EXPERIMENTAL WIRELESS & The WIRELESS ENGINEER

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Editorial.

The Losses in Air Condensers.

ON p. 656 of this number we publish a paper by Mr. Wilmotte in which he describes a method of measuring the losses in air condensers and gives examples of the results obtained in some actual tests. The method itself is the well-known one in which a current is induced in a tuned circuit containing the condenser under test which is then replaced by a standard condenser, in which the losses are small and known, in series with a resistance which is varied until the combination is exactly equivalent to the condenser under test, as indicated on a thermal ammeter in the tuned circuit. Those who have tried to carry out this measurement at high frequencies will know how difficult it is to obtain consistent and reliable results, and will appreciate the useful hints which the author gives and the description of the special apparatus devised for the purpose of the test. The method has been used for frequencies up to 6×10^6 ($\lambda = 50$ metres); at these frequencies, unless special precautions are taken, it is easy to obtain results which are so inaccurate as to be entirely worthless.

Mr. Wilmotte's analysis of his results is expressed by what he calls an empirical formula, but we doubt if the adjective is quite justifiable. We may assume that the losses in an air condenser are made up of two parts, one due to the resistance of the leads, connections, plates, etc., and the other due to losses in the solid dielectric material situated in the electric field. The former may be regarded as a series resistance, probably variable to a slight extent with frequency; the latter may be regarded as due to a solid dielectric condenser in parallel with the air condenser. If we assume that the loss W due to hysteresis in the solid dielectric is proportional to the frequency and to the square of the voltage, we may write $W = a\omega V^2$, where a is a constant. The condenser current $I = \omega CV$ to a high degree of approximation, and for an equivalent series resistance R to give the same loss of power as the solid dielectric we must have

$$I^2R = W = a\omega V^2$$

and $$R = \frac{a\omega V^2}{I^2} = \frac{a\omega V^2}{\omega^2 C^2 V^2} = \frac{a}{\omega C^2}.$$

The total apparent series resistance will therefore be

$$r + R = r + \frac{a}{\omega C^2},$$

where a is a constant and r probably varies but little over a wide range of frequency. This is exactly the result obtained by Mr. Wilmotte from his tests, which therefore serve to confirm the above assumptions. One disadvantage of the method is the necessity of having a standard condenser for comparison, the losses in which must be small and known. The National Physical Laboratory is, of course, well provided in this respect, but Mr. Wilmotte does not state what condenser he used for the purpose nor what assumptions were made as to its losses

G. W. O. H.

The Comparison of the Power Factors of Condensers.

By Raymond M. Wilmotte, B.A., A.M.I.E.E.

Introduction.

THE usual method of comparing the power factors of two condensers at radio frequencies is to measure the resistance of a circuit containing one of the condensers, then to substitute the other condenser for the first and again measure the resistance of the circuit. The difference between the two readings gives the difference between the effective series resistances of the two condensers.

Those who have employed such methods will know how tedious the measurements are. When the two condensers are of similar quality, many of the errors inherent in the usual methods of resistance measurements do not appear, as they cancel one another, but, when bad dielectrics are being measured, this is by no means the case and the most difficult cause of error to overcome, namely, reaction back from the circuit being measured on to the source of high-frequency power still remains.

It was in order to see to what extent a simple substitution method could simplify the usual method of measurement that the apparatus described in this article was developed. The degree of accuracy reached was considerably superior to that anticipated. Moreover, much higher frequencies than are suitable for the ordinary method have been found to be workable. The upper frequency limit of the method is not known. The highest frequency used has been 6,000 kilocycles, but there is no reason to suppose that still higher frequencies could not be used.

The principle of the method is very simple; it consists of tuning a circuit with each condenser separately and rapidly switching from one to the other. A resistance is inserted in series so that the current is brought to the same value in the two cases. The value of the resistance will then be the difference between the effective series resistance of the two condensers. One of the condensers is usually a standard the power factor of which is either known or else negligibly small.

Design of Continuously Variable Resistance.

An essential instrument for the application of the method is a continuously variable resistance suitable for high frequencies. This instrument will not be described in detail as this was done in a previous number of the *E.W. & W.E.* ("A variable resistance suitable for high frequencies," by R. M. Wilmotte, *E.W. & W.E.*, Vol. 2, 1925, pp. 684–686). Since this instrument was designed a few alterations have been made. The variation of resistance is obtained by making part of the wire of copper and part of eureka. The brushes are kept fixed and the wire moved so that when the pointer is at zero the wire between the brushes is nearly all copper, and when it is at full scale (1.1 ohms) the wire is nearly all eureka. In this way the shape and position of the electric circuit remains absolutely unaltered. The real difficulty in the design is to prevent too large a variation of resistance occurring with frequency. For this it is essential that the wire be very thin or that thin strips be used. Actually, the thickness of the strips used was 0.05 mm. When such thin strip is used it is difficult to allow the brushes to make contact with much pressure without fouling the strip, so that normally the contact resistance is large and variable. In order to overcome this difficulty, in the first design the contact was moistened with oil, but this was not found completely satisfactory and the contacts are now kept permanently under oil. A further difficulty arose after the resistance had not been used for several weeks, the contact was found to be bad owing to the wire having been attacked by the sulphur contained in the oil and in the ebonite, of which the instrument was made. This was satisfactorily overcome by making the instrument wholly of bakelite and using medicinal paraffin for the oil. Even now it is advisable to vary the resistance backwards and forwards a few times before using, so as to thoroughly oil the whole wire and remove any impurity from its surface by means of the brush friction. In Fig. 1 is shown the measured variation of resistance with frequency. This has been measured up to a frequency of 12,000 kilocycles.

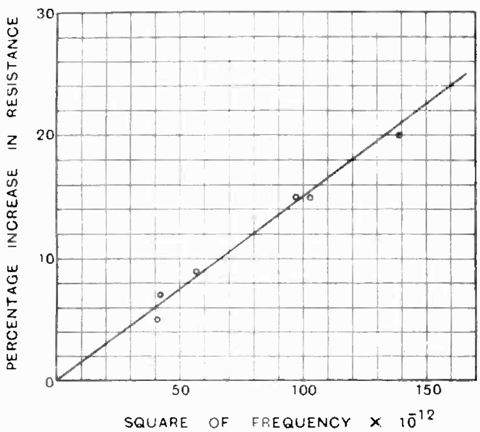


Fig. 1.

The resistances as described here have now been in use at intervals for over a year and have been found satisfactory.

The Complete Apparatus.

The complete circuit is shown diagrammatically in Fig. 2. The high-frequency E.M.F. is induced in a convenient coil L. Actually L consists of two coils in series, which can be adjusted relatively to each other to give a variable self-inductance. A number of flat coils have been designed for this purpose. The coil is connected through a reversing switch Q to either of the condensers C_1 or C_2 which are being compared, *via* the leads A and B and the key S. The design of this key will be considered below. In series with the condensers, are two variable resistances R_1 and R_2 of the type already described. In order to permit differences of resistance greater than 2 ohms, mercury cups are put in series with the continuously variable resistances, and in these cups may be inserted fixed resistances, made of very fine (No. 47 s.w.g.) resistance wire. The current is measured by means of a thermo-junction non-contact ammeter T of the type recently described by F. M. Colebrook and the author (*E.W. & W.E.*, Vol. 5, 1928, pp. 538–544) connected to a galvanometer G. The use of the potentiometer P and the condenser C_0 will be considered later.

The procedure is to tune the circuit first with the point 2 of the key S connected to the point 1 and, secondly, with the point 2 connected to the point 3. The resistances R_1 and R_2 are adjusted until the same current flows in the thermo-ammeter T for both positions of the key S.

In order that consistent and correct results may be obtained by such a method, it is essential that the E.M.F. induced in the circuits corresponding to the two positions of the switch S should be accurately equal. That is, the two circuits should be as electrically similar as possible. For this reason everything possible should be screened. The leads A and B are screened by each other, the lead B being a tube surrounding the wire A. These two leads are made as long as is conveniently possible (in the actual apparatus they are about 3 ft.), so that the E.M.F. induced from the source into the critical portions of the circuit beyond the thermo-ammeter T might be as small as possible. This critical portion of the circuit from the thermo-ammeter T to the condensers C_1 and C_2 is unscreened. This part of the circuit is kept as small and as

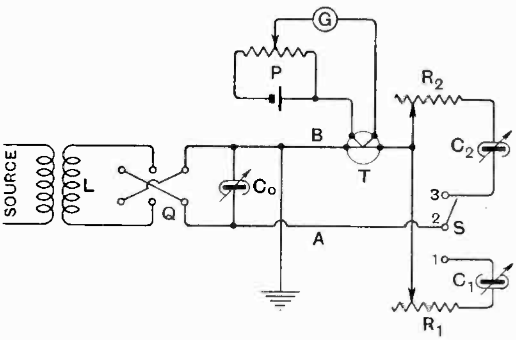


Fig. 2.

close together as possible. It was not found necessary to screen the resistances R_1 and R_2 because they were on the low-tension side of the circuit being connected to the screens of the condensers and to the earth lead B. It is necessary, however, to have both condensers C_1 and C_2 screened.

In order to eliminate any small difference in E.M.F. between the two circuits that may be induced in the part beyond the switch S, the main E.M.F. induced in the circuit is reversed by means of the reversing switch Q. The tuning will have to be readjusted and a small change will occasionally be found to be necessary in the adjustment of the resistances R_1 and R_2. This precaution is unnecessary except for very accurate work.

It will be noted—and this is essential to the success of the method—that the screens of the condensers are permanently connected together through very low impedances (the resistances R_1 and R_2) so that any current to earth *via* the screen will be constant for both positions of the key S. The only earth current that may vary is that from high-potential leads going from the key S to the insulated terminals of the condensers. These are very short (about 6 in. long), but were the cause of some trouble. For a considerable time there was an unknown source of loss in one of the circuits. It was very small (of the order of 0.02 ohm), but still always present. It was finally found to be due to dielectric losses in the wood in the neighbourhood of the high-potential leads from the switch to the condensers. This source of error was removed by screening the wood from the leads and connecting this screen to the common terminal of the resistances R_1 and R_2.

Another source of error which is liable to occur in the setting of the apparatus is due to the screens of the condensers C_1 and C_2 being in contact with each other either by touching directly or through the bench on which the apparatus is set up. A closed circuit is thereby formed in which there is a bad contact, which causes some trouble and errors in the measurements.

The accuracy of the methods largely depends on the accuracy of tuning the circuits, and everything should be done that this may be sharp. It is, therefore, a great help to have variable condensers with easy adjustments. The standard condenser should be fitted with some form of reduction gear, such as a worm drive, but this is not always available on the condenser under test, which, incidentally, may be a fixed condenser. The tuning in such cases is carried out (for the circuit with the condenser under test) at first roughly by means of the coil L and finally with the screened condenser C_0 fitted with a worm drive. This condenser, being always in circuit, need not have a particularly good power factor. The circuit standard condenser is tuned in the ordinary way. An error may here occur owing to the different manner of tuning the two circuits. In one case the condenser, which is varied, lies between the thermo-ammeter and the coil, while in the other it lies on the other side of the thermo-ammeter. The difference will always be very small unless the tuning is very blunt (if, for instance, the capacity of the condensers under test is very large), but it is nevertheless advisable to keep the value of C_0 smaller than that of the condensers under test. If the thermo-ammeter T were placed immediately after the switch Q and before the condenser C_0, this error would not occur. This mode of connection was not tried and would no doubt be satisfactory, but the apparatus having been found to be amply suitable, it was not considered worth while to alter it. There is something to be said in favour of putting the thermo-ammeter immediately after the switch Q, for although the existence of C_0 would not affect the sensitivity compared with that of the arrangement described (Fig. 2), yet a greater current could be obtained for a smaller coupling with the source. In either position of the thermo-ammeter the condenser C_0 reduces the sensitivity approximately in the ratio of

$$\frac{C_1^2}{(C_0 + C_1)^2}$$

where C_1 is the value of the capacity under test.

On the score of sensitivity, therefore, it is also advantageous to keep the value of the condenser C_0 as small as is conveniently possible.

A thermo-ammeter is a square-law instrument. This means that a small change in the current will produce a change in the deflection which is proportional to the value of the current. Hence the greater the current in the ammeter the greater the sensitivity of the method. It is possible to pass a current up to the full carrying capacity of the instrument by tightening the coupling of the coil L to the surface, but the galvanometer will then be deflected off the scale. In order to bring it back into the scale, a potentiometer arrangement P is inserted in the galvanometer lead producing a potential difference in opposition to the E.M.F. in the thermo-junction of the ammeter. In this way it is possible to use a very sensitive galvanometer and still pass a large current in the ammeter. The coupling of the source of the coil L can be made much tighter than in ordinary methods because reaction back on to the source produces no error, but it must not be made so tight that the source becomes unstable at some frequency, for it then becomes impossible to tune the circuits.

To facilitate working it is important that the contact resistance at the key S should be as perfect as possible and that its motion should be rapid. The advantage of a rapid motion is that the galvanometer has not time to move appreciably while switching over, and measurements can be carried out far more rapidly. Originally a simple mercury switch was used, but it was found too slow and a mechanical key of special design has now been substituted.

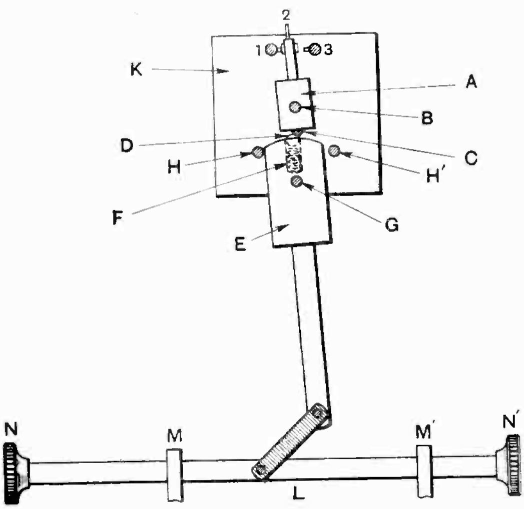


Fig. 3.

The design of this key, due to Mr. Murfitt, is shown in Fig. 3. It is entirely made of ebonite except for the shaded portions which are of brass or copper. The contacts 1, 2 and 3 have small lengths of platinum wire brazed on them so as to ensure low contact resistance. The moving contact 2 is screwed into a small ebonite block A pivoted at B. At the other end of the block B there is a brass wedge C against which presses a ball D. This ball is held within another ebonite block E and kept pressed against the wedge C by means of the spring F; the ebonite block E is pivoted at G and its motion is limited by means of two stops H and H'. The contacts 1 and 3, the pivots B and G and the stops H and H' are all fixed into a square ebonite support K. The key is worked by means of links from the ebonite rod L moving in guides M and M'. There are two knobs N and N' shown, so that the key can be worked from either side.

It will be seen that the contact 2 will not start to move until the ball D has been forced past the edge of the wedge C. As soon as this is reached the contact will rapidly move to its other position. In this way a very rapid motion is obtained which facilitates and quickens very considerably the working of the method. The contact pressure and the rapidity of the motion largely depend on the strength of the spring F.

The link mechanism for working the key is very useful, in that it allows the observer to move the switch without his hand approaching any high-potential wires. This is particularly important at very high frequencies, when any motion of the observer may alter the tuning.

Precautions and Advantages.

It may be useful to summarise the precautions necessary in order to obtain reliable results with this method.

These are :—

(1) That the condensers under test should be screened.

(2) That the screens of the condensers under test should not touch. The condensers are best placed on blocks of paraffin wax.

(3) That the condensers under test should be connected to the apparatus by short thick copper leads as nearly equal for the two condensers as possible.

(4) That the observer and other neighbouring objects should not alter their positions during a measurement otherwise the tuning may be affected, especially at high frequencies. Tuning is made easier by earthing the outside of the long concentric lead.

(5) That the condenser C_0 be kept small.

(6) For very accurate work the switch Q should be reversed, the tuning readjusted and the mean of the resistance readings taken. It will be found that both tunings can be readjusted with condenser C_0 alone.

(7) For sensitivity the current in the ammeter should be as large as possible, the galvanometer as sensitive as possible, and the coil L as low in resistance as possible.

The advantages claimed for the method compared with the ordinary methods at present in use are:

(1) Increased sensitiveness.

(2) Elimination of error from reaction back on to the source (particularly when a bad condenser or dielectric is being measured).

(3) Suitability for measurement at much higher frequencies.

(4) Greatly increased rapidity and ease of working.

The experimental evidence for the reliability of the method is very simple. If there is a difference of E.M.F. induced in the two circuits, different results should be obtained if the condensers be interchanged. This has been tried a very large number of times using many types of condensers, at frequencies varying from 50 kilocycles to 5,000 kilocycles, but when differences have been obtained they have always been found to be caused by some inattention to the precautions detailed above. The effect of earthing the long screened lead was also tested in the same way but no difference was ever found.

Experimental Results.

Tests on two variable air condensers will be given here. The losses in a condenser are due first to the loss in the dielectric and secondly to the ohmic loss of the current flowing in the connections and plates of the condenser. The dielectric loss will be proportional to the square of the voltage across the condenser, unless the voltage is so high as to be approaching the breaking stress of the insulation, while the ohmic loss will be proportional to the square of the current. Both will depend to a certain extent on the frequency, but at any given frequency they should be independent of the condenser setting. At any given frequency, therefore, the losses in a variable condenser should be amenable to representation by means of a fixed series resistance to represent the ohmic loss, together with a fixed shunt resistance to represent the dielectric loss. With alteration of frequency the change in the series resistance should be very small, but that in the shunt resistance may be expected to be very appreciable. This representation of dielectric loss by means of a constant shunt resistance at a given frequency depends on the assumption that the distribution of electric lines of force remains unaltered within that part of the dielectric which is causing loss, as the condenser setting is varied. This condition is likely to exist in variable air condensers (free from dust), for the portion of the dielectric which produces losses is usually at a comparatively large distance from the moving plates. If, however, the losses in the air dielectric between the plates are not negligible, it is not likely that a constant shunt resistance would satisfactorily represent the dielectric losses at any given frequency.

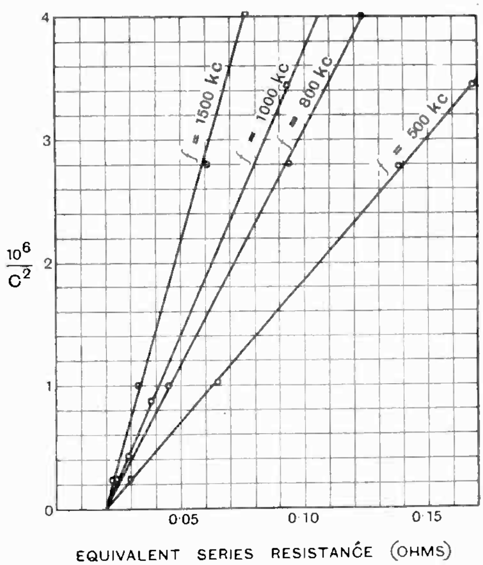


Fig. 4.

A constant shunt resistance can be represented by a variable series resistance the value of which varies inversely as the square of the capacity of the condenser at any given frequency. If the losses of a variable condenser can be represented by means of a constant series and a constant shunt resistance at any given frequency, the total equivalent resistance at this frequency should, therefore, consist of two terms, one of which is constant and the other which varies inversely as the square of the capacity of the condenser.

In Figs. 4, 5 and 6 are shown the results on two condensers. In order to investigate the truth of the above statements, the equivalent series resistance was plotted against the reciprocal of the square of the capacity. In every case tested, and many have been tested besides those shown here, straight lines have been obtained. These lines do not pass through the origin, and the intercept on the abscissa no doubt corresponds to the series resistance due to internal leads and conduction over the plates of the condenser. This is all the more likely to be true as the intercept appears to be constant over very wide ranges of frequency.

From Figs. 4, 5 and 6 the loss of a condenser at any given frequency F can be put in the form of an equivalent series resistance R given by

$$R = a + \frac{1}{b'C^2} \quad \cdots \quad \cdots \quad (1)$$

where a and b' are constants. a is independent of frequency over a very large range, while b' is a function of the frequency.

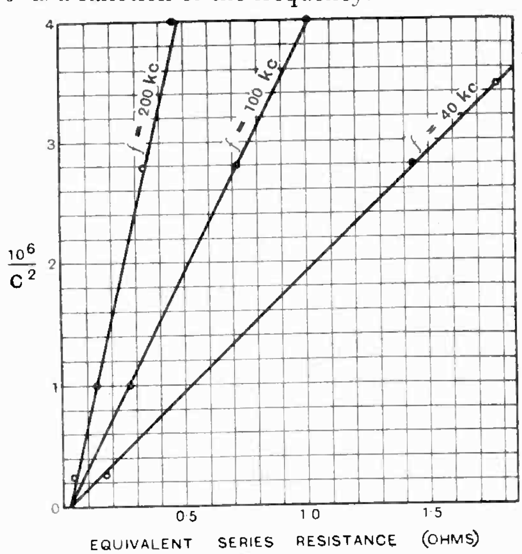


Fig. 5.

The next step was to find the variation of b' with frequency. A remarkable result was here obtained.

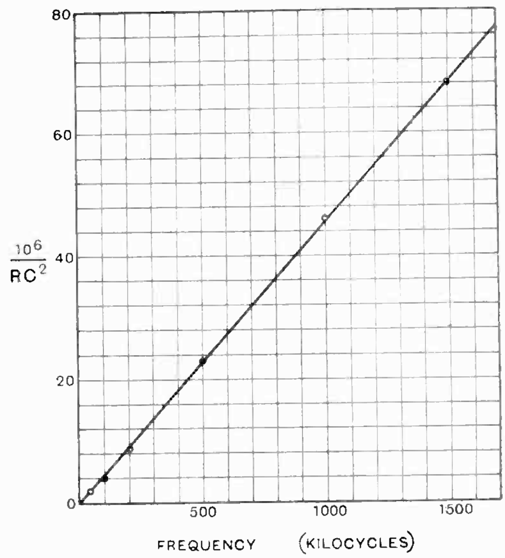


Fig. 6.

If the gradient of the curves such as those given in Figs. 4 and 5 be plotted against the frequency, as is done in Fig. 6, an accurate straight line passing through the origin is obtained. The final empirical law is, therefore,

$$R = a + \frac{1}{bC^2 f} \quad \cdots \quad \cdots \quad (2)$$

where a and b are constants.

The power factor P of the condenser is, therefore, given by

$$P = aC\omega + \frac{2\pi}{bC} \quad \cdots \quad \cdots \quad (3)$$

The results shown in Figs. 3, 4 and 5 give

$$a = 0.02$$

and $$b = 46 \times 10^{-6}$$

where C is in micro-microfarads.

The results given in Fig. 7 are interesting, for they represent a condenser in which the series resistance a was large. The first results gave curve (b). On tightening the bolts screwing the plates together, this line was altered to the line (a). The lines are accurately parallel so that the dielectric losses have remained unaltered, but the resistance was materially reduced.

The above empirical law (equation 2) has been tested for air condensers having as insulating material amber, keramot,* quartz and ebonites variously loaded and having been variously exposed to sunlight.

The Use of a Guard Ring.

When measuring the power factor of dielectrics, it is necessary, in order to obtain very accurate results, that a guard ring should be used. The method previously described by the author for the use of a guard ring in the ordinary variation of resistance method ("Note on the Measurement of Dielectric Losses and Permitivity at Radio Frequencies," *E.W. & W.E.*, Vol. 4,

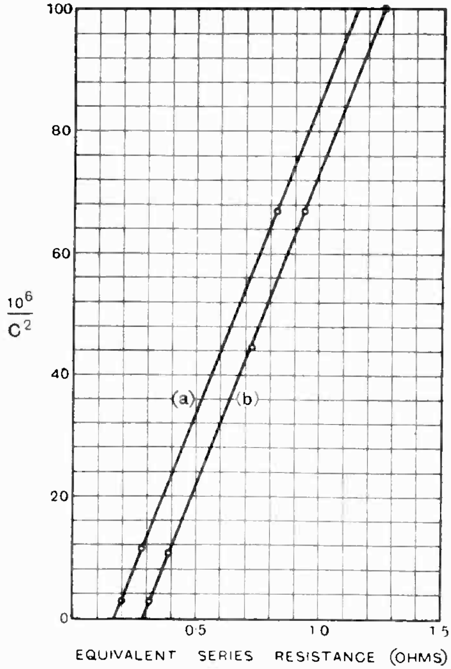


Fig. 7.

1927, pp. 569–570) can be applied to the substitution method described above.

In this case the coil L (Fig. 2) should be made of stranded wire, one strand of which is connected to special terminals on the switch Q, Fig. 8. This strand, whatever the position of the switch Q, has one or other

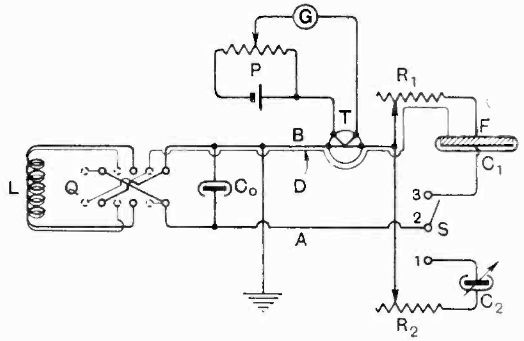


Fig. 8.

of its ends connected to the wire A and the other to a wire D closely intertwined with the wire B. The wire D follows closely the circuit containing the dielectric C_1 under measurement and is connected to the guard ring. The guard ring is shown completely screening the central electrode except for a portion F, which is connected to the resistance R_1 as in an ordinary measurement.

It will be seen that the potentials of the guard ring and of the plate F are practically identical, apart from the small ohmic drops and whatever small E.M.F. may be induced between the two closely intertwined circuits, but that the dielectric current flowing to the guard ring passes neither through the resistance R_1 nor the thermo-ammeter T. Apart from a small correction which may be applied for the air-gap between the plate F and the guard ring, the electric lines of force between the plate F and the central electrode should be very nearly straight and parallel.

The author has had no occasion to use a guard ring and has not tried the method experimentally, but he feels confident that it should prove satisfactory. Should any reader try it the author would be very glad to hear what difficulties are encountered and what success is obtained.

* A loaded red ebonite.

On the Effect of the Ground on Downcoming Plane Space-Waves.

By E. T. Glas.

THE state of polarisation of radio waves has in recent years been the subject of much investigation, experimental, as well as theoretical. As a matter of fact, however, the results which can be unreservedly accepted are not abundant, particularly from the theoretical point of view. As successful workers we find especially T. L. Eckersley, Smith-Rose and Barfield in England, and Pickard and Alexanderson in the United States. A preliminary theory of the variable state of polarisation due to the influence of the earth's magnetic field was given in the year 1925 by Nichols and Schelleng,* of the United States. According to their theory the rotation of the plane of polarisation (we define this plane as is usual among radio engineers as the plane containing the electric vector and the direction of propagation) tends towards a certain limit, independent of wavelength, for extremely long space-waves, whilst it grows smaller and smaller for very short waves as the wavelength decreases. The original magneto-optical theory has been shown by P. O. Pedersen,† of Denmark, to contain several errors. The main cause of these errors is that the frequency of collision between the charged particles has not been taken into account from the start. Thus the correct attenuation does not appear in the formulas of Nichols and Schelleng. Pedersen has worked out the theory more completely and has shown that the rotation of the plane of polarisation also decreases continuously for the extremely long waves without reaching any constant limit. The phenomenon should not consequently be marked on extreme wavelengths. The main cause of the highly variable state of polarisation on short waves ($\lambda < 100$ m.) is attributed to asymmetrical structure of the conducting layer by v. Korshenewsky.‡ Some portions, like clouds of this layer, will deviate the electric vector from the original angle with the vertical line, thus causing rotation of the vector. If this explanation is correct, all kinds of polarisation ought to be equally probable. A certain polarisation, such as a horizontal one, does not follow, but Pickard§ proved in the year 1926 that horizontal polarisation may dominate on the usual short waves. It is doubtful, however, if the influence of the ground was actually eliminated by the fact that the measurements were undertaken in a raised wooden tower 7 metres in height. Pickard's conclusions can be summarised as follows: the state of polarisation depends on wavelength, distance and time of day, but not on the type of transmitting aerial or geographical position of transmitter. No selective effect with regard to the magnetic meridian could thus be traced. Meissner,‖ also, in Germany, did not succeed in finding any such effect, transmitting in the vicinity of the "critical frequency" (~200 m.) in different directions during night-time. The magneto-optical theory in its present state cannot at all explain the rotation into a vertical direction of a field that is horizontally polarised near the transmitter as observed by Alexanderson¶ of the United States, because such a rotation is only predicted by the present theory for the component of the electric vector propagated along the earth's magnetic lines; it decreases very rapidly with decreasing wavelength, and in no case tends to attain a definite limit. Appleton,** Hollingworth and Naismith††, in England, among others, have found circular or approximately circular polarisation both on the long commercial waves and the lower broadcasting-band.

* *The Bell System Technical Journal*, April, 1925.

† P. O. Pedersen: "The Propagation of Radio Waves," Copenhagen, 1927, Chapter VII.

‡ Jahrbuch der D.T., Dec., 1926.

§ *Proc. Inst. Rad. Eng.*, April, 1926.

‖ *Elektrische Nachrichtentechnik*, Sept., 1926.

¶ *Ingeniörsvetenskapsakadeniens Handlingar*, No. 48: "Radio Wave Propagation," by E. F. W. Alexanderson, Stockholm. 1926.

** *E.W. & W.E.*, May, 1928.

†† *Nature*, 4 Febr., 1928, etc.

This phenomenon can possibly be attributed to magneto-optical dispersion, but the matter is not yet proved.

It is rather tempting to assume that the phenomena dealt with can be attributed, at least partly, to the influence of the conducting surface of the earth, more particularly as the published experimental investigation seems to be restricted to the proximity of this surface. Of course, it is the resultant

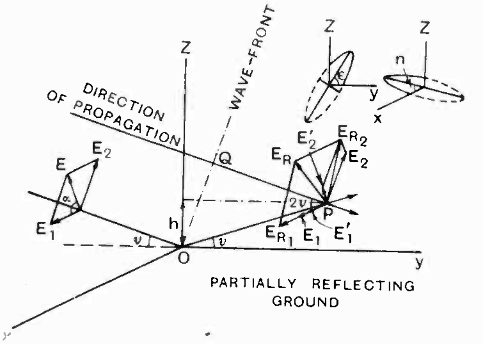


Fig. 1.—*Distortion of wave-front by reflection at a conducting surface. Above are shown the elliptical loci indicating apparent direction of electric field as well as state of polarisation.*

field, the components of which are formed by the direct downcoming radiation and the indirect radiation due to the ground by reflection or otherwise, that is measured. This resultant and the originally downcoming field may possess different properties. Consequently the pure space-radiation may be but little accessible to measurements at the earth's surface. In the following calculations we consider a homogeneous downcoming radiation forming the angle δ with the surface of the earth. Thus all the rays are equal and parallel to each other. We assume the electric field to be originally a pure alternating one. The influence of the ground will be referred to by introducing the reflected rays. The refracted ones, which penetrate into the earth, are wasted. Nevertheless, the corresponding earth-currents give rise to a field above the surface. This field will however not be taken into consideration beside the reflected field. Starting from these assumptions it is proposed to show how the originally pure field will be distorted by superposition of the reflected field. In fact, an elliptical, rotating field will result. When the field-ellipses are sufficiently narrow we can, to a first approximation, content ourselves by studying the direction and size of the major axis.

Let $E = E_0 \, . \, e^{j\omega t}$ be the electric field-vector of the downcoming radiation, the polarisation of which is determined by the angle α in Fig. 1. Further, let E_R be the field-resultant after the aforementioned superposition. Inspection of Fig. 1 will verify the following equations.

1.—*Field-component perpendicular to the plane of incidence* E_{R_1} (in the xz-plane)

$$\left.\begin{aligned} E_z &= (E_2 + E_2') \, . \cos\delta \\ E_x &= E_1 + E_1' \end{aligned}\right\}$$

At the origin O we have

$$E_1' = E_0 \, . \cos\alpha \, . f_1 \, . \, e^{j\theta_1}$$

where f_1 is the coefficient of reflection perpendicular to the plane of incidence and Θ_1 the corresponding additive phase-angle. At the height h above the surface of the earth we have to add a phase-angle, which is due to the difference of path $OP - QP$ or $2h \sin\delta$. Thus

$$\left.\begin{aligned} E_2 + E_2' &= E_0 \, . \sin\alpha \, . \\ &\left\{\cos\omega t + f_2 \, . \cos\left(\omega t + \Theta_2 + 4\pi \, . \frac{h}{\lambda} \, . \sin\delta\right)\right\} \\ E_1 + E_1' &= E_0 \, . \cos\alpha \, . \\ &\left\{\cos\omega t + f_1 \, . \cos\left(\omega t + \Theta_1 + 4\pi \, . \frac{h}{\lambda} \, . \sin\delta\right)\right\} \end{aligned}\right\}$$

Substituting

$$\Theta_1 + 4\pi \, . \frac{h}{\lambda} \, . \sin\delta = \psi$$

$$\Theta_2 + 4\pi \, . \frac{h}{\lambda} \, . \sin\delta = \phi$$

we further have

$$\left.\begin{aligned} &\cos\omega t \, . \, (1 + f_1 \, . \cos\psi) \\ &\qquad - \sin\omega t \, . f_1 \, . \sin\psi = x \, . \frac{1}{\cos\alpha} \\ &\cos\omega t \, . \, (1 + f_2 \, . \cos\phi) \\ &\qquad - \sin\omega t \, . f_2 \, . \sin\phi = z \, . \frac{1}{\sin\alpha \, . \cos\delta} \end{aligned}\right\}$$

where
$$x = \frac{E_x}{E_0}$$
$$z = \frac{E_z}{E_0}$$

Finally eliminating the time (t) we have the equation

$$A_1 \, . \, x^2 - 2 \, . \, B_1 \, . \, xz + C_1 \, . \, z^2 = D_1 \, . \, . \quad (1a)$$

with the coefficients

$$\begin{cases} A_1 = 1 + f_2^2 + 2f_2 \,.\, \cos\phi\,; \\ B_1 = \dfrac{\cot\alpha}{\cos\delta} \,.\, [1 + f_1 \,.\, \cos\psi + f_2 \,.\, \cos\phi + f_1 f_2 \,.\, \cos(\phi - \psi)]\,; \\ C_1 = \left(\dfrac{\cot\alpha}{\cos\delta}\right)^2 \,.\, (1 + f_1^2 + 2f_1 \,.\, \cos\psi)\,; \\ D_1 = \cos^2\alpha \,.\, [f_1 \,.\, \sin\psi - f_2 \,.\, \sin\phi - f_1 f_2 \,.\, \sin(\phi - \psi)]^2\,; \end{cases}$$

Evidently the locus (1a) is an *ellipse*, whose equation by well-known analysis can be reduced to a simple form. To do this, turn the axes counter-clockwise an angle η satisfying

$$\tan 2\eta = 2 \,.\, \frac{\cot\alpha}{\cos\delta} \,.\, \frac{1 + f_1 \,.\, \cos\psi + f_2 \,.\, \cos\phi + f_1 f_2 \,.\, \cos(\phi - \psi)}{\left(\dfrac{\cot\alpha}{\cos\delta}\right)^2 \,.\, (1 + f_1^2 + 2f_1 \,.\, \cos\psi) - (1 + f_2^2 + 2f_2 \,.\, \cos\phi)} \quad .. \quad .. \quad (1b)$$

To find the relative position of the axes we calculate the ratio of the intercepts on the x and z axes

$$k_1 = \sqrt{\frac{c_1}{a_1}}$$

Finally the axes are calculated from

$$a = \sqrt{\frac{D_1}{A_1'}} \qquad b = \sqrt{\frac{D_1}{C_1'}} \quad .. \quad (1c)$$

where A_1', C_1' are the two roots of the following equation

$$u^2 - (A_1 + C_1) \,.\, u = B_1^2 - A_1 C_1$$

The state of polarisation, originally plane and rectilinear, is thus changed to elliptical. In fact, the point of the component-vector perpendicular to the plane of incidence moves along an elliptical path determined by the formulæ 1a, 1b, 1c.

2.—*Field-component in the plane of incidence* E_{R_2} (in the yz-plane).

$$\left.\begin{aligned} E_z &= (E_2 + E_2') \,.\, \cos\delta \\ E_y &= (E_2 - E_2') \,.\, \sin\delta \end{aligned}\right\}$$

At the origin O after reflection in the plane of incidence we assume

$$E_2' = E_0 \,.\, \sin\alpha \,.\, f_2\, e^{j\theta_2}$$

where f_2 is the coefficient of reflection in the plane of incidence and Θ_2 the corresponding phase-angle. Introducing

$$y = \frac{E_y}{E_0} \text{ and } z = \frac{E_z}{E_0}$$

calculation analogous to that in the preceding section, will give a locus of the form

$$A_2 \,.\, y^2 - 2 \,.\, B_2 \,.\, yz + C_2 \,.\, z^2 = D_2 \quad .. \quad (2a)$$

where

$$\left.\begin{aligned} A_2 &= 1 + f_2^2 + 2f_2 \,.\, \cos\phi \\ B_2 &= (1 - f_2^2) \,.\, \tan\delta \\ C_2 &= (1 + f_2^2 - 2f_2 \,.\, \cos\phi) \,.\, \tan^2\delta \\ D_2 &= (2 \,.\, \sin\alpha \,.\, \sin\delta \,.\, f_2 \,.\, \sin\phi)^2 \end{aligned}\right\}$$

Again we get an *ellipse* (2a). Now turn the axes counter-clockwise an angle ϵ so that

$$\tan 2\epsilon = -\frac{\sin 2\delta \,.\, (1 - f_2^2)}{(1 + f_2^2) \,.\, \cos 2\delta + 2 \,.\, f_2 \,.\, \cos\phi} \quad .. \quad .. \quad (2b)$$

The ratio of the intercepts on the y- and z-axes is

$$k_2 = \sqrt{\frac{C_2}{A_2}}$$

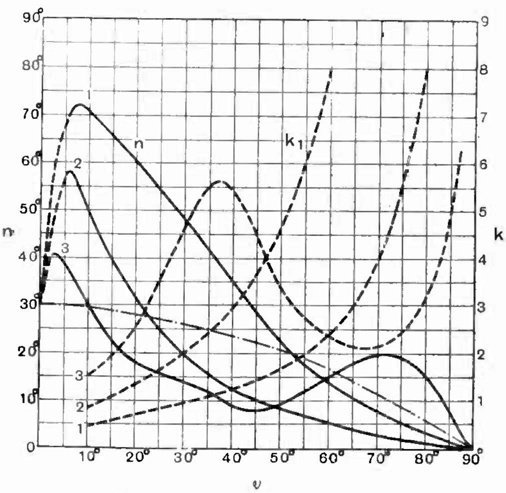


Fig. 2.—*Field ellipse perpendicular to the plane of incidence* ($\alpha = 30°$), $\lambda = 26.5$ *m. Inclination of major axis to ground and ratio of intercepts.* —·—·— *no reflection from the ground.* $1\ \frac{h}{\lambda} = \frac{1}{8} : 2 = \frac{1}{4} : 3 = \frac{1}{2}$.

The axes themselves can be found from

$$a = \sqrt{\frac{D_2}{A_2'}} \qquad b = \sqrt{\frac{D_2}{C_2'}} \quad .. \quad (2c)$$

A_2', C_2' being roots of

$$u^2 - (A_2 + C_2) \,.\, u = B_2^2 - A_2 C_2$$

A measurement of the apparent earth-angle of downcoming space-waves may thus not give any sharp value as the field in the plane of incidence is not pure but elliptical. Also, the true earth-angle is not necessarily obtained unless the influence of ground can be safely eliminated.

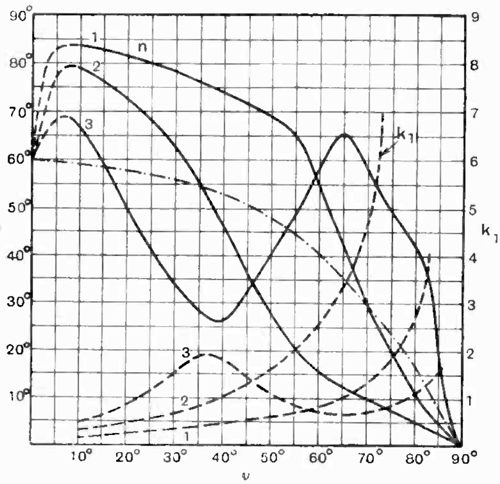


Fig. 3.—*Field ellipse perpendicular to the plane of incidence.* ($\alpha = 60°$), $\lambda = 26.5$ *m. Inclination of major axis to ground and ratio of intercepts.* —·—·— *no reflection from the ground.* $1\frac{h}{\lambda} = \frac{1}{8}$: $2 = \frac{1}{4}$: $3 = \frac{1}{2}$.

As the derived formulæ are complicated a numerical calculation would be rather laborious. We reproduce graphically the actual result for a short wavelength ($\lambda = 26.5$ m.) assuming the conductivity of the earth to be $H = 5.10^{-14}$ e.m.u. The state of polarisation of the downcoming plane waves may be given by $\alpha = 30°$ or $\alpha = 60°$. The earth-angle of the major axes of the field-ellipses (η, ϵ), and the ratio of the intercepts on the x-, y- and z- axes (k_1, k_2) are calculated for the plane of incidence and for a plane perpendicular to it as functions of the earth-angle of the downcoming radiation. Three different heights above ground are considered namely,

$$h = \tfrac{1}{8}\lambda, \tfrac{1}{4}\lambda, \tfrac{1}{2}\lambda$$

The corresponding curves are shown in Figs. 2, 3, 4.

The curves in Pedersen's* above-mentioned work, showing f_1, f_2 as well as θ_1, θ_2 for different wavelengths, earth-angles and conductivity of ground have been used in order to simplify the calculation.

* Loc. cit., pp. 132–135. Owing to different definitions from the start, Pedersen's value of θ_2 differs from our value by π.

Some field-ellipses are worked out in Figs. 5, 6, and 7 for $\delta = 20°$, but for various heights above ground and different original polarisation.

The following conclusions may be drawn from this numerical example.

(1) A relatively steep radiation (large value of δ) may give narrow ellipses and consequently a pure field. Nevertheless, a nearly grazing incidence will give the same result (very small δ).

(2) The field-component in the plane of incidence is rather pure but somewhat raised or tilted owing to the influence of ground. Thus the apparent direction of propagation differs from the true one.

(3) The state of polarisation of the downcoming radiation is altered. A steep radiation may be more horizontally polarised, but a radiation the rays of which form a relatively small angle with the surface of the earth will to a certain limit always be more vertically polarised.

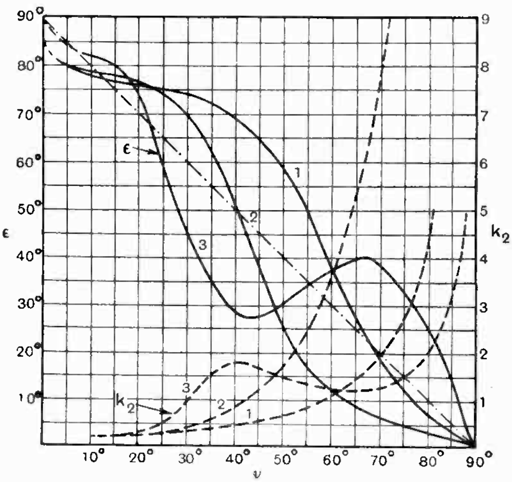


Fig. 4.—*Field ellipse in the plane of incidence.* $\lambda = 26.5$ *m. Inclination of major axis to ground and ratio of intercepts.* —·—·— *no reflection from the ground.* $1\frac{h}{\lambda} = \frac{1}{8}$: $2 = \frac{1}{4}$: $3 = \frac{1}{2}$.

(4) The resulting field which is generally elliptically polarised is very dependent on the height above ground as regards its intensity, purity and polarisation.

Long-distance communication on short waves is probably due either to rays emitted with small earth-angle or to rays which penetrate directly from the transmitter to a considerable height, where the radius of curvature of the path equals the radius of the earth. With regard to the first alternative the really grazing rays as a rule should not be of considerable importance, because the topographical conditions and the highly variable state of the lower atmosphere disturb the propagation. The second manner of propagation—the rays, so to speak, sliding forwards at constant height above the surface of the earth and reaching this surface by gradual leakage far from the transmitter—is strongly emphasised by Pedersen.* This author shows how improbable the propagation by multiple-reflection from the earth's surface ought to be if the serious loss by such a reflection on very short waves is considered. Pedersen's view seems to be consistent with the experimental results of Friis† in the United States. Friis measured, among other quantities, the earth-angle of downcoming radiation from the well-known beam-transmiitter at Bodmin (GBK 16 m.). He found that the earth-angle was continually varying within wide limits up to $\delta = 60°$. It is difficult to explain the existence of such a steep ray at $\lambda = 16$ m. in any other way, remembering the small refractive power of the ionised layer on this typical daylight-wave and assuming the earth-angles to be substantially equal at the transmitter and the receiver. The existence of relatively steep rays ($\delta = 30° - 60°$) at great distance makes it probable that horizontal and non-linear (*i.e.*, circularly polarised) resulting fields may be created by the action of ground-reflection independent of distance or magneto-optical influence (Figs. 2 and 3).

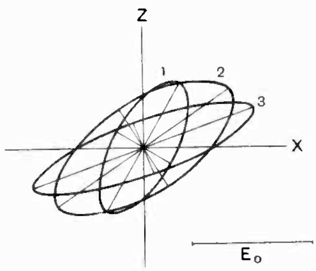


Fig. 5.—*Field ellipses perpendicular to the plane of incidence.* $\alpha = 30°$, $\delta = 20°$, $\lambda = 26.5$ *m.* $1\frac{h}{\lambda} = \frac{1}{8} : 2 = \frac{1}{4} : 3 = \frac{1}{2}$.

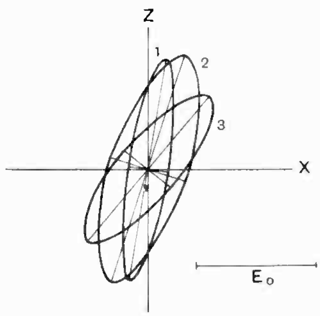


Fig. 6.—*Field ellipses perpendicular to the plane of incidence.* $\alpha = 60°$, $\delta = 20°$, $\lambda = 26.5$ *m.* $1\frac{h}{\lambda} = \frac{1}{8} : 2 = \frac{1}{4} : 3 = \frac{1}{2}$.

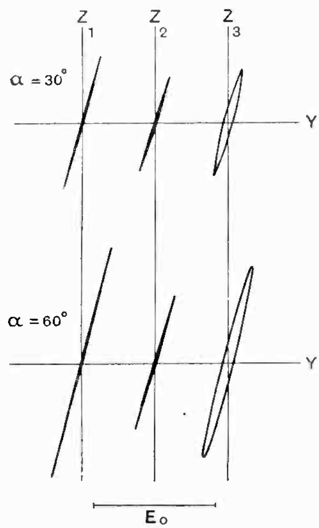


Fig. 7.—*Field ellipses in the plane of incidence.* $\delta = 20°$, $\lambda = 26.5$ *m.* $1\frac{h}{\lambda} = \frac{1}{8} : 2 = \frac{1}{4} : 3 = \frac{1}{2}$

We can probably look for systematical errors in the measurements of the earth-angle of a downcoming ray where the influence of ground is not eliminated, because the resulting field, whether pure or not, only gives an apparent value.

The continually changing polarisation of the resultant field by ground-reflection with

* Loc. cit., p. 199.

† *Proc. Inst. Rad. Eng.*, May, 1928.

varying earth-angle may possibly explain the variation of the rotation of the plane of polarisation as the distance from the transmitter increases, discovered by Alexanderson*. By inspection of Figs. 2 and 3 we find that the polarisation in the case considered tends to be more vertical as the earth-angle decreases, the really grazing incidence not included. Further from the transmitter the earth-angle as a rule decreases, as the rays emitted relatively near the surface of the earth seem to be most important for some experienced long-distance communication†, and certainly should be so for " moderate long-distance " propagation. Consequently, *the polarisation may become more vertical with increasing distance due to the influence of the ground itself*, as observation indicates.

* Loc. cit., p. 4.

† *Journal I.E.E.*, T. L. Eckersley " Short Wave Wireless Telegraphy," extr., *E.W. & W.E.*, April, 1927, p. 220.

The field-structure thus varying with the height above ground, the total induction in a receiving aerial should be extremely complicated. Equalising currents are likely to be caused, the resulting action of which is not easy to predict. As a matter of fact, the most suitable form of a receiving aerial for short waves cannot be designed in advance. Very peculiar shapes of aerials, as is well known, may give good reception.

The foregoing discussion of the deforming action of the ground on downcoming space-radiation has been numerically restricted to a special case which, for the purpose of the problem, has been considered as typical. The object has been to raise the question whether the ground itself cannot be held responsible for some peculiar phenomena observed in short-wave work.

Book Review.

SPEECH AND HEARING. By H. Fletcher. (Macmillan and Co., Ltd., 1929. 20s.)

This is an invaluable account of recent work on the attributes of speech and hearing which can be physically measured, with special reference to the investigations carried out by the Bell Telephone Laboratories during the last fifteen years. The preliminary work of analysing electrical currents into their component frequencies and of measuring the intensity of such frequencies is first described, together with the devices for examining the performance of telephones and loud-speakers.

Next we are given an analysis of the mechanism of speaking, the artificial production of speech sounds, and figures as to speech power in various circumstances.

Wherever possible, figures are expressed in decibels, which have replaced the old transmission units ; thus we are told that if average speech power be taken as unity, very loud speech is 20 decibels up, weak speech is 20 decibels down, and a soft whisper is 40 decibels down.

Part 2 gives the acoustic spectra of typical musical instruments : at low frequencies the piano gives harmonics strongly, but the fundamental is almost silent : with the clarinet the high harmonics are powerful and the tenth harmonic has one-half the amplitude of the fundamental. Various methods have been devised for measuring noise, and noise surveys are given for streets and busy offices ; in an average typist's office the noise is such that speech must be raised by 30 decibels to override the noise : in the noisiest street in New York the figure is 50 decibels, i.e., speech must be made 100,000 times as loud as in quiet surroundings.

Part 3 opens with the examination of the sensitivity of the ear to change of pitch and intensity : we can detect about 2,000 gradations of pitch in the audible region. A fascinating chapter deals with the masking of one tone by another. A low pitched tone deafens the ear for tones in the immediate pitch region, but if the disturbing tone is made more intense harmonics are generated in the ear which obliterate sound of more distant pitch and a very loud tone of low pitch obliterates all other sounds.

In Part 4 we are told the amount of distortion which speech can suffer before the intelligibility becomes gravely affected. A strange result is that although 60 per cent. of the energy of speech is carried by frequencies below 500 c.p.s., yet the suppression of these frequencies only decreases the intelligibility by 3 per cent.

The book shows that the problems of speech, hearing, and noise can now be treated quantitatively: accordingly, we can approach two great problems in a systematic way : one is the menace of noise ; the other is the making of feminine speech intelligible over the telephone.

R.T.B.

Book Received.

TELEGRAPHY AND TELEPHONY, INCLUDING WIRELESS. By E. Mallett, D.Sc.(Eng.), London.

An introductory text book to the science and art of the electrical communication of intelligence. Comprising Line Telegraphy for short and long lines ; Line Telephony including a chapter on manual and automatic exchanges ; Wireless Telegraphy and Telephony and an appendix of mathematical formulæ and tables relating to the subjects dealt with. Pp. 413 + ix with 287 diagrams and illustrations. Published by Chapman & Hall, Ltd., price 21/– net.

A Sensitive Valve Voltmeter Without "Backing Off."

By Manfred Von Ardenne.

FOR the measurement of alternating voltages *greater* than one volt, there is available a whole series of quite simple arrangements suitable for practical needs. For measurements of amplification, however, where the voltages used cannot overstep certain limits without introducing overloading, it is required to determine accurately voltages of *less* than one volt. Even voltages of this order can be determined with the aid of a valve voltmeter. The peculiarity by which such sensitive valve voltmeters can be recognised is usually the compensation of the anode current, or "backing off."* By compensation of the current in the anode circuit of the voltmeter the range of measurement is considerably extended in the direction of small voltages, since a more sensitive instrument can be substituted for the milliammeter usually employed. But the introduction of compensation increases the difficulties of using and reading the voltmeter, and there is always the danger that the measuring instrument mentioned may be damaged by too great a voltage. For these reasons it is desirable to avoid "backing off," and to attain high sensitivity by other means.

The Construction and the Properties of a Sensitive Valve Voltmeter.

The circuit† of a valve voltmeter that is very sensitive, but yet does not employ the principle of "backing off," is shown in Fig. 1. The rectification of the voltage to be measured is achieved in a stage consisting of a valve of high amplification factor in the anode circuit of which there is a resistance of several million ohms, bridged, for the frequency of the alternating current to be measured, by a condenser. With the values of components given the necessary bridging capacity across the anode resistance is satisfactory for all frequencies over about 50 cycles, so that the calibration of the voltmeter is independent of frequency for all higher values of the latter, no matter

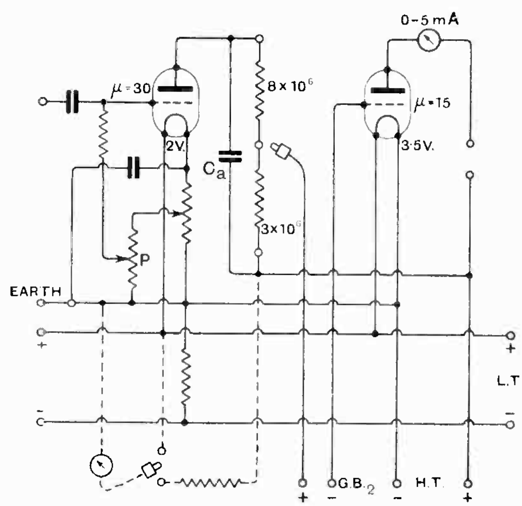


Fig. 1.

whether audio- or radio-frequencies are being dealt with. It is therefore possible in practice to calibrate the voltmeter with a medium audio-frequency, and to use it with this same calibration at high frequencies. This type of anode rectification, which has already been proposed for the construction of sensitive voltmeters‡, is, as measurements have shown, more sensitive than normal anode rectification in which there is no anode resistance§, and is very nearly as sensitive as leaky-grid rectification.

* In this connection attention should be drawn to the important paper "The Thermionic Voltmeter," by W. B. Medlam and U. A. Oschwald, EXPERIMENTAL WIRELESS, 1926, No. 37 and following issues.

† M. von Ardenne, "Ein empfindliches Röhrenvoltmeter für Hochfrequenz," *E.T.Z.*, 1928, Part 15.

‡ "Ueber Anodengleichrichtung," *Zeitschr. für Hochfrequenztechnik*, Vol. 28, p. 87.

§ "Ueber Anodengleichrichtung II," *ibid*, Vol. 31, p. 51.

The special advantage of this type of anode rectification for the purpose of measurement lies in its relatively great independence of the battery voltages applied. In contrast to leaky-grid detection, and ordinary anode-bend detection, with which it is always necessary to work at a point of maximum curvature of the grid-current or anode current curve, in the present type of rectification the presence of the high anode resistance ensures an *automatic* adjustment to a point of great curvature of the anode-current curve. In Fig. 2 is given the characteristic of a stage used for rectification, together with the measured response to alternating voltages of frequency 800 cycles for various values of the condenser in the anode circuit. It will be seen from these curves that the response of the rectifier when using the battery voltages mentioned, and which are those intended for use in the completed voltmeter, is only subject to very small percentage variations over a range of grid potential of nearly 3 volts. When carrying out measurements with such an instrument, the constancy of calibration produced by this peculiarity of the rectifying stage is extremely convenient. It will later be shown in more detail that in this type of circuit the calibration is not only comparatively independent of the control-voltages, but is also nearly independent of the filament voltage. From the fact that in a circuit of this kind, the valve is operated with voltages much smaller than those for which it was originally designed, it is found possible to employ valves with thoriated cathodes without incurring appreciable variations in the emission.

Fig. 1 shows that the rectification effect is not measured directly in the first stage, but that the change in anode voltage produced here is measured in the plate circuit of a second valve coupled, through a battery, to the first. This second valve, especially if it has a high mutual conductance, enhances very considerably the sensitivity of the voltmeter, as is well known from other circuits. In order to prevent the second stage from interfering with the adjustments of the first, care must be taken that the grid current of the second valve is always small in comparison with the very low anode current of the first. For this reason it is necessary to use in the second stage a valve with a good vacuum, and to provide a suitable grid-battery $G.B._2$ for supplying a large enough grid bias. The voltage of this battery must be a little greater than the anode voltage which appears on the rectifying valve when adjusted to its working point.

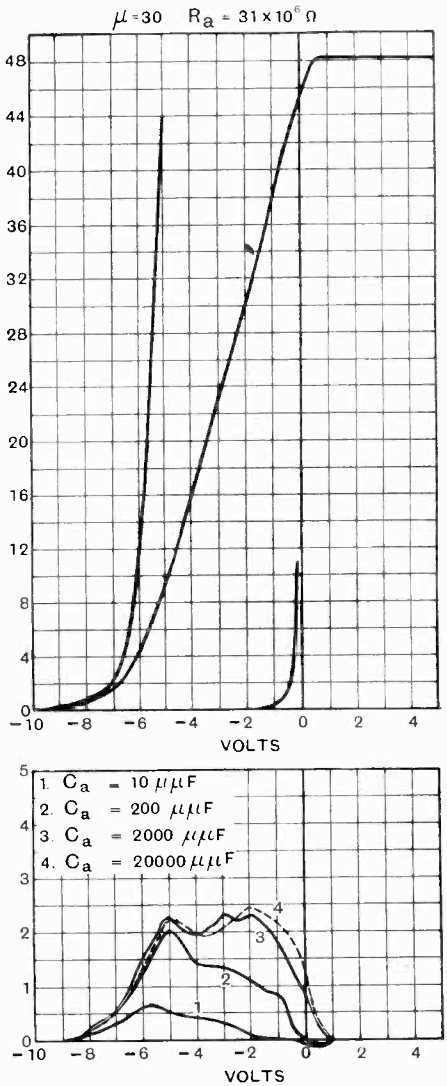


Fig. 2.

In order to make it possible to measure voltages lying within various ranges, the anode resistance of the first stage is divided into sections. As with every change of connection here the direct-voltage conditions with respect to the second valve change, it is necessary to make a corresponding change in the voltage tapped off from the second grid-battery whenever a change is made from one range to another.

The potentiometer P in Fig. 1, in parallel with a small part of the filament resistance, is used to adjust the working point of the first valve to such a point on the characteristic that by the use of a high enough voltage from the battery $G.B._2$ the instrument situated in the anode circuit of the second valve shows exactly full-scale deflection. For modern valves ($\mu = 15$) the range of this instrument will be chosen so that it reads up to about 5 milliamps. As the response of such an instrument is very rapid, high-frequency measurements with this valve voltmeter occupy no more time than simple measurements of direct current.

If alternating voltages are applied to the voltmeter, the current in the anode circuit of the rectifying stage increases, and as a result the anode current of the second stage falls to a more or less small value. The calibration curves of a voltmeter built to the circuit, and with the values of components shown in Fig. 1, are reproduced in Fig. 3 to give an idea of the results obtainable. On this diagram are also given the values of the working voltages and for the voltage of the grid-battery for two different ranges. With a milliammeter that permits the detection of a current variation of a fiftieth of a milliampere it is possible to measure alternating potentials of 0.01 volt. Thus in practice about the same sensitivity is attained as with valve voltmeters in which compensation of the anode current is employed.

In contrast to these instruments, it is claimed as a special advantage of a voltmeter on the lines indicated in Fig. 1 that if a large alternating voltage is applied the deflection of the measuring instrument in the anode circuit of the second valve drops down to zero, so that in spite of the high sensitivity overloading of this instrument is practically impossible.

There is shown in Fig. 1 a grid-leak and condenser on the input side of the voltmeter, in order to make it possible to measure an alternating voltage upon which is superposed a direct voltage. If only alternating voltages are to be measured, this combination can, of course, be omitted, and the alternating voltage can be connected directly between grid and the potentiometer P. In this case no damping of the circuit being measured by the grid-leak occur.

At high frequency an appreciable load can also be caused by the grid capacity of the voltmeter; this is chiefly due to the static capacities between grid-and-anode and grid-and-cathode of the first valve. To attain the smallest possible loading of

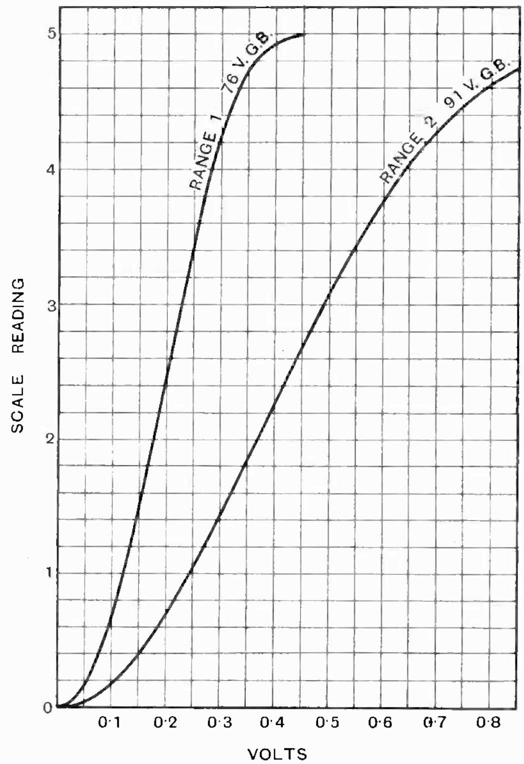


Fig. 3.—*Calibration curves of the valve voltmeter.*

the input circuit at high frequencies, the grid capacity must be reduced as far as possible. In a valve voltmeter on the lines of Fig. 1, the interior of which is shown in Fig. 4, a capacity of only 6 $\mu\mu$F was found between the grid-terminal and earth. To this capacity must be added that between the connecting wires to the terminals of the voltmeter and earth, which, with wires of about 20 to 30 cms. length, amounts to about 3 $\mu\mu$F. The total capacity of a valve voltmeter such as that of Fig. 1 need not therefore exceed 9 $\mu\mu$F. This value of capacity is small enough to permit of carrying out exact measurements of amplification, even on wavelengths down to 200 metres.

In order to keep the grid-capacity as small as possible, the grid-lead was arranged to be as far as possible from all other wires. In the interest of low capacity the valve used as rectifier was de-capped. In this connection it is worth mentioning that in the rectifying stage a *screened-grid valve* with separate lead for the grid, such as has been developed in America for use with aperiodic frame aerials, has great advantages.

The outside of the instrument of which Fig. 4 shows the interior, may be seen in Fig. 5. The voltage to be measured is led to the instrument by the shortest route through the hole visible on the left-hand side of the containing box. For practical work with the instrument described, there is a certain convenience in the fact that the adjustment of the operating point for the second stage, and above all the sensitivity, are within certain limits practically independent of the filament voltage. There is, therefore, no need to take any elaborate precautions to ensure that the filament voltage is adjusted to exactly the value at which the calibration curves were made.

Fig. 5.—*External view.*

In a circuit of this type an increase of the filament voltage in the first stage only results in a certain decrease in the anode current in the second stage. On the other hand, if the filament voltage is increased in the second stage only, the plate current increases. It must be ascribed to a lucky

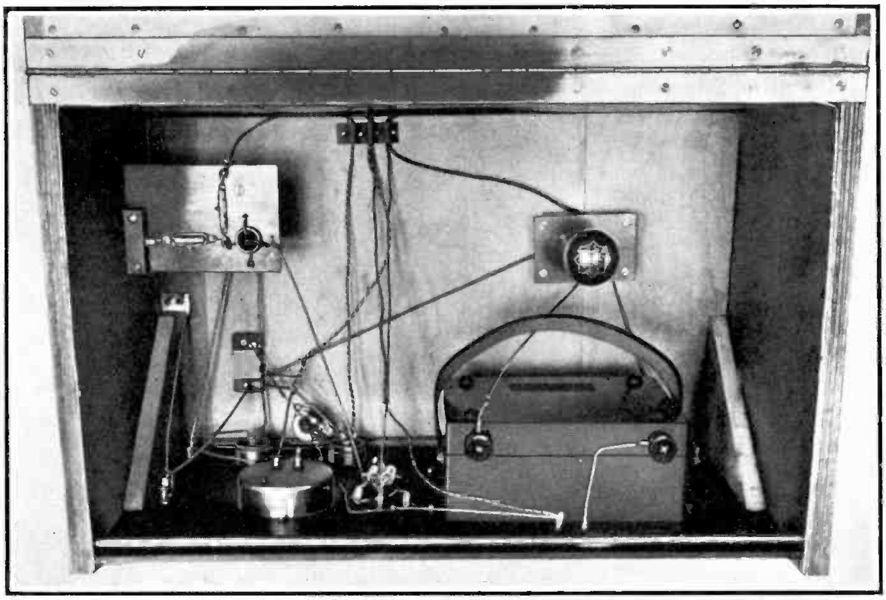


Fig. 4.—*Interior of the voltmeter.*

accident that variations in filament voltage occurring in both stages simultaneously almost exactly counterbalance one another, so long as the variations are small.

The special advantages of the valve voltmeter described are now briefly summarized as follows :—

High sensitivity is obtained without the use of current-compensation; in consequence the time spent in adjusting the instrument is small.

Damage by overloading is almost impossible.

The calibration-curve is independent of frequency for all frequencies above 50 cycles, so that measurements may be undertaken at both high and low frequency. Within certain limits the variation with battery-voltage is small, so that the anxious care that has to be bestowed on obtaining perfect constancy of voltage for most other types of valve voltmeter is here not nearly so essential.

The stray capacities amount to only a few micromicrofarads, and are small enough to permit the carrying-out of nearly all high-frequency measurements.

The Use of the Valve Voltmeter.

Measuring arrangements, in which a valve voltmeter is used in conjunction with an audio-oscillator and a resistive potential-divider for determining the degree of amplification of a low-frequency amplifier at different audio-frequencies have already been described so often that it would be superfluous to go into the details of such an arrangement here. The valve voltmeter is specially suited* for measurements on high-frequency amplifiers, which have been regarded up to the present as being the most difficult measurements to make in the whole range of receiver technique. With an equipment such as that shown in Fig. 6, these measurements are however so simplified that it is possible to determine, for example, the amplification attained on any given wavelength by the use of a multiple valve within the space of a few seconds. The measuring equipment consists of a high-frequency generator, a calibrated resistive potential divider for high frequencies, and

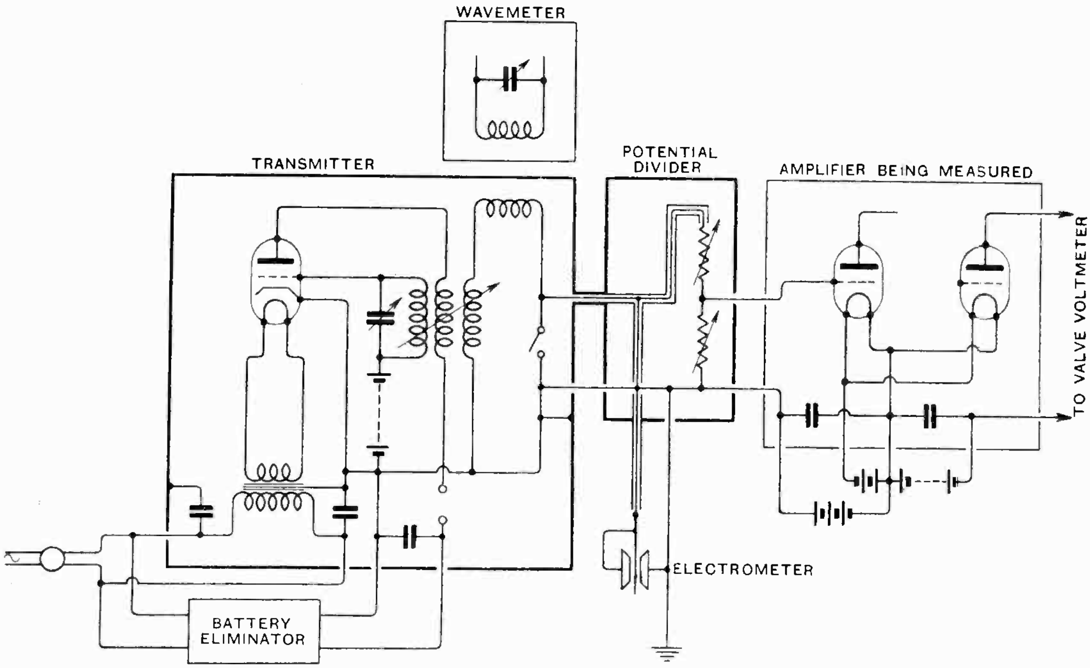


Fig. 6.—*Circuit of complete equipment.*

* Because of its great sensitivity and small input capacity.

the valve voltmeter. In order to obtain accurate results the oscillator and the potential divider must be completely enclosed in a metallic screen. The measurement of amplification is made very simply, by applying to the amplifier under examination a small known input voltage and measuring the output voltage with the valve voltmeter. The degree of amplification is given directly by the ratio of these voltages.

If there is connected in front of the voltmeter an aperiodic high-frequency amplifier the amplification of which at different frequencies has been determined with apparatus similar to that of Fig. 6, the resulting combination permits of the measurement of extremely small high-frequency voltages. Measurements made in the author's laboratory, using as aperiodic amplifier three special Loewe high-frequency multiple valves in cascade, have shown that voltages down

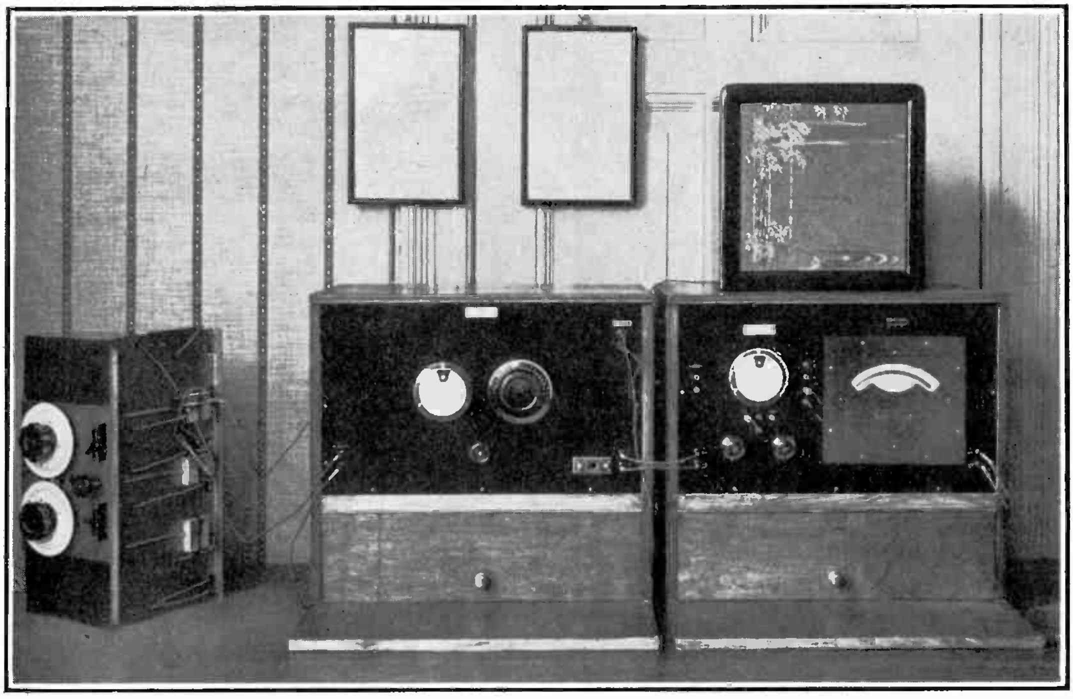


Fig. 7.—*General view of the apparatus.*

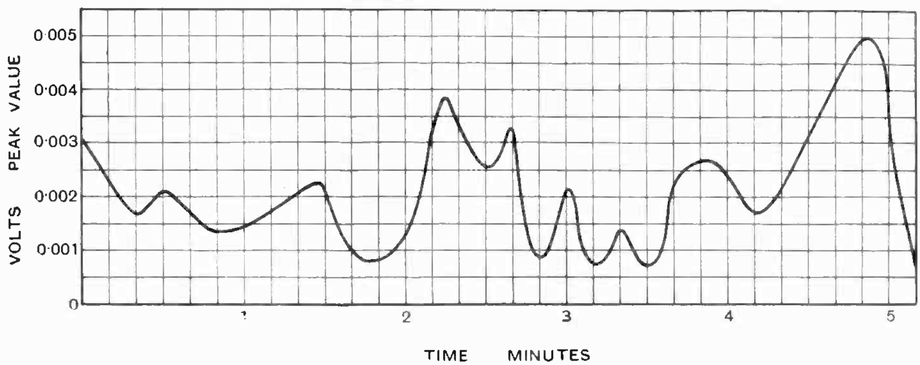


Fig. 8.—*High-frequency voltage from the Prague transmitter* (λ348.9 *metres*) *in frame-aerial circuit.*

to 10^{-5} volts can be determined. The complete apparatus used for these measurements is shown in Fig. 7, in which on the left, with the completely-screened aperiodic amplifier, is seen in the middle. It has been found possible to measure directly the voltages produced by distant transmitters in a small frame aerial tuned to resonance, and to carry out measurements of the field strength from distant stations. It has been found possible, for example, to follow the changes in intensity of the signals from many stations with time, and to take interesting curves of the voltage variations, which provide useful information for examining the phenomena of fading. As an example of this Fig. 8 shows a curve of the voltages of a transmitter at a distance of only a few hundred kilometres. The measurements show the typical variation of input voltage due to fading. In particular this arrangement was used to compare the intensity of different stations, during the evening hours, at the receiving station near Berlin. For this purpose an average value, representing a period of some six minutes, was obtained. Measurements of the field-strength of a stronger stations can, of course, be made without the need for a special amplifier.

Wireless Progress in the Past Two Years.

I.E.E. Wireless Section, Chairman's Address.

IN his inaugural address as chairman of the I.E.E. Wireless Section on November 6th, Capt. C. E. Kennedy Purvis, R.N., reviewed wireless progress during the past two years. In the broad field of communications the merger between the Marconi and the Eastern Companies should lead to the development of Empire communications. A strategic need for cables still existed. An improved service was now being given by the Beam system, and short-wave channels to smaller colonies were in progress. At the same time long wave work should not be abandoned. In radio telephony the judicious use of long and short waves was giving a 24-hours transatlantic service, while other long-distance telephony systems were already in operation ; e.g., Holland–Java, Germany-Argentine, etc. Experiments on multiplex telephony and telegraphy on one channel were also in progress.

Amongst broadcasting matters, the Prague plan was a notable step. The previous Geneva and Brussels plans paved the way to the Prague plan, which was a formal agreement between Governments.

In the field of theory our knowledge of the mechanism of propagation had been greatly advanced by the work of the Radio Research Board and of the Marconi Company, and the lecturer reviewed the effects of the ionised layer on various wavelengths; dealing with scattering, fading, interference and rotation of polarisation. The layer was a complex structure, and there appeared, in fact, to be two layers, one at 250 k.m. and one at 100 k.m. A notable feature was the development of aerials and apparatus for short waves, especially the Adcock direction finding system. On short waves it was possible to d.f. a nearby station with a ground ray. In the " skip distance " the scatter effect precluded d.f., but at greater distances, with a single indirect ray, d.f. again became possible. At very great distances there was, of course, the possibility of the waves arriving by several routes.

As regards apparatus, the H.T. generator schemes of Rugby and the B.B.C., were giving satisfactory performances. The rectifier scheme of H.T. supply gave perhaps greater security from " flash over." A slide was shown of valves for short wave transmitting purposes. Frequency constancy had been well solved for Rugby and the B.B.C. (on shared wavelengths) by the use of valve-maintained forks for the long and medium waves. For short waves master oscillators or quartz crystals were available, and it was hoped that the study of the quartz oscillator might evolve a source which was stable in frequency to 2 parts in a million.

Amongst receivers, the screened grid valve and the pentode were features of development, while moving coil loud speakers had made notable advances in the period under review. In short wave receivers better screening was a notable feature, but at frequencies above 8,750 k.c./s. little progress had been made. Other developments in apparatus included picture transmission systems, such as that of the Marconi Co. and the Fultograph, while television broadcast was now actually in operation. In directional working, the R.A.F. rotating beacon had been developed for aircraft and marine navigation, and a beacon of this type had been installed at Orfordness. Fixed beacon systems were also briefly reviewed, including experimental systems of sound and wireless emissions. In mercantile marine apparatus spark transmitters were vanishing, being replaced by I.C.W. on the 600-800 m. range. Short waves were also being put to maritime use.

The lecturer then reviewed the work of the Comité Consultatif International, Radio (C.C.I.R.), and outlined the subjects of discussion at the committee's recent conference at the Hague. The committee was intended to bridge the gaps between international conventions, the next of which was due at Madrid in 1932.

In connection with future work, the speaker suggested the need for the development of the very high frequencies, i.e., above 30,000 k.c., and the need for valve development for short-wave working generally. Frequency stabilisation was a matter of the greatest importance, and methods of automatic control of gain to compensate for fading were another problem for future solution. The hope of material improvement in the immumity from atmospherics seemed small on the longer waves, but was not so serious in the short wave region.

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.

Experimental Transmitting and Receiving Apparatus for Ultra-Short Waves.

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

SIR,—In their interesting and comprehensive review of the above subject in the October issue of *E.W. & W.E.*, Dr. Smith-Rose and Mr. McPetrie point out that an oscillating valve circuit employing a single *LC* circuit is symmetrical about the D.C. supply (or, to be quite general, about *a* D.C. supply —that is, either grid or anode), and can therefore be represented by a symmetrical bridge network. The writer would suggest that the bridge shown in Fig. 8a for the particular circuit of Fig. 8 (page 538 of *E.W. & W.E.* for October) is not the most satisfactory way of showing this. First, the bridge shown is not generally applicable to circuits of this type and, secondly, the bridge in this particular case is *not* symmetrical as it is definitely stated in the text that the capacity of the anode stopping condenser forming one capacity branch of the bridge is greater than the grid-anode capacity forming the other and this would certainly usually be the case in practice. It is suggested that for the general type of circuit shown in Fig. 1 the most convenient bridge arrangement is that indicated in Fig. 2. Here two arms of the bridge are formed by the anode-filament and grid-filament capacities (C_{ga} forming a shunt across the "output" terminals of the bridge) and the other two by the two parts into which the nodal points of the capacity and inductance divide the oscillatory circuit. The existence of these nodal points is not, of course, dependent on whether actual connection is made to either or both of them, and the two *LC* circuits which represent the oscillatory circuit in the bridge diagram are the electrical equivalent of the single coil and condenser of the most common practical

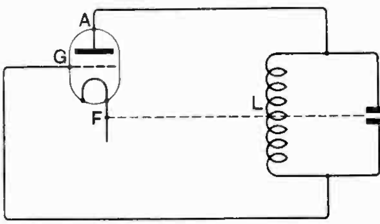


Fig. 1.

example of this circuit. It may be well to recall here that either the grid or anode D.C. supply may be introduced at the nodal point of the inductance and both may be if a stopping condenser of low impedance is introduced at the nodal point. Incidentally, this last scheme was not mentioned in the paper referred to, but it is worthy of note as being the only single *LC* circuit arrangement which avoids making any D.C. connection to a point of high alternating potential through a choke or high resistance. It does, however, introduce certain difficulties of its own. Returning to the bridge of Fig. 2, since C_{af} and C_{gf} are not in general equal, it is evident that the balance of the bridge will be upset if both the filament and the geometrical centre of either the inductive or capacitative branch of the oscillatory circuit are connected to earth and the result of such unbalancing will be a flow of

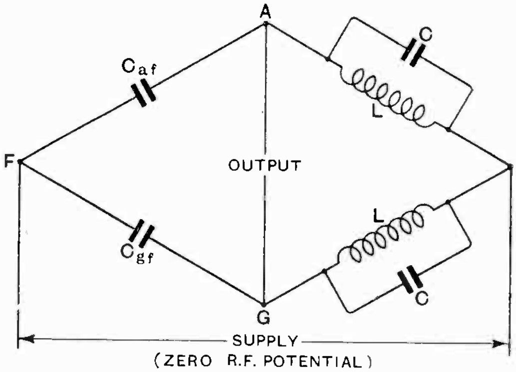


Fig. 2.

radio frequency current through parts of the circuit where it is neither useful nor desirable. The writer is of the opinion that much of the trouble and instability often experienced with ultra high-frequency oscillators is due to neglect of this point. This was confirmed by some recent experiments using the circuit in which the anode D.C. supply is connected at the nodal point of the inductance and the grid D.C. supply through a choke direct to that electrode. By using a small variable grid condenser (C_{gf} is usually greater under operating conditions than C_{af} and the condenser also serves to reduce grid circulating current) and an adjustable nodal tap a very satisfactory bridge balance could be obtained with any desired grid excitation and little or no trace of R.F. current in the D.C. supply circuits even at the highest frequencies. Compared with the usual centre-tapped coil arrangement a very gratifying improvement in purity and stability of the heterodyne note was noticed, particularly when rotary machinery was used for the H.T. supply. A 75-watt valve was used in these tests at frequencies ranging from 25 to 80×10^6 cycles.

E. C. S. MEGAW.
City and Guilds (Engineering) College,
South Kensington.
18th October, 1929.

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

SIR,—Having read the first instalment of the paper by Messrs. Smith-Rose and McPetrie, dealing with their experiments upon the generation and reception of ultra short waves, I looked forward with keen anticipation to the succeeding ones, with the idea of cribbing some useful information therefrom, it being much less trouble to obtain information from the work of others than to obtain same by one's own efforts, even if one is capable of so doing.

If the instalment contained in the current issue of *E.W. & W.E.* is the final one (as it appears to be), I must confess to a feeling of disappointment. One obtains the impression that much has been left unsaid, in this otherwise immaculate paper.

It will be inferred from the foregoing that I am particularly interested in this line of research.

I have been working upon somewhat similar lines during the past year, with the idea of developing a practical low-power apparatus for use on wavelengths of the order of 3 metres.

The points upon which I looked in vain for fuller information (seeking confirmation or otherwise of my own experiences) are set out below, together with my own (I hope not superfluous) comments.

(A) TRANSMISSION.

(i). *Screening of valve envelope.*

The use of metallic foil in close contact with the outside of the valve envelope is mentioned, but the authors apparently did not use it in their work, or investigate its effect.

I have found that, apart from its possible use as a preventive of possible puncturing of the glass envelope, it has a marked effect upon the performance of valves when used in ultra short-wave work.

I tried a large number of valves of different types (ratings up to 100 watts, all with glass envelopes, of course) for this work, and found that in every case the upper limit of frequency at which the valve would work was considerably raised by adopting this expedient.

To give an instance, a D.E.T.1. S.W., which could not by any means be induced to oscillate at a wavelength below 4.5 metres, worked quite efficiently at 2.7 metres when about 60 per cent. of the external surface of the envelope was covered by a coating of tinfoil pasted upon it.

This wavelength (or to be more precise 2.65 metres) was the lower limit on account of structural considerations, i.e., shortest possible length of external leads.

(A possible explanation of this effect of envelope screening is offered in a paper submitted to the Editor a short time ago.)

(ii). *Keying.*

The method used by the authors sounds extremely ingenious. Details of the actual arrangement would have been welcome.

In my own experiments with I.C.W. and telephony, grid circuit modulation being used, the only satisfactory method of keying I could think of was the well-known expedient of interrupting the primary current to the modulating transformer.

(iii). Why was the "push-pull" type of oscillator used (apparently) exclusively?

The reasons given by the authors do not seem adequate. (This form of circuit seems also to have been a favourite with many well-known Continental workers, many of whom are mentioned in the extensive bibliography given by the authors.)

(iv). *Feeders.*

Was there any particular reason for the use of the carefully spaced feeder shown?

I have found ordinary "cab-tyre" twin-twisted "flex" quite satisfactory in a practical outfit working on 2.8 metres. This latter form of feeder was used for both transmitter and receiver.

Was any difference noted in the aerial current obtainable (for a given input) with aerial

(*a*) Inductively coupled directly to oscillator.

(*b*) Inductively coupled via feeder to oscillator?

In my own experiments the results were as follows:—

On a wavelength of 2.8 metres.

Input to oscillator = 30 watts.

Aerial current (maximum obtainable at centre of half-wave "dipole"):—

(*a*) .1875 A.

(*b*) .15 A.

This difference could not be accounted for by radiation or resistance losses occurring in the feeder.

(B) RECEPTION AND WAVE PROPAGATION.

(i). It is not definitely stated in the paper whether pure or modulated C.W. was used in the tests.

(As the authors mention the use of "anode circuit modulation" in the case of the transmitters used by them, it was presumably the latter.)

(ii). Was heterodyne reception with pure C.W. found to be possible?

I did not try it, but used only modulated C.W.

(iii). What was the objection to super-regeneration?

My own experience was that it made all the difference between an apparatus only suitable for laboratory investigations and a practical working outfit.

Under average ground surface conditions the maximum ranges obtained were:—

Without super-regeneration	500 yards.
With super-regeneration ..	8,000 yards*
Mean height of aerials ..	7 feet.
Input to transmitter ..	20 watts.
Wavelength	2.8 metres.

Same receiver was used in both cases with same number of valves (self-quenching detector when super-regeneration was used).

(iv). Information in regard to the effect of the initial plane of polarisation of the waves and the relative amounts of absorption under different conditions would have been interesting.

The conclusions which I arrived at during the course of my experiments cannot very well be set out here, but are dealt with in some detail in the paper previously mentioned.

(v). No information is given about the ranges obtained, especially as regards the effect of using high power in getting signals "through" by "brute force."

*Longest range tried.

I have had no experience of the use (during range tests) of input powers greater than 30 watts, but even with this small amount of power signals were (using the super-regenerative receiver) *invariably* readable up to a radius of 1,000 yards from the transmitter, presumably owing to the "brute force" effect, because at greater ranges than this the presence of screening objects frequently interrupted communication.

In conclusion, I do not wish this communication to be construed either as an attempt to take the authors to task for their sins of omission, or, on my part, to pose as an exceptionally able investigator in this department of radio science.

I do hope that it is the purpose of Dr. Smith-Rose and his colleague to deal with the matter more fully in later papers.

C. WHITEHEAD.

S. Farnborough, Hants.

Moving Coil Loud Speakers.

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

SIR,—Mr. Cosens' letter in your November issue raises the question of priority, and the acrimony of disputes. My letter in the August issue neither raised the question of priority nor introduced the atmosphere of acrimony. I commiserated with Mr. Cosens in his labours due to delay in the publication of my analysis. I do not agree with his dates. The June *Phil. Mag.* supplement was in my hands on the first of that month and not one month later. It is obvious that both authors worked independently. I would indicate, however, that I outlined the theory of the M.C. in a lecture at Cambridge University in November, 1926. (Where was Mr. Cosens ?)

In writing scientific papers, references are a *sine qua non*, and one's inner consciousness is merely a useful reminder. Mr. Cosens has no excuse for not quoting references when he admits they exist.

So far as my book and articles in *The Wireless World* are concerned, I would point out that my main object has been to disseminate as much information as possible to the largest circle of people interested in radio. In so doing an author must write to the level of his readers. Neither my book nor *The Wireless World* were suited for the inclusion of highly technical matter. The academic mind usually jumps to conclusions—it seldom pauses to consider. In the preface of my book, line 7, I wrote, "The purely analytical side of the problem has not been broached, since it is beyond our present purview, etc." On p. 65 I wrote "The radiation of sound from a vibrating disc has been treated by the late Lord Rayleigh. The remarks which follow are based on an analysis by the author, in which Rayleigh's formulæ are incorporated." This analysis existed early in 1926 and had been read privately and checked by others. It was summarised in my *Phil. Mag.* and Roy. Soc. papers, from which it ought to be clear that I can think in differential equations as well as in vectors !

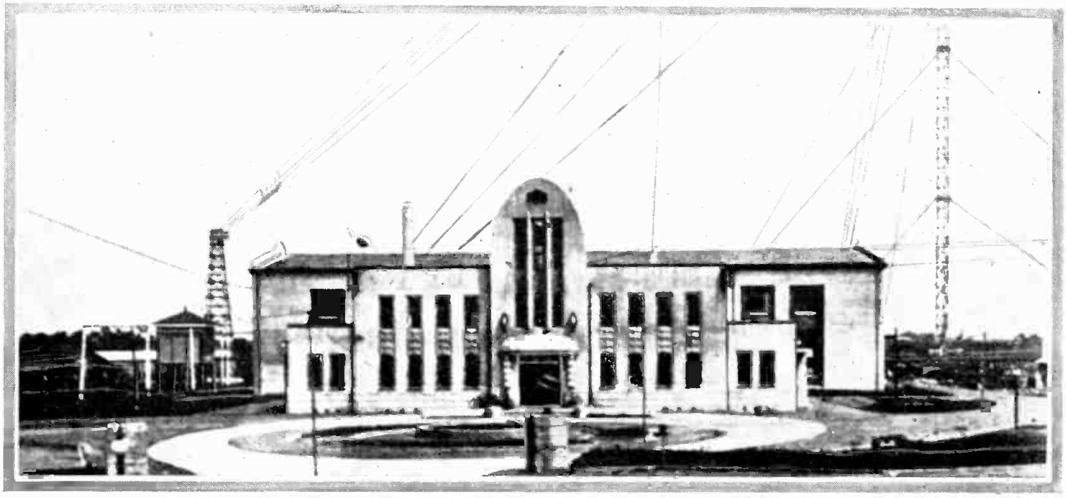
In his analysis Mr. Cosens has omitted the acoustic pressure distribution round the disc and the equivalent circuits of the M.C. which are useful in studying the physical properties of the device.

We are told that Rayleigh introduced "accession to inertia" in 1887. I gave this reference to Rayleigh on p. 65 of my book. What I said in August was that I introduced this subject into loud speaker design some years before the reference to which Mr. Cosens ardently adheres.

In *The Wireless World*, March 23rd, 1927, prior to the publication of my book, I gave a simple outline of M.C. theory. This embodied calculations on accession to inertia, etc., and the formula for the motional capacity. If Mr. Cosens had consulted this and other *Wireless World* articles his criticism against my book would not have materialised.

N. W. McLACHLAN.

London.



Station buildings at Nagoya Radio, Japan.

Some Recent Patents.

The following abstracts are prepared, with the permission of the Controller of H.M. Stationery Office, from Specifications obtainable at the Patent Office, 25, Southampton Buildings, London, W.C.2, price 1/- each.

PICTURE-RECEIVING SYSTEMS.

Application date, 28th April, 1928. *No.* 318117.

The screw-threaded spindle driving the feeler or recording stylus is fitted with a conical end-part. At the completion of each traverse the driving-wheel mounts the screw-threaded conical part, and lifts the feeler above the surface of the recording drum, thus preventing the possibility of damage due to drag on the rotating parts. The wheel is prevented from being entirely detached from the cone by running the last spiral into a circular groove.

Application date, 28th April, 1928. *No.* 318119.

The interior of the recording drum is fitted with a bobbin carrying a supply of sensitized paper. The end of the paper passes through a slit provided with a clamping device for stretching a fresh length of paper in position.

Application date, 28th April, 1928. *No.* 318120.

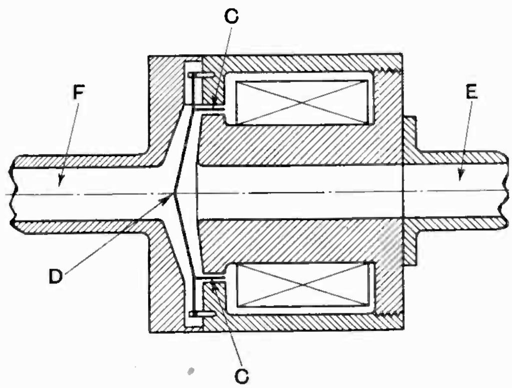
Instead of damping the sensitized paper prior to fixing it on the recording cylinder, it is mounted in a dry condition, and a capillary damping-wheel is arranged over the cylinder surface, just in advance of the feeler or recorder. This ensures a regular moistening action, and prevents "speckling" due to dry or semi-dry spots.

Patents issued to O. Fulton.

MICROPHONES.

Application dates, 1st June and 1st November, 1928. *No.* 318279.

Relates to a moving coil type of microphone, particularly sensitive to sibilants and similar high-pitched frequencies. The moving coil *C* is mounted on a shell fixed to the periphery of a conical diaphragm *D*, the angle of the cone being so selected that any disturbance originating at the centre of the diaphragm travels outwards to the periphery with the velocity of sound in air. The horn is attached to the inlet *E*, and the sound-waves pass round the periphery of the diaphragm and escape through the outlet *F*, the direction of ripple propagation set up in the diaphragm being the same as that of the passing air-waves.



No. 318279.

Patent issued to F. W. Lanchester.

DRY-CONTACT RECTIFIERS.

Convention date (U.S.A.), 25th August, 1927. *No.* 296077.

The metal casing used to protect copper-oxide rectifiers from mechanical shock has the disadvantage of storing up the heat generated. According to the invention the sides of the casing are clamped into close contact with the outer radiating fins on the element, the necessary insulation being provided by a thin sheet of mica. This permits sufficient heat transfer to enable the whole of the protective cover to function as a heat-radiator. In addition the outer casing may be perforated to facilitate the free circulation of air.

Patent issued to The Westinghouse Brake and Saxby Signal Co., Ltd.

INDIRECTLY HEATED VALVES.

Convention date (Germany), 25th June, 1927. *No.* 308823.

The cathode or electron emitter is heated by conduction (as distinct from radiation) from the heating-element, which is formed as an extension of the cathode. The arrangement is such that the heating-current flows directly through the heating-element, but not through the cathode, the latter being shunted across points of equal potential on the current-supply leads.

Patent issued to S. Loewe.

Convention date (U.S.A.), 29th September, 1927. *No.* 297847.

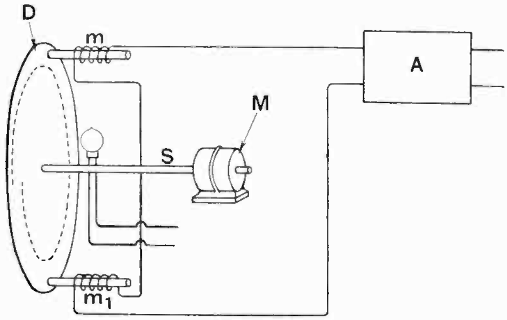
In a valve of the .8 type, taking raw A.C. direct from the mains, the fluctuating current through the filament sets up a corresponding magnetic field which deflects the flow of the electron stream from filament to plate, so creating plate current fluctuations which have the frequency of the mains supply. In order to compensate for this effect an auxiliary winding, in series with the filament, is mounted inside or outside the glass bulb, and is so adjusted as to produce an equal and opposite magnetic field to that of the filament.

Patent issued to Marconi's Wireless Telegraph Co., Ltd.

TELEVISION SYSTEMS.

Application date, 31*st May*, 1928. *No.* 318278.

In a combined television and telephony system, the usual exploring-disc is made to act also as the diaphragm of the loud speaker. As shown in the



No. 318278.

Figure, the exploring-disc D, fitted with a spiral series of holes, is rotated by a motor *M*. A series of magnets m, m_1, etc., mounted around the outer periphery of the disc, apply impulses of audible frequency from the amplifier *A*. The disc may be splined to the driving-shaft *S* to permit the slight longitudinal movements which occur in sound reproduction, the restoring force being provided by a spiral spring (not shown). Or the disc may consist of a peripheral strip of metal combined with a central portion of fabric or other yielding material, in which case no restoring spring is necessary, as the rotation of the device will tend to maintain it in the plane of rotation.

Patent issued to J. L. Baird and Television, Ltd.

Application date, 22*nd June*, 1928. *No.* 318331.

A stream of electrons is produced from a photo-electric surface, upon which the image to be reproduced has been projected, so that the density of the stream at each unit area of its cross-section varies with the light-intensity existing on the photo-electric surface. The electron stream is then traversed, by magnets or otherwise, over a conductor so that each unit area of cross-section sets up corresponding currents, which are then used to modulate a carrier wave. In reception the incoming signals are first rectified and after being amplified are applied to control locally generated currents in synchronism with the transmitter.

Patent issued to C. E. C. Roberts.

Application date, 1*st June*, 1928. *No.* 318565.

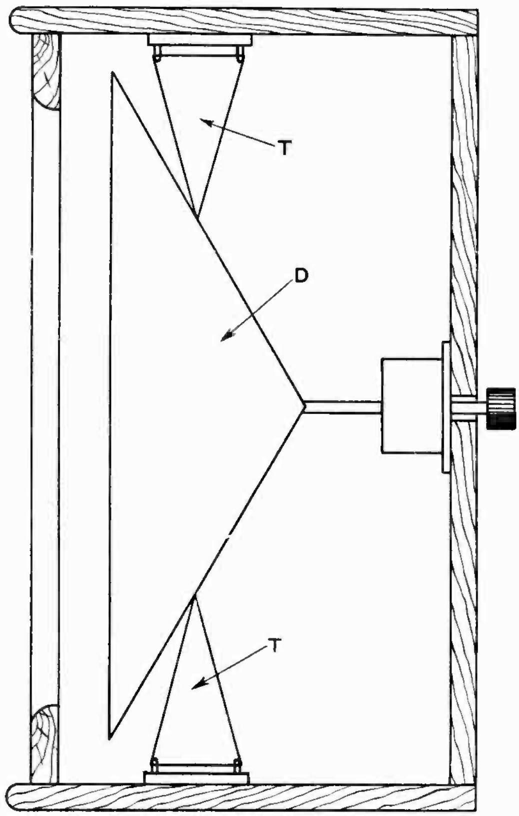
Cathode rays are used for scanning both at the transmitting and receiving ends. At the transmitter the rays energise a photo-electric plate so arranged that the image to be transmitted is projected simultaneously on the opposite face of the plate, and a control current, which corresponds at any moment to the light-intensity of each particular picture-element, is transmitted through the plate, at the point on which the cathode ray impinges at that moment. At the receiving end the cathode ray traverses a fluorescent screen, producing visible effects corresponding to the original picture. By projecting three images simultaneously in the three primary colours at the transmitter, natural-colour reproduction is secured at the receiver.

Patent issued to J. E. Pollak.

LOUD SPEAKERS.

Application date, 23*rd July*, 1928. *No.* 316007.

The diaphragm *D* is supported or poised at a number of points, preferably three, lying in a plane at right angles to the axis of the diaphragm and passing approximately through its centre of gravity. The suspension consists of a system of threads *T* forming at each points of support the apex of an isosceles triangle. The base of the triangle is carried by a bracket mounted on the inner walls of



No. 316007.

the casing as shown. As both sides of each triangular suspension are resilient and are initially in tension, any axial movement of the diaphragm as a whole will increase the tension on one side and decrease it on the other, thus ensuring a compensating action by which any damping effect is minimised.

Patent issued to A. P. Welch.

TELEVISION SYSTEMS.

Application date, 4th January, 1928. No. 314591.

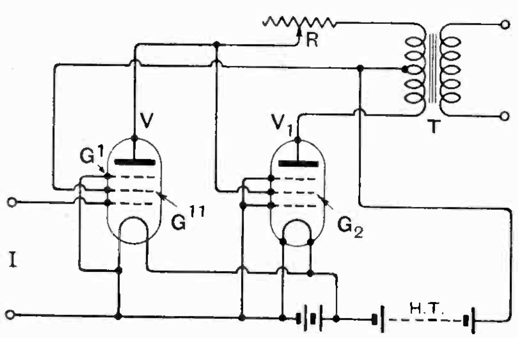
For securing coloured effects at the receiving end, the object at the transmitter is explored by a spot-light of the same, or substantially the same, colour as the object itself. For two-colour or three-colour reproduction a plurality of spot-lights of corresponding colours are used, the periods of exploration being separate and consecutive; or they may overlap, or be concurrent. A corresponding number of light-sensitive cells are used, the various cells being so selected as to be particularly selective to each primary colour. In reception the synthesizing-disc is provided with three separate spirals of lenses each covered by equivalent light filters.

Patent issued to J. L. Baird and Television Ltd.

PENTODE AMPLIFIERS.

Application date, 4th April, 1928. No. 314605.

As shown in the diagram the input circuit I is connected to the control grid of a pentode valve V. The second grid G_1 is connected to the filament, and the third grid G^{11} to the high-tension battery $H.T.$ as usual. The anode of the valve V is connected directly to the grid G_2 of a second pentode



No. 314605.

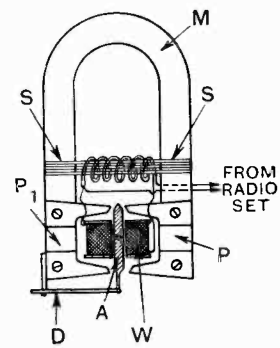
V_1, and, through a variable resistance R and part of the primary of a divided output transformer T, to the high-tension battery $H.T$. The anode of the valve V_1 is taken to positive H.T. through the lower winding of the transformer primary. Both the other grids of the valve V_1 are connected to the filament, as shown. This arrangement gives an effective push-pull amplification for operating a loud speaker. It will be noticed that no insulated grid battery is employed, the presence of which under certain conditions of working is often a source of trouble.

Patent issued to J. S. C. Salmond and L. S. B. Alder.

LOUD SPEAKER MOVEMENTS.

Convention date (U.S.A.), 18th November, 1927. No. 300620.

An armature A, pivoted at its centre, is vibrated between upper and lower extensions of the pole-pieces P, P_1, and communicates its movement to a rod D connected to a diaphragm. The novel feature lies in applying the low-frequency energising-current to a soft-iron shunt S bridged across the



No. 300620.

permanent magnet M as shown. The effect of the induced magnetism is to strengthen or weaken the magnetic flux across the polepieces P, P_1, thus vibrating the armature. Preferably the magnetic shunt S is used in combination with an energising-winding W surrounding the armature A as usual.

Patent issued to I. Kitsée and D. C. Law.

SOUND HORNS.

Application date, 3rd July, 1928. No. 315561.

With the object of securing balanced emission of both high and low notes from a horn of comparatively moderate length, the horn is so made that its area increases in geometrical proportion along a number of successive sections, *i.e.*, it is doubled at the end of the first stage, trebled at the end of the second, and so on. At the same time, the overall length of each of these sections diminishes in arithmetical proportion from the input to the output. This gives a gradual increase in area at the input end of the horn followed by a comparatively rapid increase towards the open end.

Patent issued to R. L. Aspden.

GRAMOPHONE PICK-UPS.

Application date, 19th April, 1928. No. 315488.

The volume of sound produced by the pick-up is controlled by means of a variable magnetic shunt inserted across the polepieces of the magnet. In one construction two pairs of grooves are formed at the point and rear of each leg of the magnet. These accommodate two sliding plates of soft iron. As one or both plates are moved down, by hand, towards the ends of the magnet legs, the effective flux across the polepieces is reduced. This causes a diminution in the voltage induced by the movement of the stylus, and a corresponding decrease in the intensity of sound.

Patent issued to P. D. Tyers.

AN ACOUSTIC VALVE-AMPLIFIER.

Application date, 4th May, 1928. No. 315040.

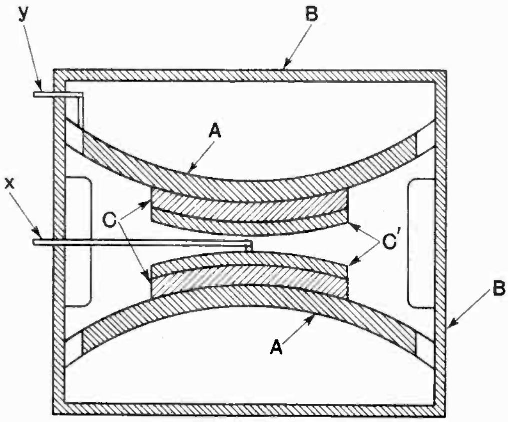
A three-electrode amplifier is adapted to effect a direct conversion of electric current into sound waves by utilising the temperature changes generated in the anode of the valve owing to the fluctuating electron stream. The anode consists of a thin metallic sheet sealed into the crown of a flat-topped bulb. One surface of the anode is open to the air, and to this surface is secured a perforated sheet of non-conducting material fitted with projecting flanges to form an air-chamber or resonator. As the value of the plate current through the valve varies, temperature changes on the exposed surface of the anode are communicated to the adjacent film of air, and set up corresponding waves of sound.

Patent issued to B. S. Cohen.

LIGHT-SENSITIVE CELLS.

Application date, 3rd April, 1928. No. 314838.

Powdered selenium, alone or mixed with powdered tellurium, phosphorus, uranium, thorium, and certain other metals, is compressed into a coherent mass, which may be heated in an atmosphere of inert or reducing gas, or *in vacuo*. This is stated to increase its reaction to light. The prepared



No. 314838.

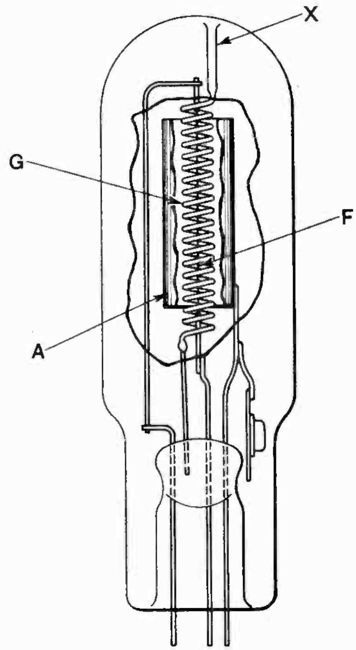
sensitive material may be moulded into a concave cylinder *A*, and mounted inside a glass casing *B*. A brush-like formation of wires *C*, attached to a metal backing-plate *C′*, forms a central contact for the electrode *x*, the other electrode *y* being arranged at the other edge as shown.

Patent issued to C. Ruzicka.

ACTINO-THERMIONIC AMPLIFIERS.

Convention date (U.S.A.), 19th August, 1927. No. 295702.

The grid *G* of a thermionic valve is made of a solid spiral of quartz or optical glass, having a monatomic coating of cæsium or other photo-electric metal. The upper end is fused into the glass bulb at *X*. A ray of light directed on to the upper end will traverse the quartz rod from end to end in a series of internal reflections. At each



No. 295702.

reflection photo-electric emission takes place from the spiral surface, thus raising the effective potential of the grid and increasing the electron stream from the central filament *F* to the cylindrical plate *A*. For any particular value of applied light-intensity, the loss of electrons by photo-electric action from the grid is balanced by fresh electrons received from the filament, so that the grid attains a definite potential.

Patent issued to British Thomson-Houston Co., Ltd.

ELECTROLYTIC CONDENSERS.

Application date, 29th March, 1928, No. 314565.

An electrolyte of jelly or paste-like consistency is used, preferably sodium silicate and a solution of sulphuric acid. This is placed in a container which is chemically inactive to the constituents and which is not a film-forming metal. The positive electrode is of tantalum, the container forming the negative electrode. The separators are of glass, porcelain, or hard rubber. The whole is sealed by paraffin, which is sufficiently porous to allow of the escape of gases formed when the cell is in action.

Patent issued to Standard Telephones and Cables Ltd.

MEASURING MECHANICAL IMPEDANCES.

Application date, 30th March, 1928, No. 314575.

The mechanical impedance of a body is defined as the force in dynes applied to the body divided by the velocity in centimetre seconds units with which the body is moved. The mechanical reactance is defined as the component of the mechanical impedance which is 90 degrees out of phase with the applied force, either lagging or leading. The mechanical resistance is the component of the mechanical impedance in phase with the force. The absolute value of the mechanical impedance is measured in mechanical ohms.

According to the invention the mechanical impedance of a system is measured directly by a hybrid bridge of the Rayleigh type, partly mechanical and partly electrical, consisting of a variable resistance calibrated to read directly in mechanical ohms, and a variable elasticity member for counteracting the mechanical reactance of the system. The element of the bridge which in operation is coupled to the apparatus under test consists of a moving coil mounted in the centre of a steady magnetic field by means of three tension members so as to ensure a single degree of motion.

Patent issued to W. E. Beatty.

RECORDING BROADCAST.

Application date 5th May, 1928. No. 314638.

In order to make a permanent record of any particular item in a Broadcast programme, a sound-recording attachment is linked up to the output of the Broadcast receiver, and switching means are provided whereby the recorded item is conveniently connected up to the input of the amplifier, so that the record can be repeated as desired. The recording outfit is preferably of the telegraphone type, in which the received and amplified currents are made to produce characteristic magnetisation on a hard steel disc. This when applied to the poles of a reproducing coil serves to generate currents similar to those originally produced. Since the current taken by the reproducing apparatus is very small, the latter is branched off in parallel with the loud-speaker leads, so that the desired item may be both heard on the loud speaker and recorded in permanent form simultaneously.

Patent issued to E. Shipton.

REPRODUCING SOUNDS.

Application date, 13th July, 1928. No. 318708.

Sounds are reproduced by thermo-electric variations of pressure created inside a pipe or conduit. A continuous flow of air is set up inside the pipe, the air passing over a thin silver grid connected in series with the primary winding of a step-down transformer fed by a wireless amplifier. Variations in transformer voltage create temperature changes in the silver grid, which in turn superimpose corresponding pressure-variations, forming sound waves, on the passing air-stream.

Patent issued to Consulting and Radio Service Ltd., and N. Turner.

PREPARING PIEZO-ELECTRIC CRYSTALS.

Application date, 6th July, 1928. No. 314680.

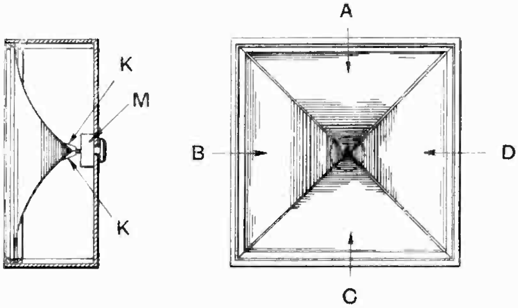
Rochelle salt crystals as usually prepared are characterised by the formation of opaque or porous regions at each end, to which the term "hour-glass" is usually applied. These regions contain occluded mother liquid, and are very difficult to dry up even under intensive dessication in absolute alcohol. When the crystal has been in use for some time there is, however, a gradual decrease in electrical conductivity owing to spontaneous evaporation, with a consequent impairment of the piezo-electric action. According to the invention, the hour-glass regions are dried out by boring drain-holes in them from the base of the crystal. The crystal is then mounted in a suitable container and subjected to compressed air. The dried-out parts are afterwards rendered electrically conductive by applying an aqueous solution of silver nitrate. On exposure to light this deposits a film of metallic silver which serves as an electrode.

Patent issued to E. W. C. Russell.

LOUD SPEAKERS.

Application date, 19th July, 1928. No. 314691.

The diaphragm consists of four triangular or sector-shaped membranes *A*, *B*, *C*, *D*, clamped at their outer edges and bent inwards to form a cone. The membranes are so cut that the curved radial edges do not come into close contact, but leave a narrow gap as shown. The ends are folded in the direction of the axis so as to form radial ribs *K* near the apex, which serve to stiffen the diaphragm as a whole. The driving-reed of the movement *M*



No. 314691.

is attached at the point of intersection of the ribs *K*. In operation the curvature of each sector decreases and increases alternatively, causing the edges to converge and diverge. The gaps are made as narrow as possible, so that, whilst affording the requisite freedom of movement to each individual membrane, undue loss in efficiency due to leakage of the air waves from the front to the back of the diaphragm is minimised. In an alternative construction, the gaps between the edges are covered over by thin strips of flexible material, such as soft leather glued to the back of each sector or membrane.

Patent issued to H. Birkbeck.