$i_n = \mu^2 a_2 EM - \frac{v_n}{R_c} \quad .. \quad (18.5)$$

In vector form this is equivalent to

$$\mathbf{I}_n = \frac{\mathbf{E}_n}{\dot{Z}_n + R_c} \quad .. \quad .. \quad (18.6)$$

where $\mathbf{E}_n$ is a vector representing an E.M.F. of frequency $n/2\pi$ and amplitude

$$\dot{E}_n = \mu^2 a_2 EMR_c \quad .. \quad .. \quad (18.7)$$

and $\dot{Z}_n$ is the impedance operator for the load at the modulation frequency. The double frequency component is given by

$$\mathbf{I}_{2n} = \frac{\mathbf{E}_{2n}}{\dot{Z}_{2n} + R_c} \quad .. \quad .. \quad (18.8)$$

where

$$E_{2n} = \frac{\mu^2 a_2 M^2 R_c}{4} \quad .. \quad .. \quad (18.9)$$

The ratio of the parasitic double frequency term to the single frequency term is therefore

$$\frac{I_{2n}}{I_n} = \frac{M}{4E} \frac{\sqrt{(R_n + R_c)^2 + X_n^2}}{\sqrt{(R_{2n} + R_c)^2 + X_{2n}^2}} \quad .. \quad (18.10)$$

where R_n, R_{2n}, X_n, and X_{2n} are the resistance and reactance components of the two impedance operators. Apart from any resonance effects it is clear that this ratio will in general be less than $\frac{M}{4E}$, *i.e.*, as a percentage it will be less than a quarter of the modulation percentage. If the latter is kept small, as it generally is in practice, the double frequency term will be relatively unimportant.

Equation (18.6) can if desired be expressed in terms of the slope of the rectification characteristic corresponding to the given value of the zero frequency resistance of the anode circuit load. From equation (16.17),

$$\frac{\delta i_c}{\delta E} = \frac{1}{R_c + R} \cdot \mu^2 R_c a_2 \,.\, E \quad (18.11)$$

$$= \frac{1}{R_c + R} \frac{E_n}{M} \quad .. \quad (18.12)$$

Therefore

$$E_n = M(R_c + R) \frac{\delta i_c}{\delta E} \quad .. \quad (18.13)$$

and

$$\mathbf{I}_n = \frac{R_c + R}{Z_n + R} \frac{\delta i_c}{\delta E} \mathbf{M} \quad .. \quad (18.14)$$

where $\mathbf{M}$ is a vector of magnitude M and frequency $n/2\pi$. For most purposes, however, the form of equation (18.6) will be the more useful.

Efficiency and Distortion in the Anode Rectification of a Modulated Continuous Wave.

The modulation frequency power consumed in the load is $\frac{I_n^2 R}{2}$. Writing P_n for this, it is easily shown from equation (18.6) that

$$P_n = \frac{\rho_n \cos\theta_n}{\rho_n + 2\rho_n \cos\theta_n + 1} \frac{E_n^2}{2R_c} \quad .. \quad (18.15)$$

where ρ_n is the ratio of the magnitude of $\dot{Z}_n$ to R_c and where θ_n is the phase angle of the load at the given frequency. For any constant value of θ_n the frequency term in equation (18.15) is a maximum when $\rho_n = 1$. The general character of the variation of this expression with ρ_n can be seen from Fig. 28, where the curve is drawn for $\theta_n = 0$. For most small receiving valves R_c may be anything from 50 000 to 100 000 ohms. (It is important to realise that it will always be greater than the internal slope resistance corresponding to the straight part of the characteristic.) The optimum impedance load for anode rectification is therefore in the region 50 000 to 100 000 ohms. A telephone load would therefore seem to be particularly unsuitable, for not only is it inefficient electrically, but it is inefficient on the wrong side of the maximum, the side where its efficiency varies most rapidly with frequency. In general it seems likely that a telephone load will greatly favour the higher frequencies. A full discussion of the frequency distortion associated with anode rectification on account of the variation of the load impedance with frequency is beyond the scope of the present paper, for it would involve a number of other factors, physiological and physical. It is a subject for which much more data are required than appear to be available at present. The above brief discussion can only be regarded as an outline of the electrical side of the question.

19. *Heterodyne reception with anode rectification.*

The analysis of this case will follow so closely that already given in Sections 14, 16 and 18 that only a brief outline need be given here. As in Section 14, the resultant E.M.F. due to the sum of the signal and the local oscillation will be expressed in the form

$$e = E\sin(\omega t + \alpha) \quad .. \quad (19.1)$$

where

$$E^2 = E_1^2 + E_2^2 + 2E_1E_2\cos(nt+\beta)$$
$$= E_r^2 + e_n \quad (19.2)$$

Using the same symbols as in the sections referred to above,

$$\delta E_s = \mu E\sin(\omega t+\alpha) - i_a'R - i_cR - v_m \quad (19.3)$$

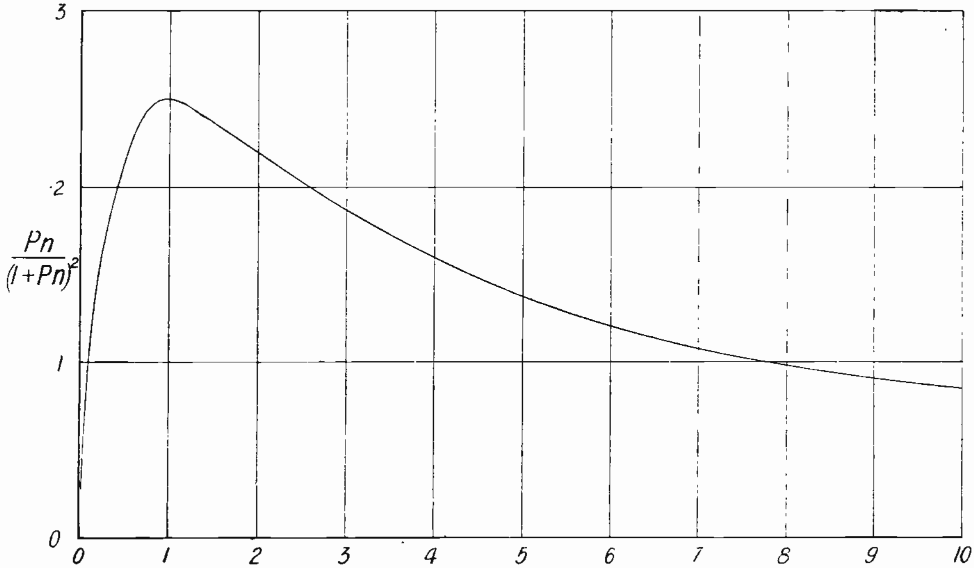
The various components of the change of anode current due to the heterodyned signal can be found by substituting this value of δE_s in equation (16.5) and then equating separately the terms of equal frequency. It will be found that the continuous component is given by

$$i_c = \frac{E_c}{R_c + R} \quad .. \quad (19.4)$$

where

$$E_c = \tfrac{1}{2}\mu^2 a_2 R_c (E_1^2 + E_2^2) \quad (19.5)$$
$$= \tfrac{1}{2}\mu^2 a_2 R_c E_r^2 \quad .. \quad (19.6)$$

R_c being the same as in Section 16.



Pn Fig. 28.

The fundamental beat frequency component will be found to be

$$i_n = \mu^2 a_2 E_1 E_2 \cos(nt+\beta) - v_n/R_c \quad (19.7)$$

or in the more convenient vector form

$$\mathbf{I}_n = \frac{\mathbf{E}_n}{\dot{Z}_n + R_c} \quad .. \quad (19.8)$$

where $E_n = R_c\mu^2 a_2 E_1 E_2$

$\dot{Z}_n$ being the impedance operator of the load at the beat frequency.

In the corresponding case of a modulated continuous wave, it was shown that there would be in addition a small double frequency component (see equation (18.8)). In the present case, however, since δE_s^2 contains only the first power of e_n, there will be no double frequency term (except an exceedingly small factor derived from the square of v_n, itself a small quantity). This fact should be noted, as it has a useful significance in relation to the super-heterodyne reception of telephony.

Returning to equation (19.8), the chief features of this result are :—

(1) The amplitude of the beat frequency component of the anode current is proportional to the product of the amplitudes of the signal and the local E.M.Fs. This was not true of the corresponding case in grid rectification. This does not mean, however, that an indefinitely great increase in effective sensitivity can be obtained by increasing the amplitude of the local oscillation, for the above equations only apply exactly for signal amplitudes not exceeding about two volts. For large amplitudes of high-frequency grid voltage the change of anode current will no longer be proportional to the square of the high-frequency amplitude, tending ultimately to proportionality to the first power. This condition will set an upper limit to the increase of effective sensitivity.

(2) There is in the present case no loss of sensitivity such as that associated with the grid condenser in grid rectification (see Section 13). Under certain conditions, therefore, particularly at long wave-lengths, anode rectification may have a greater net sensitivity than grid rectification in heterodyne reception, though the sensitivity of the latter method will be very much greater than that of the former in relation to the rectification of a pure continuous wave.

This, together with the fact that only a single frequency is produced by the anode rectification process, makes the latter method particularly suitable for super-heterodyne reception.

More will be said about the comparison between grid and anode rectification in the last section of the paper.

(To be concluded.)

The Wireless Annual for 1926.

PROBABLY the outstanding impression gained from a first perusal of this year's *Wireless Annual* * is of the rapid expansion of amateur communication during 1925. New experimental stations have sprung up in all corners of the world, so that the Directory of Transmitting Stations, which has always formed a feature of this useful publication, is now swollen to approximately 30 pages of closely-packed type. British call signs absorb about a third of the allotted space, the remainder of which is devoted to stations as far asunder as Spain and Argentina, South Africa and India, Finland and Australia.

Another valuable section rightly retaining a place in the volume is that giving useful tables and data to which every serious experimenter must have recourse from time to time.

There are some noteworthy contributions on the purely technical side. Among these must be mentioned " Valves, Their Uses and Characteristics," an article by W. James in which the basic principles of the thermionic valve are lucidly explained, together with methods of finding the amplification factor, and of obtaining a characteristic curve of any particular specimen. A valuable appendix provides data regarding valves of all the leading makes.

Mr. F. H. Haynes deals with circuits for broadcast reception, giving over forty examples with a brief explanation of each, and this section is followed by a clearly-written article on " Finding and Rectifying Faults in Receivers," in which the various shortcomings likely to be encountered are classified together with a list of " probable causes."

In a review of wireless progress during 1925, Mr. Hugh S. Pocock touches upon the formation and work of the Geneva Broadcasting Bureau, general commercial developments as revealed in the adoption of the " beam " system, and the enormous strides made by amateurs in short-wave research work. The advances made in broadcasting, particularly as a factor in international relationships, are brought home to us very forcibly in an article by Mr. A. R. Burrows, setting forth the work and aims of the International Broadcasting Bureau.

As a survey of the present position of wireless in its many ramifications, *The Wireless Annual* is of undoubted value to every experimenter.

* *The Wireless Annual for Amateurs and Experimenters*, 1926. London : Iliffe & Sons, Limited, Dorset House, Tudor Street, E.C.4. Price 2s. 6d., post free 2s. 8½d.

Rectifiers for High-Tension Supply.

By R. Mines, B.Sc. **[R355·5**

Addition to Part V.

XIII.—Use of Curved Electrodes.

IT may be shown that if the electrodes are curved (in the same plane as the direction of the electron paths), for example, so that they become two concentric cylinders, then the shapes of the paths are different according as the electron starts from one or other electrode. In this case the mathematics tell us that the *critical value* of the field is different for the two kinds of path, assuming the same P.D. between the electrodes in either case. This result may also be stated conversely—that for a constant field the *critical value of the P.D.* is different; and this means it is different for the two directions in which it may be applied to the tube, since electrons proceed only from the negative electrode when conduction is taking place.

This apparatus, then, constitutes a *rectifier* as distinct from a *switch*, there being no operation or control of the magnetic field in synchronism with the alternating supply. The necessary magnetic field may, in fact, be applied to the gap from a permanent magnet; and in actual rectifiers that have been constructed on these lines it has been found easiest to apply it in a direction parallel to the axis of the cylindrical electrodes. An example was shown in E.W. & W.E. for May, 1925 (p. 472), *q.v.*, which showed the improved magneton rectifier developed by Bush and Smith.*

With a constant P.D., the critical field is inversely proportional to the radius of curvature of the electrode; and with a constant field the critical P.D is inversely proportional to the square of the radius.

XIV.—Further Reduction of Gas Pressure: Production of Cathode Rays.

Continuing from Section II our description of the effects obtained in a discharge tube as the gas pressure is reduced; we find that, when the pressure is between 1/1 000 and 1/10 000 of atmospheric, the glows associated with the anode have disappeared, and those originating near the cathode have expanded well up to the anode. This is called the "fourth type" of Geissler discharge. Beyond this again (in the region between 100 and 10 millionths of an atmosphere) "cathode rays" are produced. These rays are nothing more nor less than a stream of electrons issuing from the cathode; they have the important properties of *rectilinear propagation* (travelling in straight lines) and *normal emission* (*i.e.*, they are projected perpendicularly from the cathode surface, however this may be placed). These properties are easily accounted for by the *cathode fall*, which, though present at all gas pressures, becomes accentuated as the gas pressure is the reduced "conductivity" of the gas at these extremely low pressures, which necessitates the application of a very high P.D. between the electrodes (running into thousands of volts) before any discharge will pass. The electrons are released by positive ion bombardment in the manner already described; in the immediate neighbourhood of the cathode the electric field is perpendicular to the surface, and it is in this direction that the electrons receive the bulk of their momentum; and the comparatively weak fields in the remainder of the discharge tube effect no appreciable alteration in the velocity or direction of their motion.

XV.—The Lodge Valve.

The normal emission property of the cathode rays is utilised in an ingenious manner in the high-tension rectifier developed by Sir Oliver Lodge. The constructional features of this are shown in Fig. 12. Note that when the side electrode is cathode, a parallel cathode ray stream is produced which travels past the spiral electrode; a good proportion is arrested by it and the remaining electrons will largely find their way via the gas and the glass walls. When the spiral electrode is made negative, the

* *P. Inst. Radio Eng.*, Vol. 10, p. 41, Feb. 1922.

electrons ejected from it travel away in all directions and only a small proportion will find their way to the other electrode.

The device therefore shows a marked asymmetry of conduction. It is, however, only a partial rectifier, though it proves very satisfactory in connection with X-ray tubes, for which use it was originally designed. In common with other apparatus employing the cathode ray stage of vacuum discharge, it is suitable for use only with high P.D.s., due to the reduced conductance in the tube; this factor also places a limit on the current that may be passed through such a rectifier.

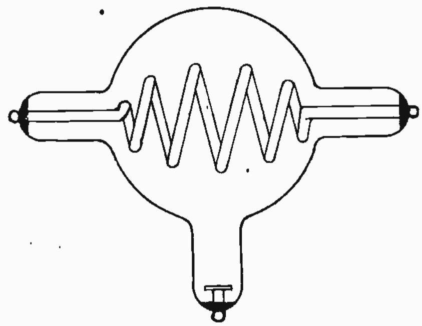


Fig. 12. *The Lodge valve.*

Part VI: Vacuum Arc Rectifiers.

I.—The Arc Discharge in a Vacuum.

We have noted in Part IV on Arcs at Atmospheric Pressure that the potential drop across the arc terminals is dependent largely upon the ionisation potential of the gas or vapour taking part in the conduction.

This is true also of the vacuum glow discharge, and accounts largely for the use of neon in the glow discharge rectifier. The effect of this factor is greatest under the "constant cathode fall" condition (that holds in this rectifier in the conducting direction) since the cathode fall, which in such cases is the greatest component of the whole P.D., is then determined chiefly by the ionisation potential.

One direction then in which one may naturally look for an improved apparatus is to seek a gas or vapour with a very low value for this ionisation potential.

Referring again to the case of an arc burning under atmospheric pressure, one finds that the matter taking part in the conduction in the arc is vapour of the electrode material. Herein then lies a possible solution to the problem—to combine the conditions of the vacuum discharge with the use of a vapour of a metal or a semi-conductor.

II.—Practical Requirements in a Vacuum Arc.

Working under reduced pressure necessitates enclosure of the discharge in a vacuum-tight envelope; and it must be remembered that with an arc in action the vapour temperature is at least at boiling point (fortunately this is less under reduced pressure than it is at atmospheric)—the value allowable is limited by the envelope.

Further, owing to the continuous vaporisation of the electrode material, there must be provision for its renewal; obviously this must take place inside the vacuum chamber. It is found that, owing to the enclosing vessel always being kept cooler than the arc vapour by radiation and convection, the vapour condenses on its inner surface; therefore the replenishment of the evaporating electrodes may be most easily secured by choosing the electrode material so that it is liquid under the working conditions; and shaping the apparatus so that the condensed liquid drains back to the pools acting as electrodes.

III.—The Mercury Vapour Lamp.

Thus the "mercury vapour lamp" consists of a long glass tube with a pool of mercury in a bulb at each end. In action the vapour conduction takes the form of a "Zeissler discharge of the second type"; there is a bright glow (the source of the light, and known as the "positive column") filling the bulk of the tube to within a short distance of the negative electrodes (assuming D.C. is used).

In starting this lamp it is necessary to give rise to a supply of vapour that will bridge a path between the electrodes, in other words, to "strike" the arc. This is done by the tube so that mercury from one pool runs along it and makes contact with the other; on returning the tube to its initial position the mercury column runs back and breaks at a number of points, and there the arc is struck.

(In the large sizes of lamps an alternative method is used. A high-frequency alternating electrostatic field is applied to the tube ; this causes ionisation of the residual gas sufficient to produce a more intense glow discharge than is caused by only the normal P.D. being applied to the electrodes.* This relatively strong discharge heats the electrodes sufficiently to start vaporisation on which it changes into the arc type.)

IV.—Mechanism of the Discharge.

We see that there is only one notable difference between the vacuum arc and the atmospheric one—the former occupies a larger volume than the latter for the same power expended : the current density (in the arc itself) and the potential gradient are both smaller, so that the power density in corresponding parts of the two types are in approximately the same ratio as the gas pressures.

Evidently the same discharge phenomena are associated with each of the two types. Thus with a steady P.D. applied to the mercury vapour lamp, there is a fall of potential at the cathode ; this is bombarded by positively-ionised vapour, is in turn heated and emits electrons, which are projected by the cathode fall and maintain the ionisation of the vapour.

V.—Introducing Asymmetry.

As with the atmospheric arc, the conduction may be made asymmetrical by using dissimilar electrodes ; but with the vacuum arc it is much easier to produce a good result. Thus by making one electrode of iron, for example, instead of mercury, it is found impossible to strike the arc with the iron as cathode. The reasons for this also are similar—iron has a higher specific heat and higher heat conductivity than mercury, hence it is more difficult to raise its temperature locally† sufficiently for thermionic emission ; also evaporation will not take place so readily. These effects are both intensified under vacuum conditions : the latter owing to the lower temperature* in the discharge, which while being far below that necessary for iron vapour production is sufficient for mercury.

VI.—The Mercury Arc Rectifier.

A common form of the apparatus is that shown in Fig. 1. It consists of a glass vessel with four main limbs ; in *B* and *D* are the iron electrodes (there must always be more than one for reasons to be given later), and at the lowest point *C* is the mercury pool. *E* is another smaller pool

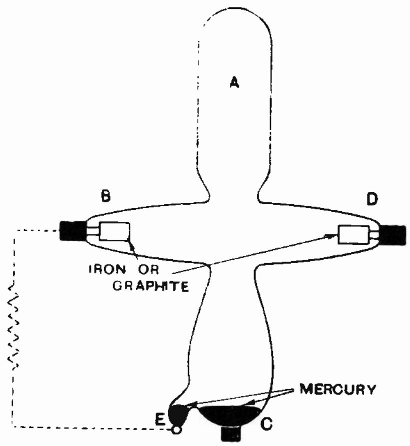


Fig. 1. *A mercury arc rectifier.*

which is connected to one of the iron electrodes through a resistance ; it is used for starting the arc by tilting the mercury into contact in the same manner as for the mercury vapour lamp. The large bulb *A* serves the functions of expansion chamber and condenser for the mercury vapour.

These rectifiers are made also with metal cases for handling large powers. It is not intended here to describe details of construction or operation since these have been given in many recent books and articles on the subject.

VII.—Extinction of the Arc.

It is much easier then to produce a rectifying arc under reduced pressure than it is at higher pressures. Nevertheless, in putting such an arc into practical use certain difficulties arise.

* It has been proved experimentally that at high frequencies a glow discharge will occur in a rarefied gas under much lower potential gradients than those required at low frequencies (which are determined by the ionisation potential).

† A. Gunther Schulze gives the current density at the " cathode spot " as 4 000 amperes/cm.^{2}

* Between 70° and 80° C.

The chief of these is due to the extinction of the arc that must of necessity take place when an alternating supply is being used, for the purpose of rectifying it—the P.D. across the rectifying arc terminals falls below the value necessary for maintenance of the arc at least once each cycle, and in the case of a "half-wave" rectification circuit it remains so (not forgetting its sign) for more than half of the cycle.*

Now we have seen that one of the causes of the attainment of a state of equilibrium in any gaseous discharge is the continuous *recombination* of ions that takes place the faster the more intense the ionisation. As soon therefore as the power supply is withdrawn, the ion cloud through which conduction was taking place vanishes with extreme rapidity. Hence for conduction to recommence when power is again applied a fresh supply of ions must be produced, the key to this process being the thermionic emission from the hot cathode.

Owing to the low boiling point of mercury in a vacuum, the cathode "hot spot," which with the arc in operation is at a high temperature sufficient for copious election emission, must consist of a layer either of dense vapour or of superheated liquid (most probably the latter turning into the former). Under these circumstances evidently the hot-spot will cool very quickly on withdrawal of the power, and the rate of decrease of its thermionic emission will be of the same order of rapidity as the rate of disappearance of the ions in the vapour.

The result is that the vacuum arc will not re-strike merely by raising the P.D. again to the value that suffices to maintain the arc, even if the time of extinction is short compared with the time period of a public supply. It is manifestly impossible to use mechanical contact between the electrodes (which would have to be operated in synchronism with the supply), and impracticable to use the high-frequency discharge (for such device would have to be in continuous operation): the best method of attack on the problem would appear to be therefore to prevent extinction of the arc.

* *Cf.* the oscillograms given in our article, E. W. & W.E., p. 580, July, 1924.

VIII.—Use of Multiple Electrodes.

It was explained in our second article* that it is possible to make one rectifying apparatus perform the function of two by using two electrodes of one kind and a common electrode of the other kind immersed in the same conducting medium.

This property is a result of the fact that in the electrolytic rectifier there described the rectification action takes place *at the electrode* and not in the conducting medium.†

Further, since only one of the kinds of electrode is active, only one kind may be multiplied. In the electrolytic rectifier the electrolyte is normally conducting, and the function of the active electrode is to *insulate* in the non-conducting direction; hence it is this electrode that may be multiplied: the other kind of electrode may not, since it will permit electricity to pass either into, or out of, the conducting medium.

In the mercury arc rectifier similar conditions hold; for though it is the arc vapour that conducts the electricity, this conduction is as we have seen essentially dependent upon the active electrode. In this case, however, the medium in which the electrodes are immersed is normally non-conducting; and since the function of the active electrode is to *produce conduction*, this electrode may *not* be multiplied.

IX.—On Polyphase Supply.

In the mercury arc rectifier therefore only one mercury pool may be used, but any number of iron or graphite electrodes—as many will be used as there are phases in the supply to be rectified.

This arrangement permits us to utilise a further useful property of the arc—that when there is an arc already playing between any two electrodes, the supply of ions produced therein renders an arc "self-striking" with respect to any other pair of electrodes provided the mercury pool is common to each pair. In fact the arc transfers itself to that electrode whose potential is most above that of the common electrode.

* E.W. & W.E., Vol. 2, pp. 783-784. Sept., 1925.

† As it does for example in the gas discharge rectifiers described last month (*see* E.W. & W.E., Vol. 2, p. 982, Dec., 1925).

The polyphase rectifier therefore automatically overcomes the difficulty of re-striking the arc. The diagram (Fig. 2) shows the action in the case of a three-phase supply. The only condition to be fulfilled

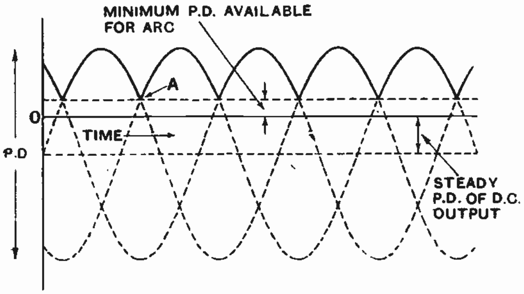


Fig. 2. *Three-phase supply.*

is that the minimum value of the maximum P.D. available between any cathode-anode pair (which occurs when the P.Ds. of adjacent phases become equal, as at *A*, Fig. 2) shall exceed the minimum arc P.D. by a reasonable margin.

Three symmetrical phases is the minimum number that will fulfil the above conditions, as is evident from Fig. 3, which depicts what occurs when two only are used—the maximum P.D. available between either pair of electrodes necessarily falls below zero.

X.—Use of a Choke.

An ingenious way that has been devised to overcome this difficulty is to insert a choke coil in the load or output circuit (*see* Fig. 4). Broadly speaking, its effect is to "smooth out" the P.D. wave.

When the P.D. between one pair of electrodes is falling the arc current between these two tends to fall—this gives rise to a

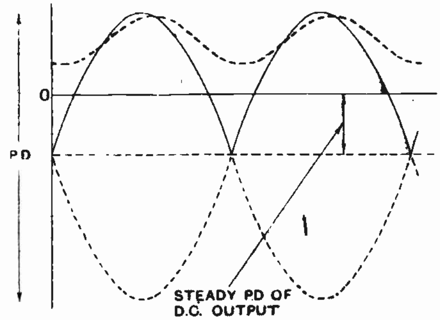


Fig. 3. *Two-phase supply.*

negative potential drop across the inductance, proportional to the rate of decrease of current. The mercury pool thereby has its potential depressed with respect to each of the other electrodes, so that not only is

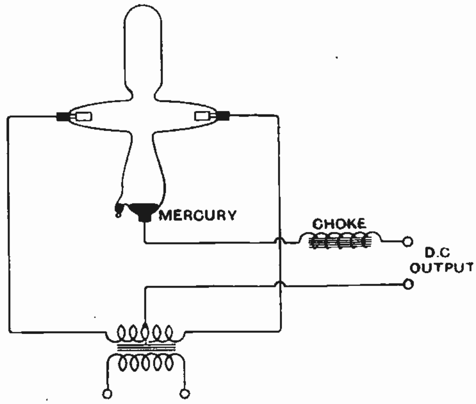


Fig. 4. *Choke in load circuit to smooth the P.D. wave.*

the positive P.D. across the arc maintained for a while but also the third electrode being made more positive to the same degree is the sooner ready to pick up the arc. The heavy dotted curve of Fig. 3 shows approximately the resultant arc P.D.

(*To be continued.*)

Curves and Tables for Short-Wave Calculations.

By A. P. Castellain, B.Sc., A.C.G.I., D.I.C. [R080; 127·3

NOW that the interest taken in wave-lengths of the order of a very few metres is becoming much more general, it is quite time that amateur experimenters began to introduce a certain element of design into their apparatus for the production and reception of such wave-lengths.

It is all very well in the beginning of things, when one's interest is first aroused, to experiment on the "try it and see if it works" principle, as this gives one an idea of some of the problems to be tackled—but the whole aim of the experimenter should be to produce and use apparatus which does its job in the best possible manner.

He should not be satisfied always with apparatus which just works, but should continually be asking himself, "Can I improve this; if so, how, and if not, why not?" This is just where the element of design, which involves knowledge of fundamental theories, comes in.

The following curves and examples have been worked out by the author in an attempt to help the serious experimenter on short waves.

There have been many expressions evolved for the inductance of a circular ring or loop, but perhaps the most convenient is that due to Kirchhoff:—

$$L = 4\pi a \left\{ \log_e \frac{8a}{\rho} - 1.75 \right\}$$

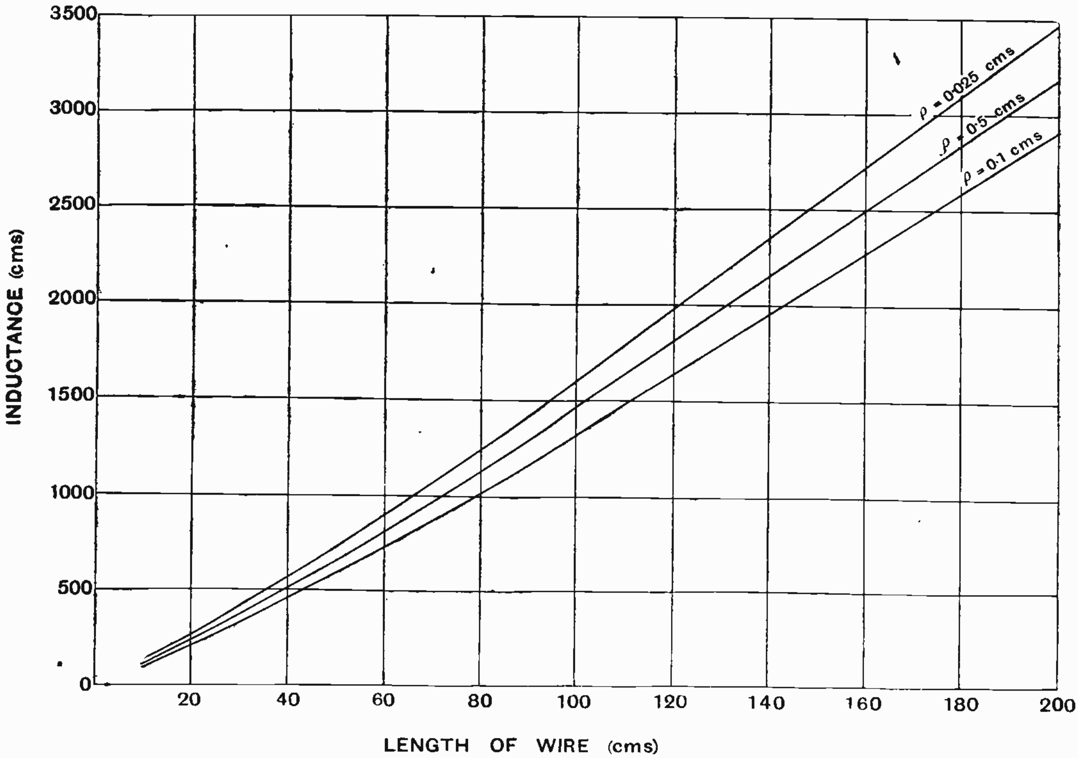


Fig. 1.

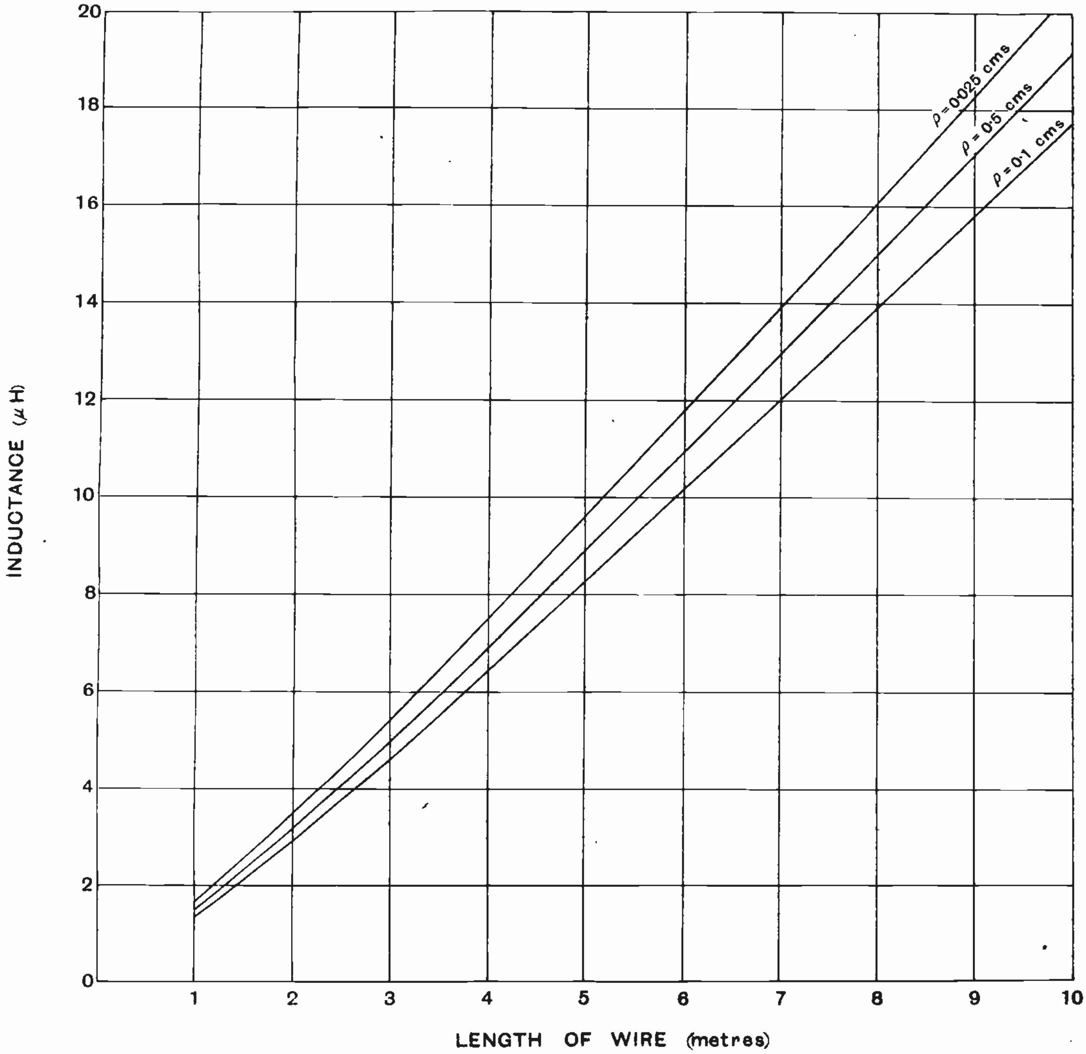


Fig. 2.

where L=inductance of loop in cms.
a=radius of loop in cms.
ρ=radius of conductor in cms.

This formula is approximate, being more correct as the ratio ρ/a is smaller, but it is sufficiently accurate (to less than 1% in the range considered) for our purpose.

As an example, we will find the inductance of a loop of 50 cms. diameter of 14 S.W.G. wire.

Here $a=25$

$\rho=0.1015$ *from Table B*

$$\therefore \quad \frac{8a}{\rho} = \frac{8 \times 25}{0.1015} = 1\,970$$

$1970=19.7\times 100$

$\log 1\,970=\log 19.7+\log 100$

From Table A.

$\log 20=2.996$

$\log 19=2.944$

difference 0.052

$0.7\times 0.052=0.036$

$\log 19 \;=2.944$

$\log 19.7=2.980$

$\log 19.7 = 2.980$

$\log 100 = 4.605$

$\log 1\,970 = 7.585$

1.75

$\log 1\,970-1.75=5.835$

Hence $L=4\pi 25\ \{5.835\}$
$=1\,832$ cms.
$=1.832$ microhenries.

Note.—1 000 cms. = 1 microhenry.

The following expression for the Inductance of a square is also due to Kirchhoff :—

$$L = 8a\left(\log_e \frac{a}{\rho} + \frac{\rho}{a} - 0.524\right) \text{cms.}$$

where a=side of square in cms.

L and ρ as before.

As an example : to find the inductance of a square of 70 cms. side wound with 1 mm. diameter wire.

Here a=70 cms.
ρ =0.05 cms.

ρ/a is small enough to be neglected—it will only make a difference of 8ρ, *i.e.*, 0.4 cms., in the result.

$$\frac{a}{\rho} = \frac{70}{0.05} = 1\,400.$$

log 14 =2.639 } *From Table A.*
log 100 =4.605 }

log 1 400 =7.244
0.524

log 1 400—0.524=6.720

$\therefore\ L=8.70\ \{6.720\}$ cms.
$=3\,760$ cms.
$=3.76$ microhenries.

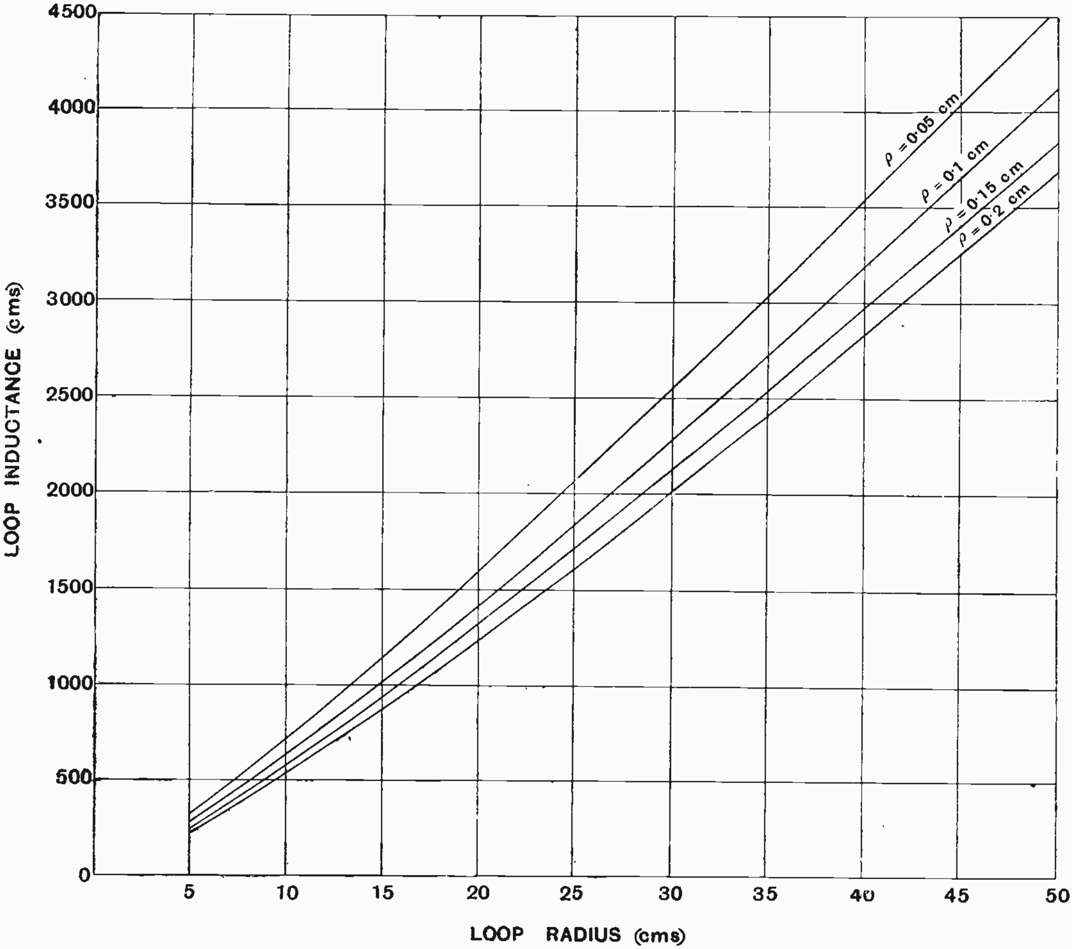


Fig. 3.

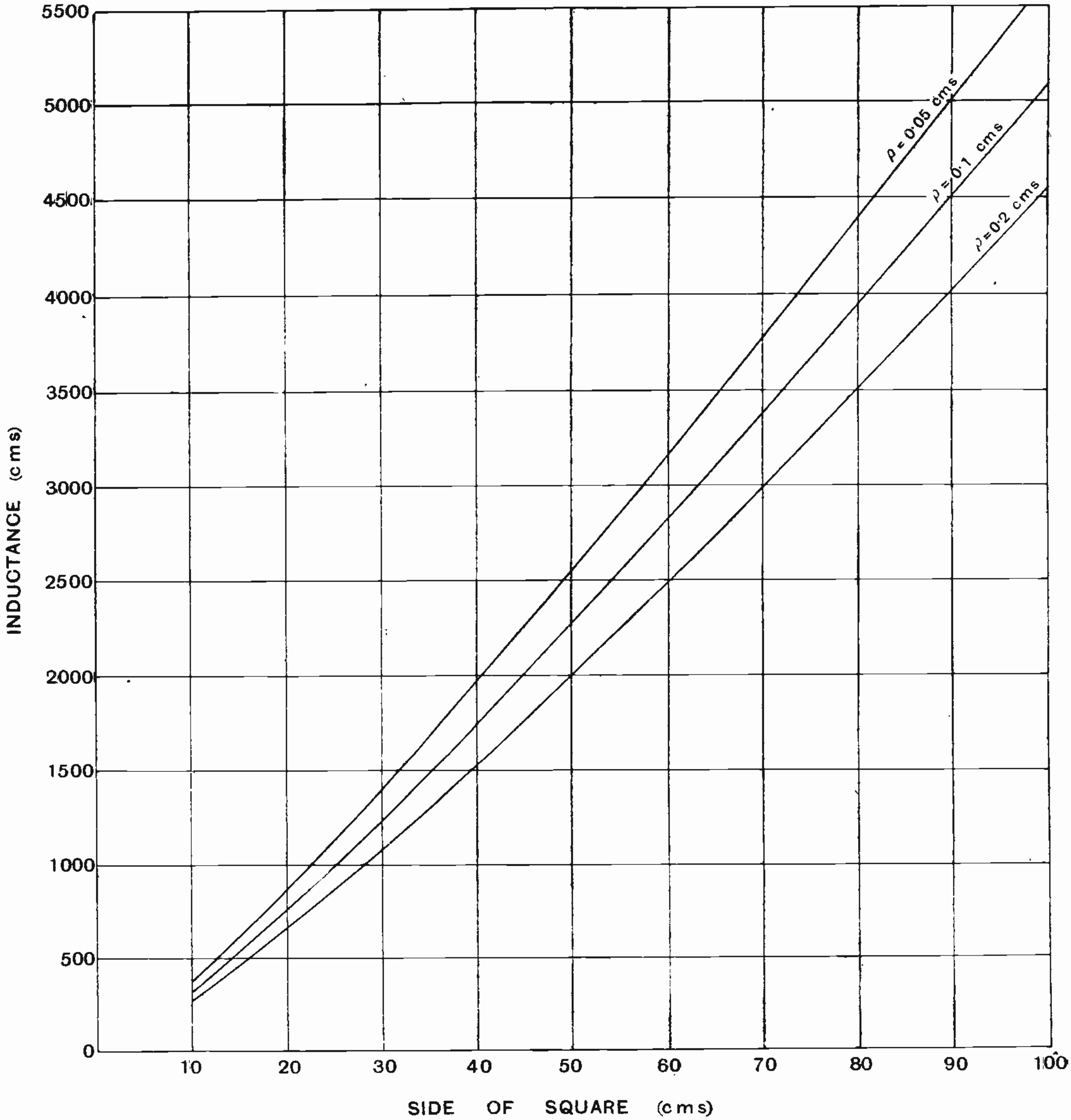


Fig. 4.

The two examples given should be quite sufficient to illustrate the method of working out the various inductance expressions.

However, a series of curves, Figs. 1-4, has been prepared by means of which the inductance of loops may be read off from 10 cms. to 1 metre diameter, of squares with sides from 10 cms. to 1 metre length and of straight wires from 10 cms. to 10 metres, the conductors ranging from 1 to 4 mm. diameter.

The following inductance expressions will be found most useful and easy to use by means of the tables provided :—

Self Inductance of a rectangle, sides a & b.

$$L = 4\left[(a+b)\log_e\frac{2ab}{\rho} - a\log(a+d) - b\log(b+d) - \frac{7}{4}(a+b) + 2(d+\rho)\right] \text{ cms.}$$ (Rosa & Cohen)

where ρ = radius of circular conductor in cms.

INDUCTANCE OF SINGLE TURN LOOP.

TABLE I.

Loop Radius a cms.	Inductance in Centimetres.			
	$\rho =$ 0.05 cm.	$\rho =$ 0.1 cm.	$\rho =$ 0.15 cm.	$\rho =$ 0.2 cm.
5	310.4	266.5	241	223
10	707	618	567	531
15	1 137	1 006	930	875
20	1 590	1 414	1 312	1 238
25	2 057	1 840	1 710	1 622
30	2 536	2 275	2 123	2 015
35	3 030	2 722	2 548	2 420
40	3 528	3 175	2 975	2 830
45	4 040	3 640	3 410	3 250
50	4 547	4 110	3 850	3 680

$$L=4\pi\, a \left\{ \log_\epsilon \frac{8a}{\rho} - 1.75 \right\} \text{cms.}$$ (Kirchhoff)

where a=radius of loop in cms.
ρ=radius of wire in cms.

INDUCTANCE OF STRAIGHT WIRE.

TABLE II.

Length of Wire l cms.	Inductance in Centimetres.		
	$\rho =$ 0.025 cm.	$\rho =$ 0.05 cms.	$\rho =$ 0.1 cms.
10	113.7	99.8	86
20	255.5	227.5	200
30	407	365.5	324
40	565	510	455
50	729	660	591
60	898	815	731
70	1 068	970	874
80	1 242	1 130	1 020
90	1 418	1 293	1 170
100	1 597	1 459	1 320
125	2 053	1 880	1 706
150	2 515	2 310	2 102
175	2 990	2 750	2 510
200	3 476	3 192	2 916
300	5 450	5 030	4 620
400	7 500	6 945	6 400
500	9 596	8 903	8 210
600	11 730	10 900	10 070
700	13 900	12 920	11 940
800	16 100	15 000	13 900
900	18 300	17 080	15 810
1 000	20 580	19 200	17 800

$$L=2l \left\{ \log_\epsilon \frac{2l}{\rho} - 1 \right\}$$ (Neumann)

where l=length of wire in cms.
ρ=diameter of wire in cms.

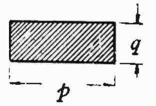
d = diagonal of rectangle in cms.
$= \sqrt{a^2+b^2}$.

Self Inductance of a square with a rectangular sectioned conductor—*e.g.*, copper strip.

$$L=8a\left[\log_\epsilon \frac{a}{p+q} + 0.2235\frac{p+q}{a} + 0.726 \right] \text{cms.}$$

(Rosa & Cohen)

where a = side of square in cms.
Section of conductor is $p \times q$ cms².



Self Inductance of a square with square section conductor.

$$L=8a\left[\log_\epsilon \frac{a}{p} + 0.447\frac{p}{a} + 0.333 \right] \text{cms.}$$

(Rosa & Cohen)

where a=side of square in cms.
$p \times p$ cms².=section of conductor.

Mutual Inductance between two parallel straight wires.

$$M=2l\left[\log_\epsilon \frac{2l}{d} - 1 - \frac{d}{l} \right] \text{cms.}$$

(Rosa & Cohen)

This is more nearly true as ratio l/d is larger,
where l=length of each wire in cms.
d=distance apart in cms.

INDUCTANCE OF A SQUARE.

TABLE III.

Side of Square a cms.	Inductance in Centimetres.		
	$\rho =$ 0.05 cm.	$\rho =$ 0.1 cm.	$\rho =$ 0.2 cm.
10	385	327	271
15	621	533	455
20	875	764	653
25	1 138	999	860
30	1 410	1 244	1 076
40	1 970	1 750	1 528
50	2 550	2 280	2 000
60	3 150	2 820	2 490
70	3 760	3 370	2 985
80	4 380	3 940	3 500
90	5 010	4 520	4 020
100	5 660	5 100	4 550

$$L = 8a\left\{ \log_\epsilon \frac{a}{\rho} - 0.524 \right\}$$ (Kirchhoff)

where a=side of square in cms.
ρ=diameter of wire in cms.

TABLE OF NATURAL LOGS FOR NUMBERS 1 to 100.

TABLE A.

No.	Log.	No.	Log.	No.	Log.	No.	Log.
1	0	26	3.258	51	3.932	76	4.331
2	0.693	27	3.296	52	3.951	77	4.344
3	1.099	28	3.332	53	3.970	78	4.357
4	1.386	29	3.367	54	3.989	79	4.369
5	1.609	30	3.401	55	4.007	80	4.382
6	1.792	31	3.434	56	4.025	81	4.394
7	1.946	32	3.466	57	4.043	82	4.407
8	2.079	33	3.497	58	4.060	83	4.419
9	2.197	34	3.526	59	4.078	84	4.431
10	2.303	35	3.555	60	4.094	85	4.443
11	2.398	36	3.584	61	4.111	86	4.454
12	2.485	37	3.611	62	4.127	87	4.466
13	2.565	38	3.638	63	4.143	88	4.477
14	2.639	39	3.664	64	4.159	89	4.489
15	2.708	40	3.689	65	4.174	90	4.500
16	2.773	41	3.714	66	4.190	91	4.511
17	2.833	42	3.738	67	4.205	92	4.522
18	2.890	43	3.761	68	4.220	93	4.533
19	2.944	44	3.784	69	4.234	94	4.543
20	2.996	45	3.807	70	4.248	95	4.554
21	3.045	46	3.829	71	4.263	96	4.564
22	3.091	47	3.850	72	4.277	97	4.575
23	3.135	48	3.871	73	4.290	98	4.585
24	3.178	49	3.892	74	4.304	99	4.595
25	3.219	50	3.912	75	4.317	100	4.605

TABLE B.

S.W.G.	Radius ρ cms.
8	0.203
9	0.183
10	0.163 5
11	0.147 5
12	0.132
13	0.117
14	0.101 5
15	0.091 5
16	0.081 3
17	0.071
18	0.061
19	0.050 8
20	0.045 8

Mutual Inductance between two equal loops.

$$M=4\pi a\left\{\log_e\frac{8a}{d}\left(1+\frac{3d^2}{16a^2}\right)-\left(2+\frac{d^2}{16a^2}\right)\right\}\text{ cms.}$$

(Maxwell)

where a=radius of loops in cms.

d=distance between loops in cms.

This formula is sufficiently accurate for distances up to a maximum of about $d=a/3$ cms.

Calibration Department.

THE announcement appeared in our December number that our Calibration Department was temporarily closed for the purpose of the checking of our standard instruments which it is our practice to do periodically. The department will be re-opened on 1st February for the calibration of readers' apparatus in accordance with the rules which will be set out in the advertisement pages of the February issue.

With the commencement of the new volume may we take this opportunity of renewing the request which we have made on previous occasions that all those making use of our Calibration Department will take the utmost care to see that the instruments forwarded for calibration are of such design and construction as to justify the work of calibration. So often in the past we have had sent to us wavemeters and other instruments which were mechanically unsound so that it was impossible to be sure that the calibration would hold good for any length of time.

A very common source of trouble is one which results from the use of cheap and badly constructed variable condensers where there is play in the bearings or where the dial is not rigidly fixed to the spindle and is liable to shift. In order that there may be no likelihood of a strain being put on the dial some designers prefer to use condensers which are free to rotate without stops, but unless the condenser is very well constructed more often than not it is then found that the connection to the rotating plates is not reliable.

By paying attention to the dependability of the instruments that are sent to us for calibration, readers will not only be rendering themselves a service but will be greatly assisting us in the work, whilst in addition it will give us the satisfaction of knowing that our labour is not wasted.

Long-Distance Work.

By Hugh N. Ryan (5BV). [R545·009·2

READERS will no doubt remember that in last month's article I said I should devote the next to the collected reports of all those experimenters who were working on the question of the relation between weather conditions and the strength and range of signals, together with any theories they had formed from their observations. I have received quite a number of such reports this month, both from amateurs whom I knew to be working on this subject and from others with whose work I was hitherto unacquainted.

Weather Conditions.

Many experimenters, however, have written that they are at present in the midst of their observations, and have therefore asked me to postpone the résumé until next month, so that all the reports may go in together. It also appears that a number of experimenters only started to record their observations when I first mentioned the matter in these columns, and have not yet been working long enough to have any very useful results. In the circumstances, therefore, I shall make the promised résumé the subject of next month's article. I might also mention that Mr. Lewer's article on the transatlantic part of the subject, which appeared in last month's issue, dealt with the matter so completely and well that I am compelled to wait awhile for some fresh facts before I can add much to what he has written, as far as transatlantic work is concerned. I understand, moreover, that he has already quite a useful bunch of observations on longer-distance signals, so between these articles and his we should be able to elicit some sort of a theory.

Nothing of unusual interest has occurred this month, so I will confine this article to a brief survey of the results obtained by our active stations in the course of their usual work.

The "High-Power" Stations.

The higher-powered stations in London and elsewhere have been working the whole world with their usual ease, the only noticeable difference being that every now and then one more station starts using phone in addition to code. Each in his turn sends phone to the ends of the earth with the greatest of ease, and each appears to be astonished at his success (and quite often drops it and goes back to code again).

6LJ, once famous as a station which spent nearly all its time receiving, has, after a very successful period of DX transmission, apparently started to drop back to old habits, and receiving work again seems to predominate. Among others, he has heard four Philippine stations, 28 Brazilians and Argentines, and a Jap. His transmitter, when used, continues to be heard in Australia.

6OP is putting two watts into the London ether, and has worked the remote parts of Europe with it, while 2VS (an old London call-sign with a new owner) has obtained similar results with the same power.

Middlesex must be a wonderful place for reception, judging by the very fine lists I receive each month from those indefatigable listeners, Mr. Guy and the Messrs. Studley. This month both report a large number of South American and Pacific stations, while the latter also report a Chinese station. They recently had the unusual experience of hearing a new Argentine station, sending him a report, and later, hearing him acknowledge its receipt, without any prearranged schedule for listening.

Recent Activities.

6VP has just started up on 45 metres, after a lot of very good DX on the longer waves. As often seems to happen on arriving on short waves, he started with some trouble, but after the loss of two valves he is now working well, though on very low power as yet.

2UD, of Chatham, has recently started DX work, on low power. He has worked the North of Scotland with 5-watt phone.

2XV is another "ex-90-metre" newcomer to short waves, and he has already covered 4 000 miles with the transmitter.

5YK, using about 8 watts, has worked nearly every country in Europe, reaching as far as the North of Norway.

2KK has been following American signals

on the very long and very short waves (80 and 20 metres), and sends in a good list. This method of listening should appeal to those who want something of interest and find 45-metre American reception too easy to be interesting.

6TD says that there are apparently no stations left in Wales. He himself finds it usually too cold to work in the early mornings, and when he has been on he has not found conditions very good. He has, however, kept up touch with the world for a few thousand miles around.

5NJ (Belfast) has now worked quite a number of Australians and New Zealanders, and 8QQ of Indo-China.

Chilian CLAA (ex-Ch9TC) is now conducting his work with Argentine MA1 on 48 metres, instead of 89 metres as before. MA1 is still on the longer wave, and both would welcome reports from this country or the Continent.

Will all who have any interesting observations on "weather and signal strength" please let me have them by 10th January, together with DX reports as usual.

Among the Experimental Transmitters.

General Notes.

MR. S. K. LEWER (G6LJ), West Hampstead, is one of several amateurs who report having received signals from the Japanese station 1PP. In his case the signals were heard at 8 a.m. on Tuesday, 8th December, when they must have either travelled 9 000 miles of daylight or taken a curved path of about 14,000 miles of darkness. The Japanese station was later called by New Zealand 2XA.

6LJ has also received NPO, NAJD and 1HR in the Philippine Islands, the South African stations A6N and A6Z, and a station in Tasmania.

New Call Signs and Changes of Address.

We publish below various call-signs and addresses recently received. In some cases, of course, the transmitters may have been on the ether for some considerable time, but have not previously given us particulars of their stations. We take as our basis the list of amateur transmitting stations published in the *Wireless Annual for Amateurs and Experimenters*, and the following names and addresses supplements and corrects that list and appendix, as regards the experimental stations in Great Britain.

We would urge our readers to keep us continually informed of any change in their call signs or addresses and of any new call-signs allotted, in order that we may keep our records as complete and up-to-date as possible. It is generally found that those who are most backward in furnishing information are the first to complain of any omissions or inaccuracies in published lists.

Additional Call-Signs.

2IT B. Walsh, "Clovelly," Victoria Street, Armagh, North Ireland (in place of E. White, St. John's, S.E.8), transmits on 23, 45-90 and 150-200 metres.

2JC G. Sykes, 13, Lingford Street, Gorton, Manchester (in place of 2ADN).

2RK C. St. V. Roper, 7, Yale Court, Honeybourne Road, N.W.6 (in place of A. E. Blackall, Surbiton).

5IR H. Field, 62, Chertsey Road, Woking.

5JD J. L. Wood, Stanhurst, Burntisland, Fife.

5KR C. M. Thorpe, The Crossways, Rhuddlan, North Wales.

5KU R. Pollock, 4, Glenhurst Avenue, N.W.5 (in place of 2APW).

5WP W. E. Russell, 5, Walton Road, Woking (in place of 2AZA and in place of F. A. Wooldridge, Birmingham).

5WV D. Woods, Station House, Braintree, Essex. Transmits on 23 and 45 metres.

5ZG R. P. Hawkey, "Tregenna," Grange Avenue, Woodford Green, Essex (in place of H. Taylor, Colne). Transmits on 45 and 150 metres.

6MW Lieut.-Colonel C. W. Thomas, Clifton House, Old Swinford, Stourbridge.

6VZ A. E. Stephens, West View, Chewton Road, Keynsham, Bristol.

6YV S. F. Evans, 3, Clarence Crescent, Whitley Bay, Northumberland (in place of 2BDY). Transmits on 45 metres.

6YW T. P. Allen, 19, Ardgreenan Drive, Strandtown, Belfast. Transmits mainly on 45 metres.

Changes of Address.

2MD C. Chipperfield, 9, Nacton Road, Ipswich (lately at Oulton Broad).

2TK K. H. Thow, 2, Victoria Road, Eltham, S.E.9 (lately at Tulse Hill).

6TH C. W. Liles, "Morningside," Fields Road, Newport, Mon.

From the World's Wireless Journals.

Abstracts of Technical Articles.

R100.—GENERAL PRINCIPLES AND THEORY.

R125.1.—THE DIRECTION FINDING EQUIPMENT AT NITON AND CULLERCOATS.—J. H. Reyner (*J.I.E.E.*, Nov., 1925).

A brief description is given of the Bellini Tosi apparatus installed for ship work at the P.O. stations named. After approximate adjustment by bearings on known fixed stations, the apparatus is calibrated by radiotelegraphic observations on a ship, whose bearing is simultaneously determined by a theodolite. An error curve is thus obtained, and such curves for both stations are shown.

R114.—LES PERTURBATIONS ORAGEUSES DU CHAMP ELECTRIQUE ET LEUR PROPAGATION À GRANDE DISTANCE.—P. Lejáy (*Comptes Rendus*, Nov. 9, 1925).

Expressions are given for the three dimensional co-ordinates of the electric and magnetic fields due to the discharge between two thunderclouds. It is shown that the expression for the electric vectors contains a term which does not return to its original value after the discharge. Simply expressed, the discharge causes a sharp change of electric potential gradient. This manifests itself at considerable distances, and the author states that he has measured such variations of the order of 1 volt per metre at 100 kilometres distance, and of several hundredths of a volt per metre at 400 kilometres. The measurements were made with a valve electrometer in conjunction with a two-valve amplifier with resistance-battery coupling. The theoretical inverse cube law for such a field with distance is approximately confirmed. It is concluded that this sharp change is more harmful to a vertical aerial than to a frame, on account of the small magnetic field associated with it.

R134.—THE RECTIFICATION OF SMALL RADIO FREQUENCY POTENTIAL DIFFERENCES BY MEANS OF TRIODE VALVES. Part I.—F. M. Colebrook (E.W. & W.E., Nov., 1925).

R134.—A DETECTION COEFFICIENT.—J. J. Dowling and J. M. P. Higgins (*Electrician*, 13th Nov., 1925).

It is pointed out that the grid-current—grid-volts characteristic (over the region involved in grid rectification) approximates to the form $\log c=(v_0+v) \tan \delta$, where δ is the slope of the g.c.—g.v. characteristic. Curves for several different valves are given, $\log c$ being plotted against v. (*cf.* previous abstract.—ED.). It is then shown that the detecting efficiency of the valve can be written $D= S \tan \delta$, and curves are given illustrating the calculating of these two slopes, *i.e.*, those of the anode and grid characteristics respectively. The effect of the grid (leak) resistance is also considered, and it is shown that, within limits, the larger the leak and the more positive the point to which it is connected, the better the rectification.

An experimental method (approximately similar to that of the previous abstract) is described for the measurement of the detection given by two valves of calculated ratios $\frac{S1 \tan \delta 1}{S2 \tan \delta 2}$, and it is shown that the relation to calculated values is sufficiently close.

R134.4.—RÉGLAGE ET MISE AU POINT DES RÉCEPTEURS A RÉACTION.—M. Roller (*Onde Elec.*, Oct., 1925).

Smooth control of reaction is referred to as a difficult matter to obtain, and the use of a separate valve for reaction only is suggested. The grid circuit of this valve is in parallel with the amplifier input across the tuner inductance, and its anode circuit contains only a reaction coil back-coupled to the tuner. The advantages claimed are: (1) With reaction from the detector anode in the usual manner, the conditions for detection are not favourable for reaction, and it is advantageous to divide the work between two separate valves; (2) Reaction coming from behind several stages of H.F. amplification, on account of curvature the currents fed back are not proportional to the input nor in phase. With a separate reaction valve a straight line characteristic can be used and strict proportionality obtained.

R140.—LES CIRCUITS POLY ONDES.—L. Brillouin and E. Fromy (*Onde Elec.*, Sept. & Oct., 1925).

The articles deal with the analyses of complex circuits with more than one frequency. It is pointed out that the mathematical study of such multi-wave circuits becomes very difficult with increasing numbers of resonant frequencies. It is shown that these circuits can be analysed by physical and graphical methods obviating complicated and different formula. The method is by considering the impedance curves of simple "parallel resonance" or "stopper" circuits, and the behaviour of the circuit to frequencies on each side of the resonant frequency. The reasoning is extended from a single stopper circuit to a chain of N such circuits of progressively increasing frequency. Complex circuits can all be reduced to the equivalent form of a single $L\ C$ series circuit with more or less complicated stoppers in series with it. The stopper itself may be a simple parallel-resonance circuit, or a complex system capable of being similarly analysed into simple elements. Certain types of circuits are considered generally, and the discussion limited to the circuit of circuits of two frequencies. Eleven such circuits are finally summed up and illustrated, divided into three general classes: (1) Circuits consisting of an inductance and capacity in series with a stopper circuit which may be complex, semi-complex or simple; (2) (A) Two semi-complex stoppers in series with an inductance or a capacity; (B) One semi-complex stopper in series with a simple stopper and an inductance or a capacity; (c) Two simple stoppers in series with an inductance or a capacity; (3) Three simple stoppers in series. It is pointed out that the presentation given permits study of the change from one circuit to another of the same type, and that the principles shown can be extended to many other cases of practical application.

R142.—ETUDE EXPÉRIMENTALE DE LA RÉSONANCE DES CIRCUITS COUPLÉS.—L. Ollat (*Onde Elec.*, Oct., 1925).

The article first discusses the two degrees of freedom which exist with coupled circuits, and deduces expressions for the frequencies and decrements of the two wave-lengths resulting.

Experiments are then described for the determination of these values from resonance methods. Resonance curves were obtained with the use of a quartz fibre electrometer (due to Gutton & Laville). The advantage is claimed for the method (as compared with the more usual thermo-junction) that it does not introduce into the circuits a resistance of any considerable or (more still) of unknown value. A fixed tight inductive coupling (coefficient=0.957) is first considered, and the curves obtained are illustrated. The values obtained by experiment and by calculation are shown to be in very close agreement. A table for variable inductive coupling is then given, the coefficients of coupling being from 0.64 to 0.052. Measured and calculated values of the two wave-lengths are shown side by side, again in good agreement. Lastly is considered the case of two circuits electrostatically coupled. Expressions are derived for the two wave-lengths in this case, and a table compares measured and calculated values.

R300.—APPARATUS AND EQUIPMENT.

R342.2.—UBER WIDERSTANDSVERSTÄRKER (RESISTANCE AMPLIFIERS).—M. v. Ardenne and H. Heinert (*Zeitschr. f. Hochfreq.*, 26th Nov., 1925).

A useful contribution to the literature of resistance-capacity amplification. After developing expressions for the voltage release in a resistance-capacity coupled system, the use of a resistance of the order of 1 megohm in the anode circuit is recommended. Tests using such a resistance, actually of 0.82 megohm, are described. The resistance used was tested for stability of ohmic value, curves being given for its performance along with three other resistances which showed considerable change. With a resistance of this value in the anode, a circuital characteristic curve (anode circuit current against grid voltage) shows a length of steep straight on the negative (g.v.) side, rapidly flattening out to horizontal as the grid becomes positive. Such curves are shown for three valves, two being Telefunken three-electrode valves, and the third a Philips dull emitter four-electrode valve. They give respectively a length of completely straight characteristic of (1) ± 5 input volts, centred on —3, with amplification of 10; (2) ± 10 input volts centred on —8, with amplification of about 5; (3) Just over ± 1 input volt, centred on —1, with an amplification of about 60. The arrangement is recommended for L.F. amplification free from distortion, frequency-output curves being given for such a three-stage amplifier compared with several others, transformed coupled. Another point of novelty recommended is the use of .000 3μF coupling condensers (even for L.F. purposes) in place of the customary much higher values. It is also said that the filament can be kept much duller than with the more usual values of anode resistance, the smaller values of both filament and anode current representing economy both of valves and batteries.

R351.—CRYSTAL CONTROL FOR AMATEUR TRANSMITTERS.—John M. Clayton (*Q.S.T.*, Nov., 1925).

The general principles of the Piezo electric crystal are first stated, with its use as an oscillator or resonator. A description then follows of the preparation, mounting, etc., of the crystal. The application of the crystal to an oscillating circuit is then shown, followed by the application of the system to a transmitting aerial, as a "master oscillator." Illustration and description is also given of the use of a crystal with a two-valve transmitter using self-rectification to give full wave rectification from a 60 cycle supply. It is stated that the tendency of the crystal to remain in oscillation helps to smooth the intermissions of the supply voltage, giving a steadiness of received note equal to a pure D.C. supply. An extension of this system is shown, adding a power amplifier also supplied by the same A.C. transformer to the previous transmitter.

The article concludes with general remarks on the care and general handling of the crystals.

R.351.—NAVY DEVELOPMENTS IN CRYSTAL CONTROLLED TRANSMITTERS.—John M. Clayton (*Q.S.T.*, Nov., 1925).

A short description of the work done at the U.S. Navy Research Laboratory at Anacostia, D.C., on the control of transmitter frequencies by Piezo-electric crystals. The first attempt was a 5-watt crystal controlled oscillator followed by power amplification to give 10 watts in the aerial on a wave-length between 500 and 1 000 metres. The gradual increases of power later effected are described, the latest set achieved being one which deliver 10kW to the aerial at 25.5 metres. The crystal actually works at 51 metres, the first intermediate power amplifier acting as a frequency doubler. Information as to power supply and general arrangements is given. A 71.3 metre transmitter, crystal controlled, is also described. This normally delivers 10kW to the aerial, but it has at times been used for nearly 15kW aerial outputs.

R355.5.—THE RAYTHEON RECTIFIER.—M. Pennybacker (*Q.S.T.*, Nov., 1925).

After discussing certain fundamental principles of conduction through gas, this article shows the application of the principles stated to the design of the Raytheon Rectifier Tube. This tube is intended to give double wave rectification from an A.C. supply for receiving H.T. voltage. A large cathode supplies two anodes, each dealing with the opposite half-waves. The discharge points of the anode are very small and are within the inner hollow of the cathode, from which they are separated by a very short distance (whose value is not stated). A circuit diagram with filter details is given, also a curve showing the variation of output voltage with load current. It is stated that under continuous operation at 50 milliamperes there has been no sign of diminishing life after 10 000 hours.

R374.1.—SOME RECENT RESEARCH ON CRYSTALS. J. P. McHutchison and G. T. MacLeod (E.W. & W.E., Nov., 1925).

R388.—MEASUREMENTS IN ELECTRICAL ENGINEERING BY MEANS OF CATHODE RAYS.—Prof. J. T. MacGregor Morris and R. Mines (*J.I.E.E.*, Nov., 1925).

An extensive survey of the present position of the cathode ray tube, both from the point of view of the instrument itself, and of its application to practice.

The paper is divided into three parts and an Appendix.

Part I. first deals with two dimensional methods of measurement, more particularly oscillographic and cyclographic. In the former only one of the components is under the control of the unknown variable quantity, the second component having the sole function of introducing the time co-ordinate. In the latter method each of the components is under the control of the variable, although commonly one is controlled so that it is a known function of time. The paper then deals with the development of instruments for delineating rapidly varying quantities, leading up to the use of the "jet" principle and to the production of cathode rays in vacuum discharge. The general phenomena of discharge through gas of diminishing pressure are discussed and well illustrated by a table summarising the effects from an atmosphere down to 1-10 millionths of an atmosphere. Next are reviewed the generation of cathode rays and their application to electrical measurements, more especially their amenability to deflection by electrostatic and magnetic fields. Part I. concludes with an account of the development of the jet or pencil of cathode rays, illustrated by earlier cold cathodes (Thomson and Braun) and by the development of the heated (Wehnelt) cathode.

Part II. covers the development of the electron jet instrument. It is largely historical, giving illustrations of various types of cold cathode, leading up to the modern cold-cathode oscillograph of Dufour. The heated cathode is then reviewed, with illustrations and information of the former lime-spotted cathode, and the bare tungsten (Coolidge) and the coated filament (Western Electric) type. Methods of focusing the jet are then described, divided into (A) electromagnetic, *e.g.*, focusing coil; (B) electrostatic, including the ionic arrangement of the W.E. tube, and (c) geometric. Indicating and recording are discussed from the use of a fluorescent screen with visual observation or external photography to the use of internal photographic plates. Time scale systems are then discussed with illustrations, more particularly of some of Dufour's classical methods of obtaining records of high and very high frequencies.

Part III. briefly reviews limitations and directions for improvement, the greatest need voiced being that of improved deflectional sensitivity.

The Appendix (by R. Mines) is chiefly mathematical, and contains some useful expressions for the deflection of a jet by electrostatic or magnetic means, with series curves facilitating determinations of these for electron beams produced under different accelerating voltages.

A very complete bibliography covering tube technique and applications is appended.

R388.—THE CATHODE RAY OSCILLOGRAPH.—Dr. A. B. Wood (*J.I.E.E.*, Nov., 1925).

The advantages of the cathode ray oscillograph are briefly stated, followed by a note on cathode rays, with expressions for their velocity, deflection in an electrostatic field and deflection in an electromagnetic field. The paper then discusses voltage, current and photographic sensitivities, with a table showing the penetrating power of the rays according to their accelerating voltage. Three recent commercial forms of oscillograph are described. These are (A) The high voltage—*circ.* 60 000v.—cold cathode tube of Dufour; (B) The medium voltage —3 000v.— tube due to the author; (c) The low voltage—300v.—tube of the Western Electric Company. These are discussed under the headings (i.) Electrostatic sensitivity; (ii.) Magnetic or current sensitivity; (iii.) Photographic sensitivity; (iv.) General. The author's statement of the respective ratios for the first three can be tabulated as follows :—

	Accelerating Voltage.		
	30 000	3 000	300
(i.)	1	10	100
(ii.)	1	$\sqrt{10}$	10
(iii.)	1	10^{-2}	10^{-4}

The paper concludes with a brief statement of a few of the many applications of the cathode ray oscillograph, with illustrations showing records made by each of the three types discussed.

R388.—THE USE OF THE CATHODE RAY TUBE AS A WATTMETER AND PHASE-DIFFERENCE MEASURER FOR HIGH FREQUENCY ELECTRIC CURRENTS.—Prof. J. A. Fleming (*J.I.E.E.*, Nov. 1925).

The paper gives expressions for the closed curve (*e.g.*, an ellipse) obtained when two E.M.Fs. of the same frequency and of a constant phase difference are simultaneously applied to the two pairs of deflecting plates of a cathode ray oscillograph, that of the Western Electric Company being specifically mentioned. It is shown that if one deflection be due to high frequency current, and the other to the voltage producing the current, the trace of the spot can be used to find the phase difference between the two, and therefore the power expended in the circuit, the arrangement becoming an H.F. wattmeter more convenient than any electrostatic quadrant form.

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.

Transformer Curves.

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

SIR,—I have followed with interest the correspondence with reference to transformer curves. I have carried out very considerable experimental work with many low frequency transformers, and find that there is no appreciable change in amplification between input voltages of .01 and .07 volts, thus agreeing with the figures given by Mr. P. W. Willans.

This disposes, I think, of Mr. Appleton's contention, and my considered opinion is that any amplifier, to be reasonably perfect, should amplify all frequencies between 50 and 10 000 cycles equally. This is somewhat difficult to attain, but no doubt the British Broadcasting Company in their transmissions approximate closely thereto.

I am glad to see Mr. H. H. Dyer's letter asking for information on the amplification of transformers beyond the ranges usually given. I enclose herewith a leaflet giving the amplification curve of a make of transformer in which I am interested as designer, for the range of frequencies from 50 to 8 000. As there will probably be difficulty in finding space to reproduce these curves in your journal, the following figures may be of interest :—

The measured amplification of this transformer with a D.E.R. valve is—

17	at	50	periods per second.
24	,,	100	,, ,, ,,
32·5	,,	300	,, ,, ,,
33·3	,,	500	,, ,, ,,

keeping at this value until a frequency of 6 000 is reached. At this point it falls off slightly till at 8 000 it is 30.

I consider that this transformer is a great step towards perfection, approaching in properties the transformers used by the British Broadcasting Company, referred to in the last-but-one paragraph of Mr. H. L. Kirke's letter. A. B.

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

SIR,—Mr. W. A. Appleton in his letter in your November issue states that "when the input energy applied to a transformer is below a certain value, the amplification factor practically disappears. . . ." This statement, if correct, certainly has an important bearing on the operation of intervalve transformers in practice. But is there any experimental evidence for this? If so, it would be of great interest to have it set forth.

If it were so, it would mean that the permeability of the iron fell away to an exceedingly small value at very low inductions. This, however, does not appear to be the case. Tests made on a certain type of transformers, in which I am interested, down to one millivolt across the primary, show the maintenance of high impedance (and ratio). Further, permeability measurements at so low an induction density as one gauss (or 1 line per sq. cm.) indicate that the iron maintains a permeability in the neighbourhood of 300 at vanishingly small A.C. magnetic forces. C. D.

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

SIR,—I am astonished at the number of correspondents who disagree with my contention regarding L.F. transformer performance having minute input values.

I regret that the curves of P. W. Willans were not published, as from the editorial note they showed no change in amplification with strength between input voltages of .01 and .035 volts. If these figures as produced in the editorial note are correct, I do not regard them as having much effect upon my theory, as these values are well within the limits of laboratory measurements and are many times greater than the values I have been considering and which in my opinion are all important.

There is one suggestion I would like to make to these correspondents, and this is, that they should compare the amplification factor of resistance capacity coupling against a similar number of stages of transformer couplings, for inputs at various frequencies which can be reduced well below initial audibility, using any well-known make of L.F. transformer. My experience has shown me, that where a transformer-coupled amplifier has a higher amplification factor for a fairly reasonable value of input than a resistance-capacity-coupled amplifier, with much smaller values of input, the amplification factor of the transformer-coupled unit will become gradually decreased and a point can be reached where the resistance-coupled unit amplifies to a greater extent than the transformer-coupled unit.

Dr. H. Kröncke, in the issue of 23rd September of the *Wireless World*, quotes Manfred von Ardenne and H. Heinert and makes the following statement :

> "The fact that the old transformer amplifiers have a fairly large consumption of power was made manifest by the consideration that a transformer with an iron core cannot be worked by a current below a certain strength."

It is owing to the above fact that it has always been considered, in telegraph receivers, better to employ the air core choke or resistance-capacity-coupled stage before an iron core L.F. transformer-coupled stage where distinctly inaudible signals are to be amplified.

An interesting experiment can be made in testing this theory by reversing the position of two such units in an amplifier designed for one resistance-capacity coupling and one L.F. iron core transformer coupling. It would be of no use, however, if relatively strong signals only were used when making the test.

Neglecting for the moment the application of transformers to valve circuits, I would ask each of those correspondents if the losses in iron core transformers are proportionate to the input and output values? Furthermore, statements are made from time to time as to certain transformers, which possess a straight line curve, in fact, almost straighter than that which can be drawn by means of the common ruler. In order to produce such a straight line, it is essential that the constants of the transformer can adapt themselves to each frequency which is applied to its terminals. Theoretically, the inductive reactance, stray capacity reactance and other factors must bear some constant relation to the valve impedance with which it is used, for *any frequency* between the points chosen. In other words *non-reactive*! How this state of affairs is obtained I must confess I do not know, as I have submitted various alleged straight line curve transformers in sealed boxes to independent authorities and the results given by them have not coincided with the straight line curve originally attributed.

Have my critics a formula which produces one set of suitable transformer characteristics *constant for all frequencies* and therefore makes possible a definite design which will produce a straight line curve?

I should like to state that we have wound almost every conceivable form of transformer coil with a view to arriving at what we consider the best compromise, as a suitable compromise according to the natural order of things is all that can be hoped for up to the present.

I am afraid that the anecdotes of our old antagonist W. D. Owen are not helping to solve the problem, and unfortunately as I am personally representing a commercial company, I have to suspect the presence of vested interests in some of the criticisms.

With regard to W. D. Owen's conclusion that a debate should be arranged in public, this I am afraid is impossible unless the commercial interests of all the persons conducting the debate could be completely eliminated.

Regarding the last paragraph of Mr. Kirke's letter, all readers will be amazed to hear a B.B.C. staff member recommend the elimination of the already too weak low notes in order to level up the overall reproduction.

With special reference to Mr. H. H. Dyer's remarks, I think, after a little misunderstanding regarding reference to harmonics is cleared up, that I may state that his views seem to me similar to our own, and as expressed are the most reasonable.

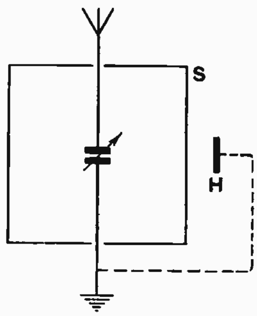
Whether our theory is correct or not, or whether the curves are applicable in their fullest meaning or not, is of secondary value to this all-important point, and this is, are the transformers which result from these theories of any value, or are the manufacturers obtaining the purchasers' money under false pretences?

W. A. Appleton.

Screening of Small Variable Air Condensers.

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

Sir,—I should like to make a comment upon Mr. D. A. Oliver's article "The Screening of Small Variable Air Condensers" in the December issue of your Magazine with reference as to whether the screen should be earthed, connected to either of the sets of plates, or left insulated.



In my opinion the best is to earth the screen in all cases, for the following reasons: In wireless receivers the main object of screening a condenser is to ensure that the capacity both between the two sets of plates and between them and earth shall remain constant for a given setting, irrespective of the variable proximity of any conductor, such as the human hand. Taking the case of the condenser in a parallel-tuning aerial circuit as an example, one set of plates is connected to earth and the other to the aerial. When there is no screen the capacity to earth is increased as the hand, etc., which is at earth potential, is brought nearer. When there is a screen either insulated or connected to the aerial set of plates the effect is as with no screen but slightly increased. This is shown in the figure, where *S* is the screen and *H* the operator's hand. When the screen is insulated the aerial plates have a fixed capacity (for a given setting) to *S*, which has a variable capacity to *H*, *i.e.*, to earth. Thus the aerial-earth capacity can vary by moving *H* without the setting of the condenser being varied. This effect is increased if the screen is connected to the aerial. If however the screen is earthed the proximity of the hand can make no difference, for it is at the same potential as the screen.

In the case of anode condensers and all other condensers the same argument holds and it would therefore seem advisable to earth all screens in whatever part of the circuit they may be used.

There is a problem that has been puzzling me for some time that would also probably interest your readers. Perhaps we could have an article explaining it in the near future.

The question is: How does the series variable condenser tune a receiving aerial circuit?

I am still looking forward to the series of articles on elementary circuit calculations and on setting up a wireless laboratory promised in the March Editorial and hope they will soon appear, as well as some articles on special branches of mathematics as hinted in the same Editorial.

R. Kay Gresswell, F.R.A.S.

Lynn Garth,
Grange Road, Southport.

Patents.

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

SIR,—With reference to your notes under "Editorial Views" (Dec. E.W. & W.E.), it is apparently wrong for anyone to construct a set (infringing patents) for musical entertainment. It appears to me that there must be some thousands of people who have built their own sets and how were they to know what patents were in force and what not? I quite appreciate your views, but doubtless your intended article by a patent agent will throw much light on the "constructor's" position. If articles are published containing instructions, "How to build a ——" and this include certain patents, there seems to be no reason why such sets cannot be built by the amateur, and this is in opposition to your statement.

With reference to your notes some time ago *re* instruction in mathematics, I should like to say that I am very much in favour of such articles being given. I have made extensive search but I have not yet come across a textbook suitable for use with wireless. I am aware that an outline of mathematics can be obtained from elementary textbooks, but their direct application to matters radio seems to present some difficulty at first. Take, for example, the excellent series of articles by F. M. Colebrook; some knowledge of mathematics is necessary for a complete understanding, and some lines of reasoning seem too deep to follow and have to be taken for granted or put aside as unintelligible. This, of course, may not be everyone's opinion, but to my mind some articles of this type would be greatly appreciated by many.

Trusting that this suggestion may be of some use, and wishing the E.W. & W.E. every success.

C. F. SCALES.

Sunnyside, Oxney Green,
Writtle, Essex.

Abstracts in Esperanto.

The Editor, E.W & W.E.

SIR,—In your last issue you had an admirable "leaderette" entitled "Why we give space to Esperanto." In your remarks you stated that the articles and abstracts now appearing are not primarily intended for British readers, but were provided for your many foreign readers, and you mentioned that possibly in the future there would be an international arrangement amongst leading wireless technical journals in different countries to publish Esperanto abstracts of their own contents.

In this connection may I be permitted to refer to an important Congress which has recently taken place in Paris. It was the first International Congress of the Technical Press, under the patronage of the President of the French Republic. Delegates from the most important technical gazettes in a number of countries took part in the discussions, amongst which was one entitled "Should the technical Press favour the development of Esperanto, the International Language?"

A special commission was appointed to consider this question under the Presidency of M. André Baudet, Member of the Paris Chamber of Commerce. The report of this commission was duly presented to the Congress, and after a discussion the following resolution was carried:—

"Considering the very favourable results to Esperanto of the Congress which took place last May in Paris, attended by delegates of 171 Chambers of Commerce, 10 Governments, 14 commercial fairs, and 208 business enterprises belonging to 33 different countries, as well as the representatives of more than 140 scientific and technical institutions belonging to some 20 countries;

"Considering the great difficulties encountered in dealing with publications on account of the increasing number of technical and scientific works published in various languages;

"Considering that an international language commonly used, whether for the editing of original articles, or at least for the publication of abstracts of articles, would simplify considerably the work of documentation;

"Considering that Esperanto, the use of which has penetrated into commercial circles, thanks to its qualities of clarity, simplicity, and richness of expression, appears to be easily adaptable to the needs of technics and science;

"The first International Congress of the Technical, Commercial, and Agricultural Press resolves:

"1. That Esperanto should be used in the Technical Press at least for the publishing of abstracts, which should follow the publication of all articles and original works in journals and reviews of the whole world;

"2. That Esperanto should be accepted as an official language on the same level as the national languages, in the International Congresses of the Technical Press."

17, Chatsworth Road,
London, E.5.

HARRY A. EPTON,
Secretary.
Internacia Radio-Asocio.

Howling in Short-Wave Receivers.

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

SIR,—With reference to Mr. Robinson's remarks on the howl in short-wave receivers (p. 770). Compare E.W. & W.E., p. 323, March, 1924. Independently, I described this in February, 1925, in *Revista Telegráfica*, of Buenos Aires, giving the same explanation. There is no doubt that the howl is built up of the clicks caused by entering and leaving oscillation.

The remedies are to increase reaction, decrease the grid-leak value, and (sometimes) touch some part of the circuit (in many case, the filament rheostat of the L.F. valve). This is only the case when wearing headphones, but the howl is not troublesome with loud-speakers. (The reason for this is obvious, but I am not satisfied with any explanation I have built up as regards the occurrence on *short* waves only.)

With reference to p. 773, the signals of this station on 48 metres are very weak (R2-3) to Ch2LD and strong (R7-8) to Ch4RM. Both receivers are in the city of Santiago, some 50 miles away.

R. RAVEN-HART, M.I.R.E. (Ch9TC.)

Los Andes,
Chile.

Some Recent Patents. [R008

AN ELECTRICAL ALLOY.

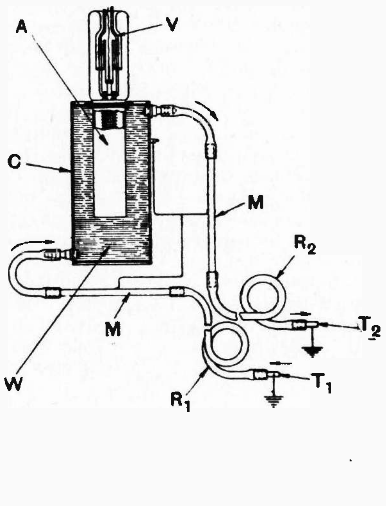
(*Application date, 11th June. No.* 240,895.)

The composition of what appears to be a very useful electrical alloy is described in the above British Patent by the Western Electric Company, Limited. The alloy is intended for the manufacture of contacts, which are normally subjected to considerable frictional wear, and also arcing, such as the wiping type contact. Accordingly, the alloy is of a phosphor bronze nature, being composed chiefly of copper to which is added 4 to 5½ per cent. of tin, and from 1 to 4 per cent. of lead and a trace of phosphorus. The specification states that a wiping contact made of this alloy shows little effect of wear and tear after 5 000 000 make-and-break operations, whereas with a normal bronze spring it is useless after about 3 000 000.

A VALVE COOLING DETAIL.

(*Convention date (Holland), 24th January,* 1924. *No.* 228,130.)

A rather interesting point in connection with the cooling of high power valves is disclosed in the above British Patent granted to N. V. Philip's Gloeilampenfabrieken. It is well known, of course, that the anode of a high power water-cooled valve is at a very high potential with respect to earth, and means have to be provided for insulating the cooling system in some way or other. In some cases the cooling water is broken up into a fine spray so as to present an infinitely fine resistance. In another method the cooling water is supplied through very long thin insulating tubes. It has been found, however, that a certain amount of leakage results which produces electrolysis, particularly at the outer surface of the anode, which becomes oxidised, and is liable to be rendered porous, and thus useless. A rather ingenious method of overcoming this difficulty is shown in the accompanying illustration. It will be seen that a water-cooled anode *A* of a high power valve *V* is located within a chamber *C* containing the cooling water *W*. The cooling water is supplied through an earthed metal tube T_1, which communicates with a long rubber tube R_1, the outlet of the system being through a similar rubber tube R_2 and an earthed metal tube T_2. Instead of connecting the ends of the rubber tubes directly to the water jacket, metal tubes *M* are inserted, and these are connected as shown to the metallic water jacket *C*. For all practical purposes the potential of the anode *A* and the water *W* in the jacket *J* and the metal tubes *M* is the same, and thus any electrolytic action which may occur will be confined to the metal tubes *M*, since they are nearer the earthed tubes *T*. Thus if any electrolysis occurs the tubes *M* can readily be replaced without any material cost or damage to the expensive valve.



AN INSULATING MATERIAL.

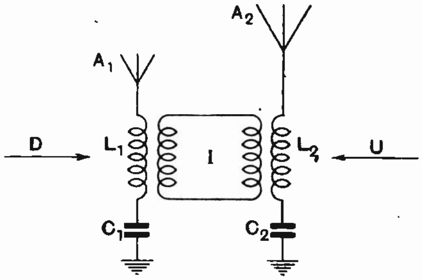
(*Application dates, 31st July,* 1924, *and 20th January,* 1925. *No.* 241,993.)

The composition of an insulating material which would appear to be of use for certain wireless purposes is described by C. Pickstone, J.P., in British Patent No. 241,993. The composition is composed essentially of powdered slate, rubber, bitumen, and vulcanising material such as sulphur. The composition is prepared by mixing slate waste, which is finely powdered, with similarly treated rubber and bitumen. The ingredients are mixed together and heated, after which the sulphur is added, when vulcanisation is carried out to the desired degree of hardness. It is stated that the resulting composition can be buffed or polished, or given a matt surface, and can also be combined with colouring matter. It would be interesting to examine the electrical properties of this composition, as it is very difficult to predict how it will perform from a knowledge of its separate constituents.

A SCREENED AERIAL SYSTEM.

(*Convention date (Germany), 11th September,* 1923. *No.* 221,825.)

A selective method of reception depending upon the screening of an aerial system is disclosed in British Patent No. 221,825 by the Telefunken Gelleschaft für Drähtlose Telegraphie M.B.H. The arrangement is indicated schematically in the accompanying diagram. It is assumed that the desired signals are coming from the direction *D*, and are to be received on the aerial system A_1, L_1, C_1. It is further supposed that the unwanted signals are coming from the direction *U*. Accordingly, another aerial system A_2, L_2, C_2 is arranged so that the aerials A_1 A_2 and the direction of the unwanted station lie in the same plane. The aerial circuit A_2 is very critically tuned to exactly the same frequency as that of the aerial circuit A. The two are coupled together by an intermediate aperiodic circuit I. It states in the specification that it is very important that the phase of the two circuits be accurately adjusted. When the disturbances from the direction of U fall on the aerial



system the system A_2 screens the system A. Another important detail of the invention is that the aerial A_2 is less than a quarter of a wave-length from the aerial A, which enables the system to be located within a small area. No extensive details are actually given in the specification of the manner in which the scheme operates.

A MULLARD FILAMENT.

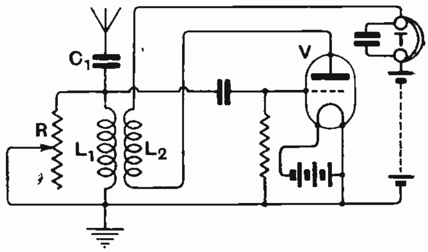
(*Application date, 1st August*, 1924. *No.* 241,996.)

An interesting dull emitter filament is described by S. R. Mullard and The Mullard Radio Valve Company, Limited, in British Patent No. 241,996. Briefly, the invention consists in forming a dull emitter filament in the form of a tube of highly active material which is slipped over a wire support which is used as a heating device. One form of the filament is made in the following manner: The foundation or core is of tungsten wire, which is drawn in exactly the same manner as an ordinary filament. The coating or tube is built up from a mixture of molybdenum or tungsten powder with 6 or 7 per cent. by weight of thorium. This may be mixed into a paste and squirted through a die, after which the resulting tube is heated to a high temperature and sintered in an atmosphere of hydrogen. The tube thus formed is slipped over the tungsten wire core which is suitably adjusted in size and used as a supporting medium. It is stated in the specification that it is only necessary to heat the core to a very moderate temperature in order to obtain sufficient electronic emission from the prepared tube.

CONTROLLING RETROACTION.

(*Application date, 21st July*, 1924. *No.* 241,618.)

A method of controlling retroaction is described in the above British Patent which has been granted to P. W. Willans. It is well known that the effect of retroaction is to overcome or neutralise the effective resistance of a circuit. Instead of varying the degree of retroaction between the anode and grid circuits of a valve receiver, the method indicated in the accompanying illustration is employed. It will be seen that an aerial circuit consisting of C_1L_1 is connected between the grid and filament of the valve V. The anode circuit contains the usual reaction coil L_2 and the telephones T. In addition, a variable resistance R is shown connected across the input circuit. It will be obvious that the ohmic value of this resistance will control the amount of retroaction necessary to bring the system to the point of oscillation, or in other words will

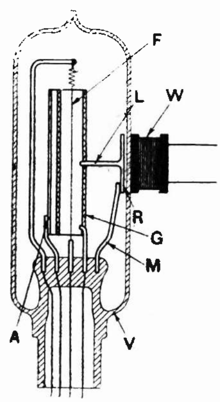


determine the amount of coupling necessary between the coil L_1 and the coil L_2. Thus it will be seen that it is possible to fix the coupling between the two inductances, and merely vary the retroaction by adjusting the value of the resistance R. Readers will know, of course, that the idea of varying the degree of retroaction by means of an adjustable resistance is quite old, a receiver operating by virtue of this principle having been described in the earlier issues of E.W. & W.E.

A VIBRATING ELECTRODE.

(*Application date, 9th July*, 1924. *No.* 240,920.)

A rather peculiar valve is described in the above British Patent by E. T. Fisk. The object of the invention is to control the anode current of a thermionic valve by mechanically varying the position of the control electrodes with respect to the filament. The specification is fairly detailed, and describes several alternative embodiments of the invention, but that shown in the accompanying illustration serves to indicate the novelty of the idea. It will be seen that a valve V contains the usual filament F and a gap or semi-circular anode A and a particular form of grid or control electrode G. This is attached by a link L to an armature R which is supported on a resilient member M. The armature R, which is within the valve, is in close proximity to the glass wall, against which is placed an electromagnetic winding W. Thus it will be seen that currents passing through the winding W will attract the armature and cause the control electrode to vibrate, thereby modulating the output of the valve. In another

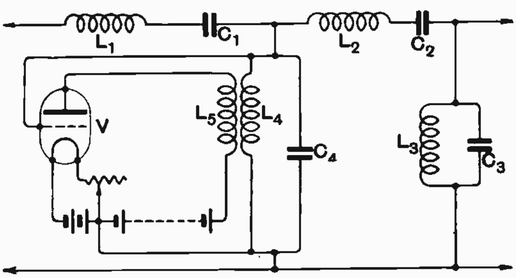


modification the control electrode is caused to vibrate simply by the sound waves impinging upon the surface of the wall of the valve, which can be specially constructed for that purpose in the form of a tympanum.

SELECTIVE FILTER CIRCUITS.

(*Convention date (U.S.A.), 9th August*, 1924. *No.* 238,211.)

It is well known that it is possible to obtain almost any degree of separation of currents of various alternating frequencies by means of filter circuits, such as high pass filters, low pass filters, and band filters, comprising essentially inductances and capacities arranged in T or $T\pi$ formation. A method has been patented by the Westinghouse Electric and Manufacturing Company in the above British Patent No. 238,211. It is well known that the effect of the resistance upon the attenuation of a filter section depends upon the ratio of $2\pi fL$ and R and is given by the ratio $2\pi fL/R$. Obviously, then, by reducing the resistance greater efficiency is obtained. It is, further, well known that the effective resistance of a circuit can be reduced substantially to zero by connecting it

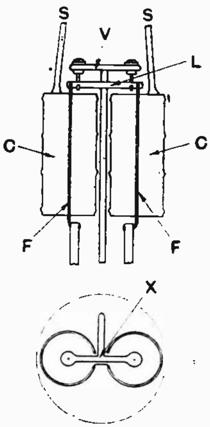


to a negative resistance device such as a retroactively coupled thermionic valve. Thus in the accompanying illustration, which shows a π section filter, we have the ordinary circuits L_1 C_1, L_2 C_2, L_3 C_3, and L_4 C_4. The circuit L_4 C_4, however, is connected across the grid and filament of a valve V which contains in its anode circuit the inductance L_5, retroactively coupled to the inductance L_4. Thus it will be seen that the effective resistance of a section, L_4 C_4, is reduced substantially to zero, thereby materially increasing the efficiency of the circuit. It will be remembered that an almost identical application in the form of the well-known Hinton rejector circuits, in which retroactively coupled valves were associated with ordinary series acceptor or rejector circuits, have been used very successfully by the Post Office.

A DOUBLE ANODE VALVE.

(*Application date, 23rd July*, 1924. *No.* 240,944.)

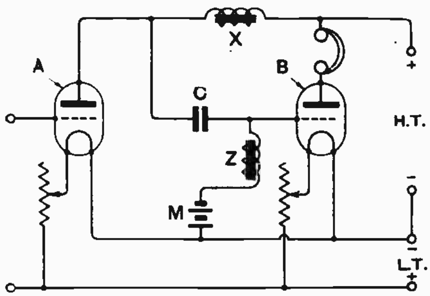
The construction of a valve with a double anode particularly designed to be used with a loop filament is described in the above British Patent by The General Electric Company, Limited and A. C. Bartlett. Instead of makingone large flat anode and providing a loop filament totally enclosing it, the arrangement shown in the accompanying illustration is adopted. It will be seen that the filament F is arranged in the form of two vertical wires, which are supported by a link L attached to a horizontal upright U. The anode consists of two cylinders C attached to their respective supports S, or while in another modification it is made from one piece of metal, a small gap being left as shown at X in the lower half of the illustraion. Readers will no doubt remember having seen a patent specification some little while ago referring to an almost identical arrangement by the Mullard Radio Valve Company.



A PECULIAR AMPLIFIER PATENT.

(*Application date, 9th July*, 1924. *No.* 241,257.)

The accompanying diagram illustrates the substance of British Patent No. 241,257, granted to H. Green in respect of amplifier circuits. Referring to the accompanying illustration it will



be seen that two valves A and B are intended to be used as low frequency amplifiers, the anode circuit of the valve A being coupled to the grid circuit of the valve B by means of a choke X and coupling condenser C. The grid circuit of the valve B comprises a choke Z and a grid battery M. A claim is made in the specification for using a choke in the anode circuit of one valve followed by a choke in the grid circuit of the next, and a further claim is made for using chokes of similar value. It is stated that 1H may be used with LS5 type valves. Frankly, we do not see very much novelty in the invention. The idea of using a choke as a coupling medium in the anode circuit to the grid of the next and also of using a choke in place of a resistance in the grid circuit is not new. We find them in ordinary choke transmitters provided with choke-coupled sub-controlled valves, and the patent appears to be of an exceedingly limited nature.

For the Esperantists. Distordado.

[R800

En tiu-ĉi parto, oni pritraktas la demandon pri distordo, kaŭze de Laŭtparoliloj, kaj donas kelke da konsiletoj pri ĝia evitigo.

PARTO VIA.

MALLONGIGOJ : A.F., Alta Frekvenco ; M.F., Malalta Frekvenco ; A.T., Alta Tensio ; M.T., Malalta Tensio ; K.K., Kontinua Kurento ; A.K., Alterna Kurento.

FUNKCIO DE LA LAUTPAROLILO.

ANTAŬAJ artikoloj en la nuna serio traktis pri la amplifikatoro, ankaŭ pri la detektoro. Ni nun diros kelkajn vortojn pri la laŭtparolilo aŭ telefonilo.

Oni devas unue tutklare kompreni, ke ni nun alvenas al tre malfacila parto de la temo, se ni deziros trakti ĝin profunde.

Ĝis nun niaj problemoj estis problemoj *elektraj*. Ni penis produkti elektran kurenton de tia forto kaj frekvenco, kiu sekvos precize (sed multe grandigite) la forton kaj frekvencon de la modulo ĉe la antena kurento. Sed nun ni devas komenci pensi pri aeraj ondoj kaj ilia efekto ĉe l'orelo. Ni deziras produkti aron da aerondoj, kiu produktos ĝuste la saman efekton ĉe l'orelo, kiel farus la originala muziko, se ni estus en la brodkastejo mem. Nature, ni unue demandas, kiel ĝuste aŭdas la orelo, kaj kiaj ĉe ĝi la efektoj de variantaj aerondoj. Sed bedaŭrinde la demando ne ankoraŭ estas solvita.

Aparte de tiu-ĉi ĉefa malfacileco, ni devas rigardi la fakton ke, kreante la aerondojn, kiuj trafas la orelon, la laŭtparolilo ne funkcias sole. Eĥoj el la muroj de la ĉambro en kiu ni troviĝas havas grandegan efekton ; tiel, laŭtparolilo, kiu donas bonegan rezulton en unu ĉambro, eble sin kondutos tute malsame en alia.

Kaj ni ne povas eviti ĉi tiujn malfacilaĵojn per uzo de telefonilo, ĉar ekzistas konvinkigaj kaŭzoj por supozigi, ke telefonilo ne povus doni perfektajn rezultojn, eĉ se ili estus perfektaj elektre. Ni aŭdas la originalan prezenton pere de liberaj ondoj en la aero, ĝuste kiel ni aŭdas laŭtparolilon. Telefonilo, kontraŭe, kiam portita laŭkutime, tute ne kreas liberajn ondojn en la aero, sed simple puŝas la aeron sur la diafragmon de la orelo. La diferencon oni ne povas tute klarigi sen longa diskutado pri la naturo de ondoj ĝenerale. Sed la diferenco estas fundamenta.

KELKAJ KONSILETOJ.

Konsiderante ĉiun el tiuj malfacilaĵoj, estas evidente, ke ni ne povas fari, kiel ni faris pri la amplifikatoro—t.e., doni klarigojn pri rimedoj por eviti distordon. Ni povas nur doni kelkajn konsiletojn.

Unue, memoru, ke la ideo uzi certan laŭtparolilon, " ĉar ĝi taŭgas por la aparato," estas fundamente malprava. Se la aparato estas sendistorda, ni bezonas parolilon ankaŭ sendistordan. Se iu alia parolilo ŝajnas taŭgi treege bone por iu alia aparato, tio estas simple ĉar la aparato distordas unumaniere, kaj la parolilo kontraŭmaniere—eble la aparato estas akratona kaj la laŭtparolilo raŭka—kaj en neniu okazo ĉi tia la rezulto estos tiel bona kiel tiu de sendistorda aparato kaj la plej bona laŭtparolilo. Diri, ke unu speciala laŭtparolilo " taŭgas " por aparato, estas konfeso, ke la aparato estas malbona.

KONTINUKURENTAJ EFEKTOJ.

Punkto rimarkinda estas, ke iu ajn laŭtparolilo estas pli-malpli influita de la

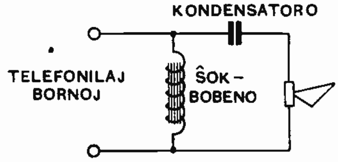


Fig. 1.

konstanta K.K. (la anoda kurento de la lasta valvo) trapasanta tra ĝin. Modernaj laŭtparoliloj estas kutime desegnitaj permesi tion. Sed ĉiam indas observi, ĉu la tono aŭ amplekso estas plibonigita per ĝia forigo. Tio estas facile efektivigebla, kiel per Fig. 1.

La ŝokbobeno permesas al la K.K. komponaĵo pasi rekte tra ĝin, dum ĝi malpermesas la parolajn kurentojn. Tiuj ĉi lastaj tamen trapasas la kondensatoron kaj funkciigas la laŭtparolilon.

Ĉi tiun aranĝon oni povas tuj kompari kun la norma aranĝo per simpla 2-voja komutatoro, konektita kiel en Fig. 2. La kondensatoro devus havi kapaciton 1 aŭ 2μF ; por la ŝokbobeno, la sekundaria vindaĵo de M.F. transformatoro taŭgos, aŭ unu el la diversaj ŝokbobenoj faritaj por ŝok-kuplitaj M.F. amplifikatoroj. Estos necese provi kelke da diversaj bobenoj por trovi la plej taŭgan.

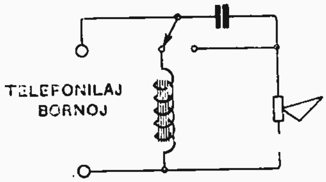


Fig. 2.

Memoru ke, ĝenerale, la alta kosto de grandaj laŭtparoliloj estas mono bonege elspezita. La granda instrumento ordinare estas pli sentema por malalta potenco ol la malgranda, kaj ĝi ankaŭ povas porti grandan enmeton. Plue, malgranda korno havas malbonan efekton per fortranĉo de la malaltaj tonoj. Ofte granda korno ĉe " bebeta " laŭtparolilo produktos miregigan plibonigon.

AKUSTIKO EN LA ĈAMBRO.

Laste, ne forgesu la ĉambron. Bona ekzemplo pri la efekto de la ĉambro estas, kiam la agorda signalo estas sendata de la brodkasta stacio. Tio estas pura tono de unu definitiva frekvenco, kaj estas tial reflektita de la muroj, k.t.p., laŭ tute konstanta maniero. Ĝenerale, oni trovos, ke iometa moviĝo de la kapo—nur kelkaj centimetroj en iun ajn direkton—duobligos la laŭtecon, aŭ preskaŭ tute malaŭdebligos ĝin. Fakte, estas en la ĉambro laŭtaj kaj kvietaj lokoj.

Ĉi tio estas pro interfero inter la rekta sona ondo de la laŭtparolilo kaj aliaj ondoj reflektitaj el de la muroj. Ĝi ne estas rimarkata kiam la komplikitaj sonoj de muziko envenos, sed ĝi ekzistas kaj kaŭzas distordon, ĉar iu difinita loko estos " laŭta " loko por kelkaj tonoj kaj " kvieta " loko por aliaj. La kuraco estas, pendigi kontraŭ la muroj ŝtofon, kiel oni faras en la brodkastejoj. La inĝenieroj ĉe la senda stacio reguligas la kvanton da eĥo, kaj devus ne esti tro da ĝi ĉe la riceva stacio.

Nur unu plua punkto. Ia distordo ordinare fariĝas pli rimarkebla dum la potenco pliiĝas ; krom tio, estas tute eble, ke aparato, kiu estas sendistorda je malalta potenco, havas distordon je pligranda elmeto. Tial oni devus konservi silenton, kiam oni deziras impresi alian personon pri la tonpureco. Tamen. *ne* malaltigu la potencon se vi eksperimentas nur por via propra celo. Altigu la laŭtecon ĝis almenaŭ 66% de la aktuala prezento ; se tiam ne estas distordo, oni povas resti kontenta, ke ĉio funkcias bone.

Jen finiĝas nia mallonga referato pri la ĉefaj kaŭzoj de nuntempa distordado.