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Editorial Views.

The Institution.

In our last issue we discussed, on this page of "Editorial Views," the proposal to found a technical institution for wireless engineers.

Since then there has been a conference between Mr. James Nelson, M.I.E.E. (on behalf of the proposed new body) and the Committee of the Wireless section, I.E.E., and the latter have issued a statement, which we reproduce practically *in extenso* herewith (the omissions are purely to save space, and do not affect the points at issue).

31st July, 1925.

Recent correspondence in the Press indicates that there is some misconception as to the eligibility of wireless engineers for membership of the Institution, and it is therefore necessary to state that it is possible for an engineer to become a member of the Institution with qualifications of a purely wireless nature.

For the admission of Wireless Engineers to the class of Associate Member (A.M.I.E.E.), it is necessary, in addition to the possession of adequate professional experience for a period of at least two years, in the case of those who do not possess an exempting examination qualification, or do not submit a satisfactory thesis, to pass the A.M.I.E.E. Examination in the following subjects . . .

The Committee of the Wireless Section of the Institution have recently considered the above syllabus and they are of opinion that it represents the minimum amount of professional knowledge which a qualified Wireless Engineer should possess. No conditions are laid down by the Institution as to how or where an applicant may have obtained his training.

In order to become a member of the Wireless Section of the Institution it is necessary that the member of the Institution shall be actively engaged in the study, design, manufacture, or operation of wireless or high-frequency engineering apparatus. The meetings of the Wireless Sections are not, however, confined to members of the section, but are open to all members of the Institution. . . .

Some valuable suggestions have emerged from the recent correspondence, and will receive the careful consideration of the Section Committee, more particularly as regards the type and number of papers read, and as to increasing the activities of the Wireless Section outside London.

As regards the suggested formation of a new society, the Wireless Section Committee considers there is no need for it, because, as indicated above, wireless engineers can obtain membership of the Institution, while amateurs are already catered for by the Radio Society of Great Britain.

Frankly, we do not consider that this statement really clears up the difficulty. The examination is known to be quite a reasonable one, but one of the difficulties is the definition of "adequate professional experience." It is alleged that the I.E.E. Membership Committee have not the qualifications to judge what constitutes this in the case of wireless engineers pure and simple, and that cases have occurred which look like discrimination against wireless experience. Again, applicants have, it is said, offered to submit a thesis as a proof of knowledge, and these offers have been refused.

Again, it is clear that any Member of the Institution *can* become a member of the Wireless Section without necessarily having any wireless knowledge at all, which is resented, as indicating that the Institution attaches no importance to pure wireless knowledge.

In fact, it seems that in spite of the conference, there is still a good case for the existence of a new body, which, it is hoped, may eventually fuse with the Institution, or at any rate work in close co-operation with it.

Two points, however, seem to us necessary in the forming of any such body :—

(1) The qualifications for membership must be fairly high—approximately equal to those of the I.E.E., but Wireless.

(2) The supporters and founders must be prepared to claim no special privilege, but be assessed for membership on their merits like all other members.

We, ourselves, although we are in support of the general idea of such a new institution, are not prepared at the present moment to express ourselves either for or against the one which is actually being organised at the present moment. Our support will depend on our being convinced that the formation is proceeding on the lines we have just suggested.

Daventry.

Our readers may be surprised that there is no article in this issue describing the new 25kW. station at Daventry. We feel, however, that nothing but a complete and detailed account of the circuit and components (such as the account of Chelmsford in our issue of September, 1924) will suffice for our readers, and we therefore propose to defer consideration of it for a little while. It is more than likely that as the result of actual experience in operation some little changes will be made here and there in the arrangements, and we wish to deal with the final assembly when we describe it.

One may, however, make a few general remarks. Substantially, the station is a repetition of Chelmsford, but on a permanent basis and with careful arrangements throughout to allow for expansion up to 60kW. if necessary. At present about 25kW. is applied to the anodes of the main amplifier, 20kW. of H.F. power goes to the aerial circuit, and about 12kW. is actually radiated.

The daily papers report bad signals in Essex, but this hardly seems to be confirmed by the reports in the hands of the B.B.C. Elsewhere, the station seems to give excellent results. At our own stations, in the heart of London, it comes in at almost exactly the same strength as Chelmsford (by measurement of carrier wave aerial current), although on the basis of cutput power and distance, it should be only half as strong. It would appear that Chelmsford must have been blanketed to some extent.

Although Daventry is a highly effective station, the total power input figures throw an interesting light on the necessity of sacrificing pure efficiency when fine quality is required: in order to put out that 12kW. or so of modulated waves, about 100kW. of input power is used!

Some Measurements on Wireless Wave-Fronts.

By R. L. Smith Rose, Ph.D., M.Sc., A.M.I.E.E., and R. H. Barfield, M.Sc., A.C.G.I.

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I. Preliminary Theory and Previous Work.

(*a*) *Elementary ideas of radiation of waves from an aerial.*

IN the study of the propagation of electromagnetic waves through space, whether from the mathematical or physical point of view, the student usually encounters at the outset a diagram of the sort indicated in Fig. 1, which represents the distribution of the electric and magnetic fields in the neighbourhood of a straight-wire Hertzian oscillator. During the period when an alternating current is flowing in the oscillator there is present a rapidly varying electric field the lines of force of which lie as shown in radial planes intersecting in the wire oscillator, and also a similarly varying magnetic field, the lines of force of which are circles concentric with the wire and in planes perpendicular to that of the wire. In converting this ideal theoretical case to that of a vertically arranged aerial connected to earth, the latter is assumed to be of infinitely high conductivity so that an image of the aerial is formed therein, completing the Hertzian oscillator the field of which is bisected by the earth's surface as the equatorial plane. The process of radiation of waves from such an aerial is then depicted in the manner of Fig. 2, in which the half-loops of electric force accompanied by the concentric circles of magnetic force are shown being thrown off from the aerial at each period of oscillation. It will be seen that at a distance of a few wave-lengths from the aerial (as at point P) the electric field at the earth's boundary surface is vertical, and the magnetic is horizontal and perpendicular to the direction of travel of the wave. Further consideration of the mode of travel of these fields shows that they are both strictly in phase, *i.e.*, at any point both fields pass through their maximum and zero values at the same instant, these two extremes of amplitude being separated in time by a quarter of the period of the oscillations in the aerial and in space by a quarter of the length of the waves produced. The quotient of the wave-length divided by the period of oscillation gives the velocity of propagation of the waves.

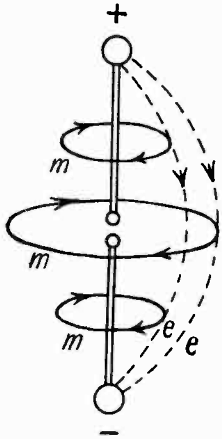


Fig. 1.

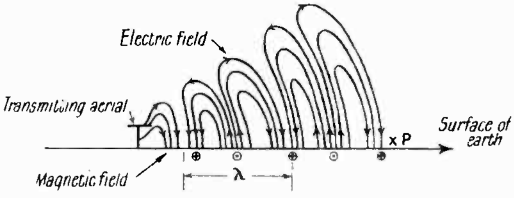
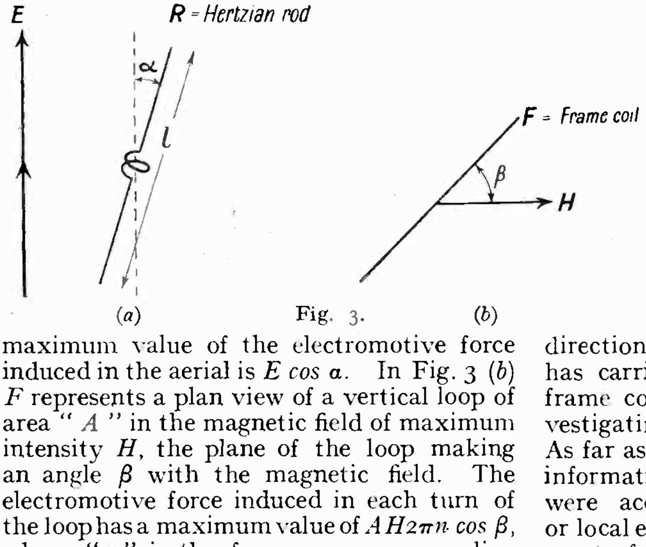


Fig. 2.

Now the surface which contains both the electric and magnetic fields is termed the wave-front of the advancing wave. In the case depicted in Fig. 2, the wave-front at the earth's surface will be a vertical cylinder concentric with the aerial. In considering a portion of this wave-front it may be regarded as plane for most practical purposes over an area whose side subtends an angle of less than one tenth of a degree at the aerial. Thus at a radius of one mile the wave-front will be sensibly plane over an area three yards square, and at greater distances this area may be increased proportionally. Further consideration of the spreading-out of the fields of the wave radiated from the aerial will show that at all points in the space surrounding the aerial the direction of propagation of the energy of the wave is perpendicular to the wave-front. The three directions of the electric and magnetic fields and of the propagation of the wave are thus mutually at right angles.

(b) Determination of wave-fronts with aerial and loop.

Now in studying the action of a receiving circuit or other obstacle placed in the path of such a radiated wave, the effects of either the electric or the magnetic fields may be considered with precisely the same result. It is usually convenient, however, to consider the action of the electric field when using an open aerial receiving arrangement and of the magnetic field when using a closed coil receiver. This will be apparent by reference to Figs. 3 (*a*) and (*b*). If E is the maximum intensity of the vertical electric field due to the wave in Fig. 3 (*a*) and a straight aerial of length "l" is placed in the field at an angle "α" to the vertical, the



(*a*) Fig. 3. (*b*)

maximum value of the electromotive force induced in the aerial is $E \cos \alpha$. In Fig. 3 (*b*) F represents a plan view of a vertical loop of area "A" in the magnetic field of maximum intensity H, the plane of the loop making an angle β with the magnetic field. The electromotive force induced in each turn of the loop has a maximum value of $AH2\pi n \cos \beta$, where "n" is the frequency corresponding to the wave.

It is evident from these considerations that the directions of the electric and magnetic fields can be determined by means of a rotating straight wire aerial and a rotating loop respectively. For if the aerial wire in Fig. 3 (*a*) be turned until no E.M.F. is induced therein, and consequently no signal received from the arriving wave, then $E\, l \cos \alpha = O$, and hence $\alpha = 90°$; which means that the electric force is perpendicular to the aerial wire. Similarly, if the loop is rotated until the signal passes through zero or a minimum of intensity the magnetic field is then parallel to the plane of the loop. For the complete definition of the directions of these fields in space of three dimensions it will be necessary to carry out this rotation of the Hertzian rod and frame coil respectively about two axes perpendicular to each other.

(c) Previous work on this problem.

For the determination of the wave-front of an electro-magnetic wave, it is thus necessary to obtain the directions of both the electric and magnetic forces. In the case of a single plane wave the determination of these forces is rendered possible by the aid of two separate receivers, one a straight open aerial and the other a closed loop, either of which can be set parallel to any plane in space.

Previous work in this direction has been carried out by Austin,[1] who used a straight Hertzian rod to determine the electric field; by Erskine-Murray and Robinson,[2] who used a Hertzian rod and a frame coil mounted on three axes for determining the direction of propagation of electro-magnetic waves; while Bellini[3] has experimented with a tilting frame coil in an attempt to measure the angle of arrival of the downcoming wave which is supposed to be responsible for night errors on direction-finders. Sir Henry Jackson[4] also has carried out experiments with a tilting frame coil, particularly with a view to investigating night errors in wireless bearings. As far as can be gathered from the published information however, these experiments were accompanied by either instrumental or local errors which prevented the establishment of any definite facts relevant to the general problem of the propagation of waves.

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1 L. W. Austin.—"The Wave-Front Angle in Radio-Telegraphy."—*Journal, Washington Academy of Science*, 1921, Vol. 40, pp. 101-106.

2 J. Erskine-Murray and J. Robinson.—"An Improved Method for Determining the Direction of Propagation of Electromagnetic Waves." British Patent 176, 127/1921.

3 E. Bellini.—"Frame Aerials and Errors in Bearings."—*Electrician*, 1922, Vol. 89, pp. 150-1.

4 H. B. Jackson.—"Directional Effects with Frame Aerials."—*Wireless World and Radio Review*, 1922, Vol. 1, 9, pp. 789-800.

(d) Notation employed.

For the sake of brevity and clarity of expression in the present paper the following notation has been adopted, which is, as far as can be ascertained, in accordance with accepted practice :—

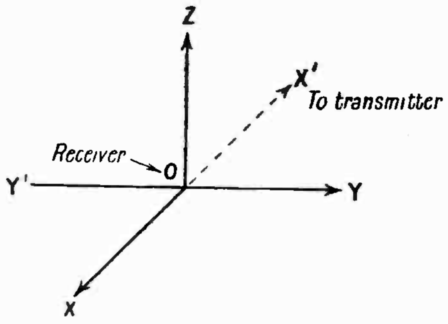


Fig. 4.

(i.) Due to the action of a transmitting station by the agency of one or more separate waves : E is the resultant electric force and H is the resultant magnetic force at a receiver.

(ii.) Rectangular axes are employed as in Fig. 4 with the receiver at the origin and arranged so that : OZ is vertically upwards ; OX is horizontal and is the great circle through the transmitter measured in the direction away from the transmitter ; OY is horizontal perpendicular to and to the left of OX.

(iii.) The plane XOZ is conveniently termed the plane of propagation of the waves.

(iv.) Angle "α" is the inclination of E to the vertical in the plane YOZ, *i.e.*, perpendicular to the plane of propagation: see Fig. 4 (*a*).

Angle "β" is the inclination of E to the vertical in the plane of propagation (XOZ) : see Fig 4 (*b*).

Angle "γ" is the inclination of the horizontal component of H to $O\gamma$; *i.e.*, "γ" is the error in apparent bearing of the arriving waves : see Fig. 4 (*c*).

Angle "δ" is the inclination of H to the horizontal plane : see Fig 4 (*a*).

(v.) A wave is considered to be "vertically" polarised when E is in the plane of propagation ; *i.e.*, when $\alpha = \delta = O$.

(vi.) A wave is considered to be "horizontally" polarised when E is perpendicular to the plane of propagation ; *i.e.*, $\alpha = 90°$, $\beta = O$.

In the next section of the paper, experimental methods of determining the directions of E and H are described with typical results obtained at the Slough Station of the Radio Research Board.

II. Determination of the Directions of the Electric and Magnetic Fields at a Short Distance from a Transmitting Station.

The apparatus employed at the Radio Research Board's Station at Slough, for the determination of the directions of the forces in the wave arriving at a receiving station, makes use of the principle outlined in Section I (*b*) above.

(a) Determination of the direction of the electric field with a hertzian rod.

A straight Hertzian rod type of receiver of 30 ft., length was built on a wooden tower 20 feet above the ground, the rod being capable of a setting in any direction in space by rotation about both horizontal and vertical axes. A view of the receiver is shown in the photograph, Fig. 5 and a diagram of connections in Fig. 6.

Leads from the centre of the rod are taken into coupling coils and an amplifier contained in a screened box supported on the centre

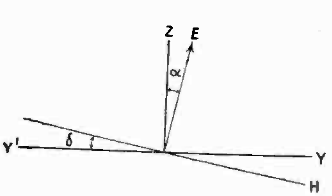


Fig. 4a.

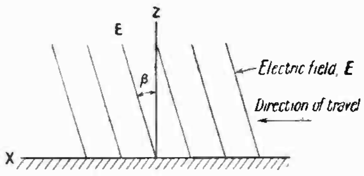


Fig. 4b.

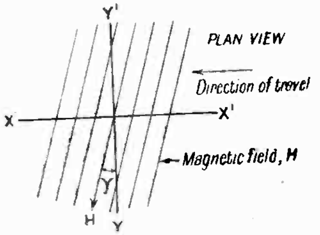


Fig. 4c.

turntable. The success and accuracy of the receiver are largely due to the efficiency of the screening of all apparatus and leads, except the actual wire forming the rod ; and in the present arrangement this screening is

Fig. 5.

so satisfactory that when using a nine-valve amplifying receiver there is no direct pick-up of signal from any transmitting station.

In making an observation, the horizontal axis of rotation of the rod is first pointed away from the transmitting station, *i.e.*, along OX, and the beam rotated in the plane ZOY until the received signal is reduced to zero, in which position the angle "α" made by the rod with the horizontal is observed on a scale. The horizontal axis is then turned through a right angle to be parallel to OY, and the rod is rotated in the plane of reception ZOX, and the zero position again observed to obtain the angle "β." The direction of the electric field is then the normal to the plane containing the directions of the rod in the above zero positions. In each position the observation is repeated after reversal of the leads between rod and receiver, and the readings are also repeated with an orientation of the rod along the axes OX' and OY'. This process practically eliminates any errors due to direct pick-up of signals and due to the scales.

(*b*) *Determination of the direction of the magnetic field with a tilting coil.*

This measurement is carried out with the aid of a frame coil capable of rotation about both vertical and horizontal axes. With its plane vertical the coil is rotated to the minimum signal position, and the ordinary wireless bearing observed. The plane of the coil in this position is then parallel to the horizontal component of the magnetic field of the arriving wave. The coil is now turned through 90° about its vertical axis to the maximum signal position. It is then rotated about its horizontal axis until the position of zero signal is found, when the angle made by the coil with the horizontal is observed. This reading gives the elevation "δ" of the resultant magnetic field due to the arriving wave, and the direction of H is the line of intersection of the planes of the coil in the two zero positions above determined. In the complete measurements the observations are always repeated after reversing the connections of the frame coil, and also after rotating the whole coil through 180° about a vertical axis. The mean readings so obtained are considered to be fairly free from any scale errors and also from the effects of any residual direct pick-up on the leads and coupling coils of the receiver.

As a check on the above method of determining the direction of H the frame coil can then be rotated about a third axis so

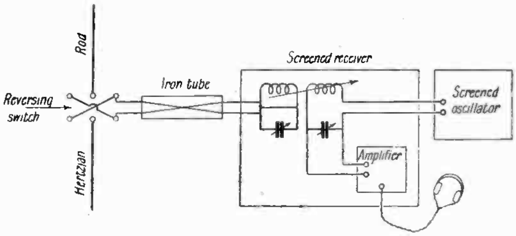


Fig. 6.

oriented in space as to be parallel to the line of intersection of the planes of the coil in the two minimum positions determined above. If complete rotation of the coil about this axis gives no signal, no magnetic force from the wave links the coil, and it must therefore be parallel to the axis of rotation. This method was first suggested by Erskine-Murray and Robinson and used by Sir Henry Jackson. Although the coil at Slough is provided with this third axis of rotation its use has so far been found unnecessary.

The receiving apparatus in this case is similar to that used with the Hertzian rod and it is completely screened from direct pick-up in the same mannner. In addition, the operator and the whole receiver, including the frame, are contained in a wooden hut which is well insulated from earth and entirely surrounded by a wire screen consisting of open untuned loops. This type of screen has been shown previously to eliminate antenna effect from the frame coil system. Views of the coil receiver and also of the exterior of the hut containing it are given in Figs. 7 and 8.

The accuracy of the observations made with both the rod and coil receivers is considered to be about 1.0°, although the mean of a number of readings is probably of a higher order of accuracy.

(c) Results obtained at Slough.

The four angular quantities, $\alpha, \beta, \gamma, \delta$, measured are considered to be of positive sign when, looking from O along either OX, OY or OZ, they correspond to a positive rotation of E and H from the axes OZ and OY respectively.

In the general investigation both the above sets of apparatus were used simultaneously and Table I. shows a summary of the results obtained.

TABLE I.

SUMMARY OF RESULTS OF SIMULTANEOUS MEASUREMENTS AT SLOUGH OF THE DIRECTIONS OF ELECTRIC AND MAGNETIC FIELDS AT SHORT DISTANCES FROM THE TRANSMITTER.

Transmitting Station.	Distance (miles).	Wave-length (metres).	Frequency (kc/sec.).	Direction of E.		Direction of H.	
				α (degs.)	β (degs.)	γ (degs.)	δ (degs.)
Northolt	9.0	6,900	43.5	+0.3	+0.7	+0.2	0.0
Ongar	36.0	3,800	79.0	+0.2	+0.7	0.0	+0.8
Teddington	11.5	2,600	116.0	—0.3	+0.6	—0.2	—0.1
,, ...	,,	750	400.0	—0.1	+2.1	+0.7	—0.3
,, ...	,,	750*	400.0	—0.1	+2.0	+1.0	0.0
,, ...	,,	450*	670.0	—0.3	+2.7	+0.9	0.0

* Indicates "spark" transmission; all others continuous waves.

In discussing the significance of these results it must be remembered that the limiting accuracy of the apparatus used is, as mentioned above, slightly under one degree for the average of a number of readings as summarised in the table. The results show that in all cases the electric force

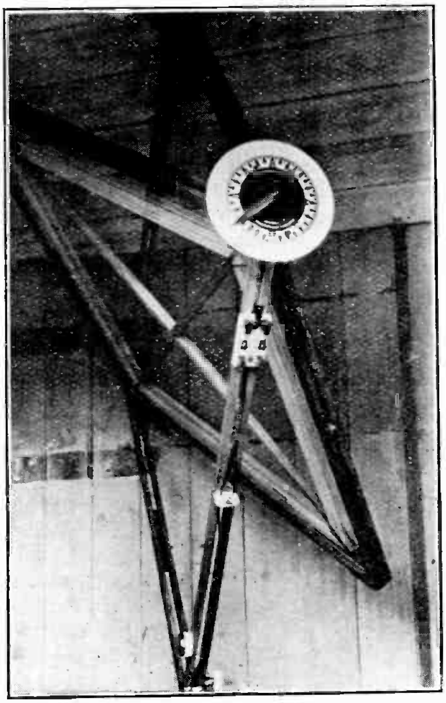


Fig. 7.

lies in the vertical plane of propagation (*i.e.*, $\alpha = 0$) but that it is tilted forward by a small angle (β) the value of which increases as the wave-length is reduced. In a similar manner it is seen that the magnetic force is horizontal and perpendicular to the plane of propagation. Having thus determined the directions of the component forces, it is known that the wave-front, which is the plane containing these forces, is travelling in the direct line from transmitter to receiver, being slightly tilted forward in the direction of propagation.

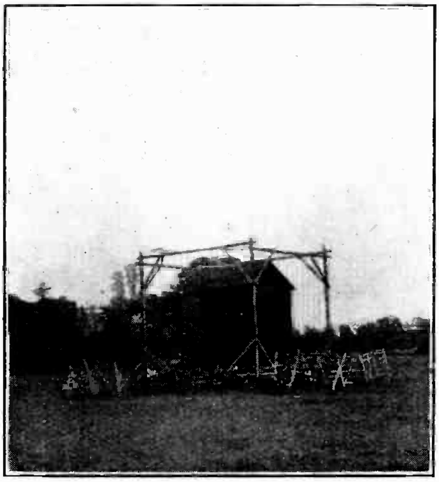


Fig. 8.

Neglecting for the moment this small forward tilt of the electric field, it will be appreciated that the observed directions of the forces are those which would be expected from the brief consideration of the mode of radiation of wireless waves from an aerial given in Section I (*a*) and depicted in Fig. 2 above. In the course of the experiments the aerial at the Teddington transmitting station was altered at intervals to such typical standard forms as: a vertical "cage,"; a *T* aerial; and an inverted "*L*" type with the horizontal portion pointed first to the east and then to the west. None of these arrangements was found to produce any departure of the fields in the waves arriving at the receiver from their normal directions as indicated in Table I. While these undoubtedly represent the usual arrangements of aerials for transmitting purposes it might be asked whether some other arrangement could be constructed which would send off waves with the component fields oriented in a different manner. Partly with this object in view, two special experiments were carried out in this investigation, as described in the next section.

(*d*) *Special experiments in an attempt to obtain a horizontal electric field and a vertical magnetic field in a radiated wave.*

In the first experiment a large aerial tuning inductance, placed with its axis vertical, was used in the manner of a coil transmitter in an attempt to send off a wave with its magnetic field vertical instead of, as usual, horizontal. The inductance consisted of a helix of 42 turns of 6 ft. diameter, and by disconnecting the station aerial and substituting a dummy, a current of 36 ampères was obtained, giving 1 512 ampère turns. Used in this manner, the radiation from the coil as such should have its magnetic field vertical; but the signals received on a frame coil at Teddington at nine miles distance were quite sufficient for accurate direction finding down to one or two degrees, and the arriving waves were found to have a horizontal magnetic field within these limits. The waves were, in fact, exactly similar to those received from the transmitter when the aerial was radiating in the normal manner.

The second experiment involved the entire removal of the usual aerial at Teddington. For transmission purposes on this aerial an earth screen was normally employed, of dimensions 600 ft. × 150 ft., and erected horizontally at a height of about 9 ft. above the ground. This earth screen was cut laterally in two halves, which were joined up to the secondary coil of the spark transmitter to form a horizontal Hertzian oscillator. The natural wave-length of this arrangement was found to be about 800 metres, and by inserting a $1000\mu\mu F$ series condenser this was reduced to the standard wave-length of 450 metres at which adjustment a current of 3-4 ampères could be obtained in the screen. The coupling between primary and secondary coils of the transmitter was made very loose, and, neglecting any effects of capacity connection to earth, the vertical portions of the "aerial" circuits were only one or two feet; even over this length the leads with current in opposite directions were run side by side with a spacing of a few inches. These distances are almost negligibly small by comparison with the dimensions of the screen (600 ft. × 150 ft.), and would appear to justify the assumption that the horizontally polarised radiation would at least be of the same order as that which is vertically polarised (the waves being assumed to be polarised in the direction of the electric force). When transmitting with such an arrangement the direction of the forces of the waves arriving at Slough were found to be similar to those in all previous cases.

In concluding this section, it may be mentioned that the signals received from this "screen aerial" were quite adequate for ordinary communication purposes at a station nearly 100 miles away.

III.—The Effect of the Earth's Conductivity on the Propagation of Electro-Magnetic Waves.

(*a*) *Zenneck's theory.*

In an elementary study of the mode of propagation of waves over the earth's surface it is usual to regard the earth as possessing infinite conductivity. It is well known that in this condition a high frequency electric current travels entirely on the surface, and that its passage along the conductor entails no loss of energy. A very little knowledge of the electrical properties of the materials comprising the earth's crust will show that these are very far from being perfect conductors. From this fact it follows that a high-frequency current will penetrate the conductor to an extent depending upon the frequency and the permeability and resistivity of the conductor.

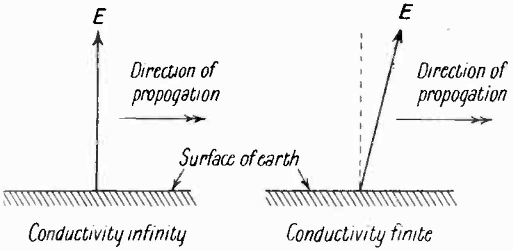


Fig. 9.

It will also be realised that the passage of current through a conductor of appreciable resistance must involve a waste of energy which must ultimately be drawn from the source of the current.

Now in 1907 Dr. J. Zenneck published the results of a theoretical investigation on "The Propagation of Plane Electro-magnetic Waves over a Plane Conducting Surface with reference to Wireless Telegraphy." Zenneck considered the case of a plane electromagnetic wave travelling without divergence over a surface which is the boundary between two media (such as air and earth) of different conductivity and dielectric constant. It was shown that the passage of waves under such conditions necessitates that the electric field shall have an horizontal as well as a vertical component, the relative magnitude of these components depending upon the electric constants of the two media and on the frequency corresponding to the waves. From this condition it follows that the resultant electric field just above the earth's surface is not quite vertical, but is tilted forward slightly in the direction of propagation in the manner depicted in Fig. 9.

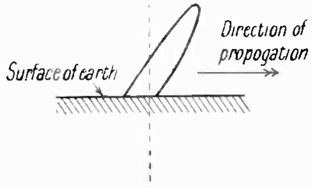


Fig. 10.

Now it was also shown in the theoretical investigation that only by certain combinations of conditions of the two media will the electric field be still represented by a straight line with such a forward tilt. In general, there is a difference of phase between the horizontal and vertical components of the field, so that the resultant electric force just above the earth is of elliptical rotating form, the plane of the ellipse coinciding with the vertical plane of propagation; as represented in Fig. 10.

Except in the case when the ellipse is very broad, the major axis of the ellipse is the more important in considering the effect of the electric field of the arriving wave. It is then evident that if the forward tilt of the axis is very marked, it will be advantageous, when possible, to arrange a receiving aerial to the same angle, in which position the E.M.F. induced therein will be greater than in a vertical aerial. It is therefore important to have some definite knowledge as to the probable value of this forward tilt in some of the cases likely to be met with in practice.

Returning now to the experimental results given in Table I above, it will be appreciated that the angle β measured is the angle by which the major axis of the ellipse departs from the vertical. For the conditions prevailing at the Slough Receiving Station, it is seen that whilst this angle is negligibly small on medium wave-lengths, its value increases to nearly 3° on a wave-length of 450 metres. The slight ellipticity

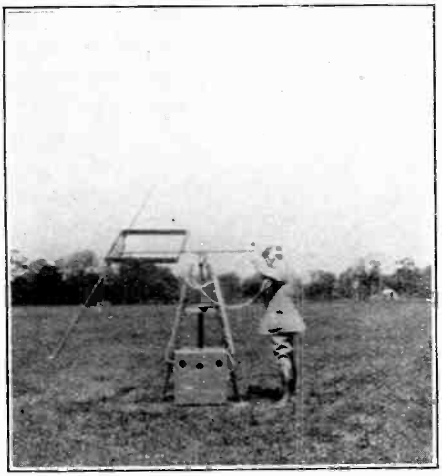


Fig. 11.

of the electric field was indicated in these experiments by the fact that when the Hertzian rod was rotated in the plane of propagation, the signal was never quite extinguished, whereas when rotated in the perpendicular plane, a perfect zero of signal was obtained.

(*b*) *Determination of the conductivity of the earth at Slough.*

In the paper referred to above, Zenneck showed that for a wave travelling over the surface of the earth, the ratio of the magnitude of the horizontal electric force (E_x) to that of the vertical electric force (E_z) is given by the equation

$$\frac{E_x}{E_z} = \sqrt{\frac{nK_1}{1+\frac{n^2K^2}{\sigma^2}}} \quad \ldots \quad (1)$$

where "*n*" is the frequency corresponding to the waves.

K_1 is the dielectric constant of the air.
K ,, ,, ,, ,, ,, ,, earth.
σ ,, ,, conductivity ,, ,, earth.

The two components E_x and E_z differ in phase by an angle "ϕ" where

$$\tan 2\phi = 2\sigma/nK.$$

These equations suffice to determine the ellipse which represents the electric field at the earth's surface due to the arriving waves. Now in the cases where σ is large compared with n, a simple modification of these formulæ gives the inclination of the major axis of the ellipse to the vertical (*i.e.*, β) in the expression:—

$$\tan \beta = \tfrac{1}{2}\sqrt{\frac{n}{\sigma}} \quad \ldots \quad \ldots \quad (2)$$

Referring to the experimental results given in Table I., it is seen that the measured values of β at Slough were 2°.0 and 2°.7 for waves whose frequencies were 400 000 and 670 000 cycles per second respectively. Substituting these in equation (2) above, the mean value of σ obtained is $0{\cdot}75 \times 10^8$. This figure is thus the measured value of the conductivity of the earth at Slough for wireless frequencies in absolute electrostatic units, and it corresponds to a resistivity of 13 300 ohms per cubic centimetre.

A knowledge of this effective conductivity of the earth is so important in the study of wireless wave propagation that the above experiments were repeated at several sites to ascertain the effect of soils of different materials and of varying moisture content, etc.

(*c*) *Extension of conductivity measurements to other parts of the country.*

For this purpose a portable Hertzian rod apparatus was constructed as shown in the photograph, Fig. 11. This apparatus is very similar in design to that installed at Slough as described in (3) above, but on a smaller scale. The straight wire forming the aerial was only 15 ft. long and the height of the supporting tripod only 5 ft. Owing to the reduction in size of the aerial system, the relative magnitude of the energy directly picked up by the tuning circuits, amplifiers, subsidiary apparatus and connecting leads was increased. By careful detailed attention to the screening of the apparatus, however, this difficulty was overcome and the apparatus was found to be quite as accurate as the larger instrument; the instrumental error was certainly less than 1°, and the mean of several readings as usually taken was probably correct to about 0°.5.

With this apparatus, experiments were carried out on some ten different sites on subsoils of as varied a nature as could be be found in the South of England, viz.: clay, sand, chalk, granite and serpentine rock. At several of the sites the measurements were repeated on a second occasion in an attempt to detect possible variations due to change in season or other causes. The results of these measurements carried out from May to September, 1924, are summarised in Tables IIA. and IIB.

These tables show that the effective conductivity of the ground at these various sites lies between 0.14×10^8 and 4.7×10^8, and that the state of the surface of the ground does not appreciably modify this value. Omitting in the first place the results obtained in Cornwall (Table IIB.), it is seen that the conductivities are of the same order as that at Slough, which gives an average representative value for the various sites selected well away from the coast. The actual value of σ at Slough given in Table IIA. is somewhat higher than that obtained in the earlier measurements given in Table I.

This discrepancy was discovered later to be due to the fact that the inclination of the

TABLE IIA.

RESULTS OF MEASUREMENTS ON FORWARD INCLINATION OF ELECTRIC FORCE (ANGLE β) AT VARIOUS PLACES WITH PORTABLE ROD RECEIVER.

Site.	Nature of sub-soil.	State of surface.	Date of Test.	Value of β measured on 2LO 365m.	5HW 450m.	5HW 750m.	Remarks.	Average Value † of σ obtained from β.
				Deg.	Deg.	Deg.		
Stoke Common, Bucks ..	Clay	Very wet	8.5.24	3.1	2.1	1.3		1.3×10^8
Walton Heath, Surrey ..	Sand	Moist	22.5.24	3.8	2.8	2.4		0.6×10^8
" " " ..	"	Very dry	8.7.24	3.3	2.8	2.1	After 4 weeks hot, dry weather	0.7×10^8
Chesham Bois, Bucks	Chalk	Wet	5.6.24	1.6	1.2	0.7	After 24 hours continuous rain.	4.7×10^8
" " "	"	Very dry	10.7.24	1.5	1.5	0.9	After 4 weeks hot, dry weather.	3.2×10^8
Marlborough Downs, Chisledon, Wilts.	"	" "	1.7.24	—	1.2	0.9	Measurements confirmed on longer waves 2 600 to 6 900m. β diminishing to 0.4 on latter wave	4.0×10^8
Slough, Bucks	Clay	Moist	3.7.24	2.4	1.8	1.3		1.5×10^8
" "	"	Dry	7.7.24	2.0	1.7	1.1		2.1×10^8
Princes Risborough, Bucks ..	Chalk	Dry	15.7.24	3.5	3.6	0.9	Taken on sloping ground.	1.6×10^8
" " " ..	"	Moist	5.8.24	1.7	15	1.4	On level site.	2.2×10^8
The Sands, Farnham, Surrey	Sand	Dry	17.7.24	2.1	2.1	1.4		1.5×10^8
Teddington, Middlesex ..	"	"	24.7.24	1.7	1.4	0.7		4.2×10^8

TABLE IIB.

RESULTS OF MEASUREMENTS ON FORWARD INCLINATION OF ELECTRIC FORCE (ANGLE β) AT VARIOUS PLACES WITH PORTABLE ROD RECEIVER.

Site.	Nature of sub-soil.	State of surface.	Date of test.	Value of β measured on 5WA 351m.	6BM 385m.	FFU & GLD 600m.	Remarks.	Average value † of σ obtained from β.
				Deg.	Deg.	Deg.		
The Lizard, Cornwall	Serpentine	Dry	9.9.24	1.9	1.5	—	On barren ground with outcropping rock, 1½ mile from coast.	2.4×10^8
" " "	"	"	10.9.24*	5.6	5.9	1.9	On rocky cliff path, ½ mile from coast.	0.51×10^8
Land's End, Cornwall ..	Granite	"	11.9.24*	7.1	—	5.3	On rocky cliffs, 200 yards from coast.	0.17×10^8
" " " ..	"	"	" *	5.7	7.4	6.7	As above ; 100 ft. nearer coast.	0.14×10^8

* NOTE.—The ground at the sites chosen at the Lizard and Land's End on 10th and 11th September was of very broken surface and varied nature. This, together with the proximity to the cliffs, probably accounts for the relatively large discrepancies in some of the results. In each case it was noticed that a slight shift in position of the apparatus resulted in a change in the values obtained, and in several positions the electric and magnetic fields were subject to appreciable sideways inclinations.

† For comparison purposes, it may be pointed out that the conductivity of sea water is of the order of 10^{10}

electric field to the vertical varied in different parts of the field, as shown by the portable apparatus, and is evidently due to some local cause (such as the masses of trees in the vicinity, which has been previously shown to give rise to errors in apparent bearings of certain transmitting stations). This variation is not, however, large enough to affect any of the conclusions drawn from these conductivity measurements.

For comparison purposes it is interesting to note that the previously published values of the conductivities range from 10^9 to 10^6 or less for specimens of moist and dry earth, sand or clay ([5]). The more uniform values obtained in the present measurements are probably due to the fact that for wireless wave propagation the effective conductivity is not solely determined by the condition at the immediate surface. In England, even in the hottest summer weather, it is doubtful if the soil ever becomes thoroughly dry to a depth of more than a few feet, and it is the moist soil below which will in this case determine the forward inclination of the wave-front. Also, as Hack([6]) has previously shown, the presence of a layer of ground water at a depth of a fraction of a wave-length in a poorly-conducting soil will almost entirely annul the forward tilt of the wave-front which would otherwise be set up.

Referring now to the measurements made in Cornwall, as recorded at end of Table IIB., it is seen that in the first of these, at the Lizard, the conductivity obtained is similar to that at Slough. It is undoubtedly explained by the fact that the highly insulating serpentine rock sub-soil was mostly covered by a layer of one or two feet of surface soil with a moderate moisture content. Only at intervals over the surface was the rock projecting through the upper soil. The currents due to the arriving waves are unable to penetrate this comparatively highly conducting soil, which thus serves to "screen," as it were, the poorly conducting rock beneath. As the coast is approached, the depth of the soil layer decreases, and within a quarter of a mile of the edge of the cliffs the measurements show an appreciable drop in the conductivity values. For these latter measurements it was extremely difficult to find suitable sites, and the discrepancies occurring in the values of β measured on the different wave-lengths are considered to be due to the uneven rock surface, the consequently varying depth of surface soil, the stratification of the rocks, and the trapping of rain water in pools in the rock surface below the soil.

It is interesting to record here that during these measurements justification was obtained for the assumption that the inclination of the wave-front is related to the normal to the ground surface at the receiver, whereas the angles measured on the apparatus were related to the true vertical. At most places a suitable horizontal site could be obtained, but it was sometimes necessary to work on slightly sloping ground and make the necessary corrections for the direction and magnitude of the slope (usually less than 1°). On one occasion, however, a site was intentionally selected on the side of a hill sloping at about 16°, but after correcting for this, it was found that the values of β agreed with those measured on a level site in the same neighbourhood.

(*d*) *Conclusions.*

It is thus seen, from the experiments described in this section that the use of a Hertzian rod receiver for determining the direction of the electric field in the wave from a neighbouring transmitting station, affords a convenient means of measuring the earth's conductivity at wireless frequencies. Although at medium wave-lengths the angles to be measured are comparatively small, at shorter waves in the region of 300 to 600 metres the angle of departure of the electric field from the vertical is about 2° or 3°. Using the apparatus under these conditions values of the earth's conductivity have been obtained which are considered to be more accurate than those hitherto available for the study of the propagation of wireless waves over the earth's surface. The mean value of the conductivity as measured for typical soils and surface conditions encountered in England, is approximately 2×10^8 electrostatic units, corresponding to a resistivity of 5 000 ohms per cc.; whereas the resistivity of sea-water is from 25 to 100 ohms per cc., depending upon its exact composition.

As a practical conclusion, it is seen that in this country at any rate, the departure of the electric field from the vertical is so small that the loss of E.M.F. induced in a vertical aerial is inappreciable.

[5] Ref. 6, p. 623.
[6] J. ZENNECK.—Wireless Telegraphy, English Translation, 1915, pp. 260-2.

IV. Wave-Front Measurements on Waves from Distant Transmitting Stations.

(a) The Heaviside Layer theory of the propagation of waves.

In the previous sections the manner in which wireless waves travel over the earth's surface at a distance of a few miles from the transmitter, has been demonstrated. It was shown that apart from the effects of local obstacles, the waves travel in horizontal straight lines, since a frame coil direction-finder indicates the true bearing of the transmitter: and that whatever shape or arrangement the transmitting coil or aerial may take, the magnetic field of the arriving wave is always horizontal and the electric field is tilted forward slightly in the direction of propagation by an amount depending upon the wave-length and the earth's conductivity. Now when the distance of transmission exceeds about fifty miles, the well known phenomena of fading of signals and variations in the apparent directions of arrival of the waves are experienced, and the above simple theory of wave propagation has to be augmented to explain these occurrences. To a limited extent both phenomena can be explained by the well known Heaviside layer theory with the modifications proposed by Dr. W. H. Eccles in 1912 and more recently elaborated by Sir Joseph Larmor, but adequate experimental evidence on the existence of the layer is still lacking.

On this theory, the direct wave travelling over the earth's surface is supposed to be accompanied at appreciable distances by a second wave or waves which were first projected from the transmitter into the upper portions of the earth's atmosphere, and then deflected sufficiently in the plane of propogation to allow them to reach the earth again at a distance. It will thus be evident that on this theory part of the energy at the receiver may be arriving at an appreciable angle of elevation to the horizontal, and the two or more waves will combine to give a resultant effect on the receiver. Owing to the varying absorption of the earth's atmosphere at different times of the day and night, however, the intensity of the downcoming wave may vary between wide limits, and its phase relative to that of the direct horizontal wave may also vary, due for example to changes in the height of the deflecting layer. Due to this phase variation, the forces of the downcoming wave may assist or oppose those of the direct wave, and this together with the variation in strength of the former may be the explanation of the variation in strength of the resultant fields commonly experienced as "fading." If also the plane of polarisation of the downcoming wave is rotated by any means, a possible explanation is obtained of the erratic manner in which the apparent bearings of distant transmitting stations vary as observed on direction-finders. This extension of the theory was first suggested by T. L. Eckersley in 1921.

(b) Arrival of downcoming waves and boundary conditions at the earth's surface.

Now, in considering the effects of a downcoming or incident wave at a receiver situated on the ground, *i.e.*, at the surface of separation between a conducting and a non-conducting medium, the effect of any reflected wave from the surface of the conductor must be taken into account. It is evident that if the earth were a perfect conductor, the reflected wave would be equal in amplitude to the incident wave, and a closer consideration of the case shows that the two waves would interfere at the surface in such a way as to tend to eliminate the horizontal component of the electric field and the vertical component of the magnetic field. Now, the experimental arrangements described in Section II. serve to determine the directions of the electric and magnetic forces which result from all waves arriving at the receiver. It is thus clear that if the earth is of sufficiently high conductivity such methods would be useless to detect downcoming waves at the earth's surface, since the resultant fields produced would be indistinguishable from those of an horizontally-propagated wave. By application of the electro-magnetic equations which apply in such a case, it can be shown that with the value of the earth's conductivity as determined above, the departure of the directions of the electric and magnetic forces from their normal directions for short-distance transmission is very small in the cases likely to be met with in practice, and that the angles concerned only become easily measurable for very short wave-lengths.

(c) Experiments on more distant stations.

In order to confirm the validity of these deductions a series of systematic measurements of the directions of the electric and magnetic fields in waves arriving from stations at appreciable distance, is being carried out at Slough. Table III. gives a summary of the results obtained over a period of seven months on the transmissions from various stations on medium wave-lengths.

apparatus for individual readings. It was frequently noticed during the observations on the frame coil apparatus, that the minimum obtained with the coil vertical was blurred, a common occurrence at night-time in wireless direction-finders. On all occasions, however, the minimum with coil in the horizontal position was sharp and well-

TABLE III.

SUMMARY OF RESULTS OF SIMULTANEOUS DIRECTIONAL MEASUREMENTS OF ELECTRIC AND MAGNETIC FIELDS AT SLOUGH.

Transmitting Station.	Distance.	Wave-length.	Frequency	Extreme Readings over a period of 7 months.				β calculated from $\sigma = 10^8$.
				α	β	γ	δ	
	Miles.	Km.	kcper sec.	Deg.	Deg.	Deg.	Deg.	Deg.
Nantes	302	9.0	33.3	+0.1 —1.3	0.0 —0.5	— 0.9 — 1.7	—0.3 —0.7	+0.5
Leafield	48.5	8.7	34.5	+1.1 —0.7	+0.5 —1.3	+12.0 —11.2	+1.0 —0.7	+0.5
Tours	165	6.8	44.2	0.0 —1.0	+1.1 0.0	+ 0.6 — 1.4	+0.3 —1.0	+0.5
Konigswusterhausen	608	5.3	56.6	0.0 —0.3	+1.5 0.0	+ 3.1 — 9.7	+1.0 —0.3	+0.6
Nauen	576	4.7	63.8	+0.5 —1.0	+1.5 +1.0	+ 9.8 — 5.7	+0.7 0.0	+0.6
Ongar (GLO) ..	36	4.4	68.2	+0.5 —0.5	+1.5 —0.7	+ 4.2 — 6.3	+0.8 —0.3	+0.8
,, (GLB) ..	36	3.8	79	+1.0 —1.0	+1.5 0.0	+ 2.3 — 2.5	+1.3 0.0	+0.8
Paris (FL)	221	2.6	116	0.0 —0.5	+1.0	+ 0.1	0.0 —0.1	+0.9

Many of the observations summarised above were purposely made on stations and at periods which experience had shown to be most likely to produce variations in γ (*i.e.*, directional errors or night effect) and it will be seen that variations as large as 23° were obtained. Yet the results show that on these occasions there were no corresponding variations in the values of α, β, and δ. In fact, throughout the whole series of observations and over the entire range of wave-lengths the values of α, β and δ do not depart from zero by more than 1.5°, a value which is inappreciably greater than the limit of accuracy of the defined, this indicating that the magnetic field was of elliptical form in a horizontal plane only.

Again referring to Table III., many of the stations are sufficiently distant for the phenomena of long-distance transmission to enter, and according to the Heaviside-layer theory most of the energy would be coming downwards from the layer. Yet in no case do the values of β differ by an appreciable amount from the theoretical values as recorded in the last column of the table; these values having been calculated from the conductivity of the ground at Slough as found experimentally.

(d) Conclusions.

The above table of results is thus seen to support the deductions made in Section IV. (*b*) that waves arriving from appreciable distances and under conditions which may give rise to variations in apparent bearings as well as in signal intensity are not easily distinguishable from horizontally propagated waves from neighbouring stations by means of directional measurements of the electric and magnetic fields. As far as they have gone, therefore, the experiments cannot be considered as evidence for or against the existence of downcoming waves as required by the Heaviside-layer theory. A consideration of the theoretical analysis upon which these conclusions are based shows that in order to obtain positive results with this directional method of attacking the problem it will be necessary to either :—

(i.) Improve the accuracy of the apparatus and then repeat the experiments at Slough.

(ii.) Repeat the experiments with the existing apparatus but on the ground of lower conductivity, if it is practicable to find this.

(iii.) Repeat the experiments on the same site (at Slough) and with the same apparatus but on shorter wave-lengths.

All these possible lines of advance have their inherent difficulties, but they are all being pursued experimentally with the advantage of the more definite knowledge of the nature of the problem gained from the experiments described in this paper.

The R.I. Variable Condenser.

A RECENT product of Radio Instruments, Ltd., of 12, Hyde Street, New Oxford Street, W.C.1., is a well-made and efficient variable condenser. It is of the so-called " square law " variety, designed to give a straight line wave-length curve.

The vanes are of stout brass, and the end plates are of best quality ebonite, ¼ in. thick and 3½ ins. in diameter. The bearings for the moving plates run in substantial bushes, and a special leaf spring of phosphor-bronze makes contact to the moving spindle and at the same time ensures an even pressure on it, so that the movement of the plates is very smooth. A single plate vernier is provided, and stops are provided for the moving plates in the shape of large ebonite washers between the fixed plates.

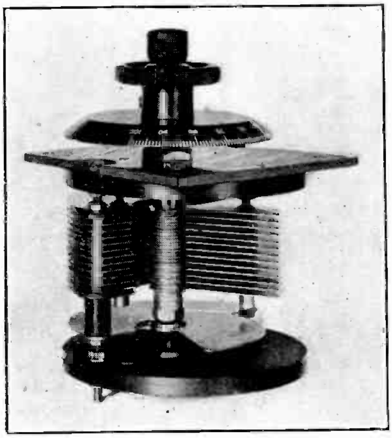
Attached to the upper end plate is a brass plate 3⅜ ins. square by ⅛ in. thick, which makes contact with the bush to the moving spindle and thence with the moving plates themselves. The effect of this is to diminish greatly hand-capacity effects when operating the knob and dial.

The condenser is arranged for the usual one-hole fixing, if desired, but owing to the fact that it is rather heavy, it is probably desirable to make use of the holes provided in the brass plate for fixing purposes. The knobs and dial are of ebonite, polished and engraved, and are fixed by means of grub screws. Altogether, the condenser is a mechanically sound job.

Electrically, it was found as good as it was mechanically. The condenser we tested was rated at .0005μF. The zero capacity was found to be remarkably low, being only 6.7$\mu\mu$F.

The capacity of the vernier was .000 03μF, and the total capacity was .000 59 μF, which is well over the rated capacity.

The condenser is made in two capacities : .0005μF and .00025μF, the prices being 24s. and 22s. 6d. respectively.



The R.I. Variable Condenser.

We understand that a new geared model is now being made, in which is incorporated a friction gear giving a reduction of 11 to 1. This should prove of great use for fine tuning purposes.

The Design of Inductance Coils having a Rectangular Winding Section.

By S. Butterworth, M.Sc. **[R382**

THE mathematical formulæ for calculating the self-inductance of cylindrical coils of rectangular winding section are very complicated and, as they stand, are of little use to the designers of such coils. To help the computation, various writers have prepared curves by means of which it is possible to determine the inductance of a coil of known dimensions and of known total turns to an accuracy of about one per cent. For more accurate computation a set of tables prepared by Grover (*Scientific Paper, Bureau of Standards*, No. 455, 1922) may be employed.

1. Let the coil of which the inductance is required have a mean diameter d, a winding length b, and a winding depth c. Also let the whole number of turns in the coil be n. If we denote the ratios $\frac{c}{d}$ and $\frac{b}{c}$ by X and Y, then the formula for the inductance L may be written—

$$L = n^2 dQ \quad \quad .. \quad .. \quad (1)$$

in which Q depends only on the shape of the coil; that is, it is a function of the two ratios X and Y. The tables of Grover and the curves of other writers enable the shape factor Q to be determined quickly.

Now formula (1) is very suitable for a coil already in existence, but what the designer usually knows initially is the inductance he desires, and he has to seek the number of turns and the diameter of coil that will give him this inductance. Usually the diameter of the wire and the spacing of the turns are fixed by considerations of current-carrying capacity and effective resistance, while the shape of the coil (fixing X and Y) depends upon the purpose of the coil.

It is preferable therefore to regard the inductance L, the turns (t)[1] per centimetre length, and the shape (X and Y) as the known quantities, while the absolute size of the coil is the quantity sought.

2. In order to use formula (1) when L, t, X and Y are given, we must remember that

$$n = t^2 cb = t^2 c^2 Y \quad (2)$$

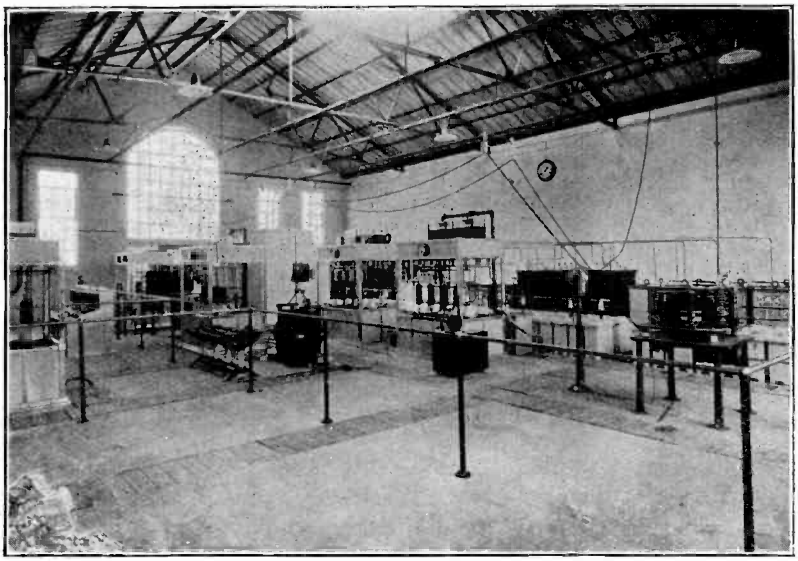
while

$$d = \frac{c}{X} \quad (3)$$

so that

$$L = \frac{t^4 c^5 Y^2 Q}{X} \quad (4)$$

This formula involves a rather



An extremely interesting view of the valve-room at Daventry.

[1]Where the number of turns per cm. in each layer is not the same as the number of layers per centimetre, t is found as follows: let t_1 be the turns per cm. in each layer, and t_2 the layers per cm. Then:

$$t = \sqrt{t_1 t_2}$$

long arithmetical computation to determine c. The formula may, however, be written—

$$c = \frac{AB}{C} \quad \ldots \quad \ldots \quad (5)$$

in which

$$A = L^{\frac{1}{5}} \quad \ldots \quad \ldots \quad \ldots \quad (6)$$

$$B = \frac{1}{t^{\frac{2}{5}}} \quad \ldots \quad \ldots \quad \ldots \quad (7)$$

$$C = \left(\frac{Y^2 Q}{X}\right)^{\frac{1}{5}} \quad \ldots \quad \ldots \quad (8)$$

A depends only on the inductance, B on the turns per centimetre, and C is a shape factor depending on the two ratios X and Y. Further, by the introduction of suitable constants, we can in nearly all cases confine the values of A, B and C to numbers lying between one and ten, so that when tables for A, B and C have been computed the operation for determining the size c is reduced to a single slide-rule setting, and no mental effort is necessary in fixing the decimal point.

Again, since formula (5) may be written—

$$A = \frac{cC}{B} \quad \ldots \quad \ldots \quad \ldots \quad (9)$$

and L may be read off immediately from the table connecting L with A, the new computation formula can be used as readily as formula (1) for the determination of the inductance of coils of known dimensions.

3. The tables given below have been computed with the help of Grover's published tables referred to above.

TABLE I.

INDUCTANCE FACTOR A.

Milli-henries.	A.	Milli-henries.	A.	Milli-henries.	A.	Henries.	A.	Henries.	A.
0.1	1.149	1	1.821	10	2.885	0.1	4.573	1	7.248
0.2	1.319	2	2.091	20	3.315	0.2	5.213	2	8.326
0.3	1.431	3	2.268	30	3.594	0.3	5.697	3	9.029
0.4	1.516	4	2.402	40	3.807	0.4	6.028	4	9.554
0.5	1.585	5	2.512	50	3.981	0.5	6.310	5	10.000
0.6	1.644	6	2.605	60	4.129	0.6	6.544	6	10.372
0.7	1.695	7	2.687	70	4.258	0.7	6.749	7	10.697
0.8	1.741	8	2.759	80	4.373	0.8	6.931	8	10.985
0.9	1.783	9	2.825	90	4.478	0.9	7.097	9	11.247
1.0	1.821	10	2.885	100	4.573	1.0	7.248	10	11.487

NOTE.—If L is less than 100 microhenries, calculate for 100 000 L and then divide the size by 10; if L is greater than 10 henries, calculate for $\frac{L}{100\,000}$ and then multiply the size by 10.

TABLE II.

TURNS FACTOR B.

t = turns per centimetre length, and is the reciprocal of the mean distance apart of neighbouring turns.[2]

t	B	t	B	t	B	t	B
1	10.000	9	1.724	17	1.037	25	0.761
2	5.744	10	1.585	18	0.990	26	0.736
3	4.152	11	1.469	19	0.948	27	0.716
4	3.298	12	1.370	20	0.910	28	0.695
5	2.760	13	1.285	21	0.875	29	0.676
6	2.385	14	1.211	22	0.843	30	0.658
7	2.108	15	1.146	23	0.814	31	0.641
8	1.895	16	1.088	24	0.787	32	0.625

[2] See previous note.

TABLE III.

Shape Factor C.

Flat coils, that is coils whose winding depth c is greater than the winding length b. (See Fig. 1.)

Formula for length of side c in centimetres is :—

$$c=\frac{AB}{C} \qquad X=\frac{c}{d} \qquad Y=\frac{b}{c}$$

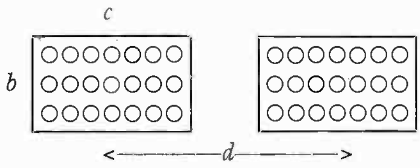


Fig. 1.

X	0.025	0.05	0.1	0.2	0.4	0.6	0.8	1.0
Y								
0.1	1.864	1.569	1.311	1.086	0.887	0.781	0.711	0.662
0.2	2.450	2.061	1.722	1.423	1.158	1.017	0.925	0.860
0.3	2.870	2.413	2.014	1.662	1.350	1.182	1.073	0.996
0.4	3.209	2.696	2.248	1.853	1.500	1.312	1.189	1.102
0.5	3.498	2.937	2 446	2.013	1.626	1.419	1.283	1.188
0.6	3.751	3.147	2.619	2.152	1.735	1.511	1.365	1.262
0.7	3.978	3.335	2.773	2.270	1.830	1.592	1.435	1.326
0.8	4.184	3.506	2.912	2.387	1.911	1.663	1,498	1.383
0.9	4.374	3.663	3.040	2.489	1.993	1.728	1.554	1.434

TABLE IV.

Shape Factor C.

Solenoidal coils, that is coils whose winding length b is greater than the winding depth c. (See Fig. 2.)

Formula for length of side b in centimetres is :—

$$b=\frac{AB}{C} \qquad X=\frac{c}{d} \qquad Y=\frac{b}{c}$$

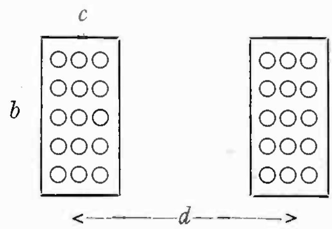


Fig. 2.

X.	0.025	0.05	0.1	0.2	0.4	0.6	0.8	1.0
1/Y								
0.1	1.020	0.829	0.659	0.510	0.386	0.324	0.286	0.261
0.2	1.622	1.335	1.081	0.854	0.656	0.554	0.491	0.449
0.3	2.114	1.815	1.430	1.142	0.886	0 753	0.669	0.613
0.4	2.546	2.117	1.736	1.397	1.092	0.932	0.830	0.761
0.5	2.937	2.446	2.014	1.627	1.281	1.096	0.978	0.898
0.6	3.298	2.751	2.270	1.841	1.455	1.250	1.118	1.027
0.7	3.636	3.037	2.510	2.041	1.619	1.394	1.249	1.149
0.8	3.956	3.307	2.737	2.230	1.775	1.531	1.373	1.264
0.9	4.260	3.563	2.952	2.410	1.923	1.662	1.492	1.374
1.0	4.550	3.809	3.159	2.582	2.064	1.787	1.605	1.480

Note.—Whether we are dealing with flat or solenoidal coils it is the *greater* of the two sides b, c, which is determined by the formula.

4. Examples.

(1) Let a coil of 100 millihenries be required wound with No. 22 D.C.C. wire and having a square winding section whose side is 0.4 times the mean diameter of the coil. From Table I. the inductance factor A is 4.573. The diameter of bare No. 22 wire is 0.71 mm., so that, allowing 0.29 mm. for insulation, the overall diameter of the wire is 1 mm. which gives 10 turns per centimetre if the coil is closely wound. Hence from Table II. the turns factor B is 1.585. From Table IV. the shape factor C is 2.064. Therefore the side of the winding section must be

$$\frac{4.573 \times 1.585}{2.064} = 3.512 \text{ cms.}$$

The mean diameter of the coil must be

$$\frac{3.512}{0.4} = 8.78 \text{ cms.}$$

For the dimensions of the coil-former we therefore have

Internal diameter $8.78 - 3.51 = 5.27$ cms.
External diameter $8.78 + 3.51 = 12.29$ cms.

The area of the winding section is 15.67 sq. cms., and as there are 100 turns per square centimetre, the number of turns required is 1 567. In practice one would wind, say, 1 600 turns and adjust experimentally.

(2) Let a flat coil of 1 henry be required having the following dimensions :—

$b = 2.5$ cms. ; $c = 5$ cms. ; $d = 10$ cms.

The number of turns is to be found.

From Table I., $A = 7.248$. Since $X = 0.5 = Y$, we have from Table III. $C = 1.52$, and since c is 5 cms., $B = \frac{5 \times 1.52}{7.25} = 1.048$. Therefore, from Table II. the turns per centimetre are 16.8, and the total turns $(16.8)^2 \times 5 \times 2.5 =$ 3 530.

5. Most Economical Shape of Coil.

It is clear from formula (1) that we may wind a coil of considerable inductance with a very small weight of copper by using very thin wire with the turns closely packed, but such a coil would possess a large direct current resistance, and with alternating currents, the close packing would bring about considerable eddy current losses in the copper. We will suppose, therefore, that the diameter of the wire and the spacing of the turns is fixed by considerations such as given above, and our problem is to determine the shape of coil which will give the requisite inductance with the smallest length of wire. This coil would clearly have the smallest direct current resistance and be the most economical in copper.

The diameter of the wire being fixed, the length of wire is proportional to the volume of copper in the coil ; and, the spacing of the turns being fixed, the copper volume is proportional to the volume of the winding space. This volume is given by—

$$V = \pi bcd = \frac{\pi c^3 Y}{X} = \frac{\pi b^3}{Y^2 X} \quad .. \ (10)$$

Using the formulæ of Tables III. or IV. to express c or b in terms of A, B and C, we have, for flat coils—

$$V = \frac{\pi (AB)^3 Y}{C^3 X} \quad .. \quad .. \ (11)$$

and for solenoidal coils—

$$V = \frac{\pi (AB)^3}{C^3 Y^2 X} \quad .. \quad .. \ (12)$$

Now, for a given inductance A is fixed, and for a given diameter of wire and spacing B is fixed, so that to determine the best shape of coil we must calculate $\frac{\pi Y}{C^3 X}$ for various shapes of flat coils, and $\frac{\pi}{C^3 Y^2 X}$ for various shapes of solenoidal coils, and find for what shape of coil this quantity is the least.

The results for three shapes of winding are given in Table V.

The first shape is that for a flat coil the winding depth of which is twice its winding length ($Y = 0.5$) ; the form ranges from a hoop-like coil whose mean diameter is 40 times the winding depth to a coil wound full from the centre as we proceed from left to right across the table. The most economical coil of this type is one whose winding depth is one-half the mean diameter or one-third the overall diameter. The volume of the winding space for this coil is $= 0.91(AB)^3$.

For the second shape (a coil of square winding section) the best case is when the side of the winding section is one-third the mean or one-quarter the overall diameter, and then $V = 0.88(AB)^3$.

The third shape, a solenoidal coil of which the winding length is twice its winding depth, should be proportioned so as to make the winding depth one-quarter the mean diameter or one-fifth the overall diameter ; and then $V = 0.91(AB)^3$. Of the three shapes the square-sectioned coil is the most economical, but it is clear from the table that we have considerable latitude without undue waste of copper.

TABLE V.

Values of *G*.

Volume of winding space $= G(AB)^3$.

X	0.025	0.05	0.1	0.2	0.4	0.6	0.8	1.0
Y								
0.5	1.47	1.24	1.07	0.96	0.91	0.91	0.93	0.94
1.0	1.33	1.14	1.00	0.91	0.89	0.92	0.95	0.97
2.0	1.24	1.07	0.96	0.91	0.93	0.99	1.04	1.08

TABLE VI. (*see p.* 755).

Values of *G'*.

Overall volume $= G'(AB)^3$.

X	0.025	0.05	0.1	0.2	0.4	0.6	0.8	1.0
Y								
0.5	15.4	6.85	3.25	1.74	1.12	0.97	0.95	0.94
1.0	13.9	6.30	3.03	1.65	1.10	0.98	0.97	0.97
2.0	13.0	5.90	2.91	1.65	1.14	1.06	1.06	1.08

The most compact coil is clearly turning out to be one which is wound full from the centre and of the "flat" type. The values of *G'* for fully wound coils ($X = 1$) are—

Y	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
G'	1.08	0.99	0.95	0.94	0.94	0.94	0.94	0.95	0.96	0.97

TABLE VII. (*see p.* 755).

Coefficients of Coupling between Coaxial Flat Coils in End Contact.

X	0.025	0.05	0.1	0.2	0.4	0.6	0.8	1.0
Y								
0.1	0.97	0.96	0.95	0.93	0.90	0.87	0.86	0.85
0.2	0.93	0.92	0.89	0.87	0.82	0.79	0.75	0.73
0.3	0.91	0.89	0.86	0.82	0.75	0.71	0.67	0.65
0.4	0.88	0.86	0.83	0.77	0.68	0.64	0.59	0.56
0.5	0.86	0.83	0.79	0.72	0.65	0.58	0.53	0.50

Note.—$X = \frac{c}{d}$ $Y = \frac{b}{c}$ and they refer to *one coil.*

TABLE VIII.

Values of *H* in Formula (16).

X	0.025	0.05	0.1	0.2	0.4	0.6	0.8	1.0
Y								
0.1	1.98	1.66	1.44	1.23	1.21	1.20	1.19	1.18
0.2	1.79	1.51	1.31	1.18	1.14	1.15	1.17	1.20
0.3	1.74	1.44	1.28	1.13	1.13	1.16	1.22	1.24
0.4	1.64	1.41	1.23	1.16	1.17	1.22	1.28	1.33
0.5	1.60	1.38	1.24	1.17	1.18	1.27	1.36	1.43

6. Most Compact Coil.

Sometimes economy in space is more desirable than economy in copper. In this case, we require to find the coil that will have the minimum overall volume when wound to have a given inductance with wire of given diameter and given spacing of turns. The overall volume is—

$$V' = \frac{\pi b(c+d)^2}{4} = \frac{V(1+X)^2}{4X}$$

Thus the condition for minimum overall volume is found by multiplying all the G factors of Table V. by $\frac{(1+X)^2}{4X}$ and finding which of these products is the least.

The results are given in Table VI. (p. 754).

There is therefore practically nothing to choose between fully wound coils whose length lies between 0.2 and 0.4 times the overall diameter.

7. Mutual Inductance Between Cylindrical Coils in End Contact.

The tables given above for the calculation of self-inductance may readily be adapted for the design of mutual inductances. Let the two coils be of similar shape and size and let them be coaxial and in end contact.

Let L_1, L_2 be the self-inductances of the two coils and M the mutual inductance. Since the self-inductances are proportional to the square of the turns and the mutual inductance to the product of the turns in either coil, the coefficient of coupling (k) which is defined by—

$$k^2 = \frac{M^2}{L_1 L_2} \quad (13)$$

is independent of the turns and may therefore be calculated for equal coils. In this case, if L' is the total self-inductance of the two coils when in series and helping, we have—

$$L' = 2(L + M) \quad (14)$$

and therefore

$$k = M/L = \frac{L'}{2L} - 1 = \frac{2Q'}{Q} - 1 \quad .. (15)$$

when the values of L' and L as given by formula (1) are used. In this formula, Q' is the shape factor for the two coils in series and Q the shape factor for either coil separately. From formula (15) Table VII. of coefficients of coupling has been calculated (see p. 754).

To determine the size of coils required to produce a given mutual inductance, when the coils are to be of equal turns, divide the mutual inductance by k, thus obtaining the self-inductance of either coil; and then calculate the size as in sections 3 and 4. For coils of unequal turns divide M also by the ratio of secondary to primary turns to obtain the primary self-inductance.

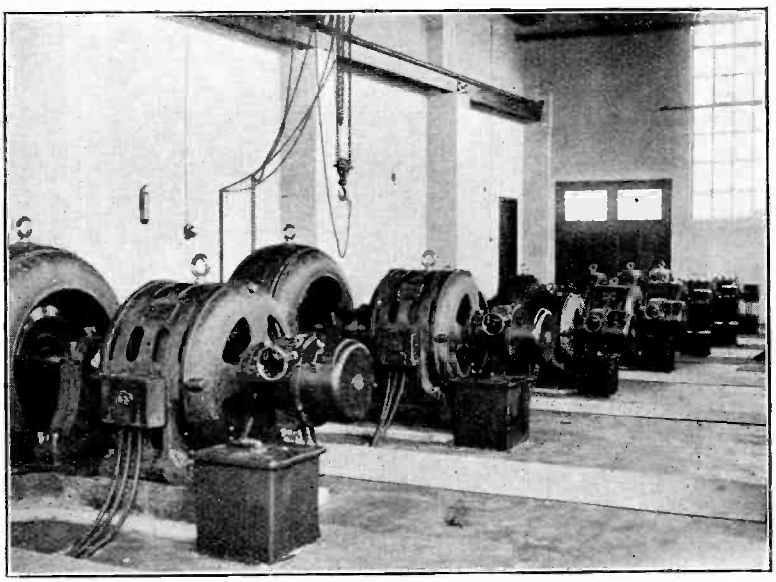
As in the case of self-inductance, we may determine the most economical pair of coils to give a fixed mutual inductance. If V is the volume of the winding space in either coil—

$$V = H(AB)^3 \quad .. \quad .. (16)$$

where $H\left(\equiv \frac{G}{k^{\frac{3}{2}}}\right)$ is given by Table VIII.

The most economical pair of coils is that for which $X = 0.3 = Y$.

The Author is indebted to the Admiralty for permission to publish the tables given in this article.



A view of the Machine Room at Daventry, where are installed three 70 kW motor alternators (two of them are visible in the foreground above); two 25kW motor alternators ; and three 10 kW motor generators.

Distortion in Wireless Telephony, and Related Applications of the Cathode Ray Oscillograph.

By E. K. Sandeman and N. Kipping. **[R135-R388**

Summary.

THIS article is divided into two main parts. The first part discusses generally the causes of distortion in wireless telephony; after various types of distortion are defined the chief sources of each type are enumerated and discussed. In the second part, the application of the cathode ray oscillograph to the study of various forms of distortion and related work is dealt with; photographs are used to show the kind of results obtained, and their interpretation is explained.

Appendices are added to deal with (I.) A mathematical explanation of the process of modulation and detection; and (II.) A description of a linear time base. There is also a note describing the cathode ray oscillograph, which is appended to the end of this part. The article concludes with a bibliography.

Introductory.

The purpose of this article is two-fold—to discuss generally the causes of distortion in wireless telephony, and to show in what way some of the effects of distortion may be studied with the Cathode Ray Oscillograph. It is not to be understood that this type of oscillograph is considered to be the only, or necessarily the best means of making such a study in all cases, but it is in itself of very considerable interest, and is for that reason being dealt with. Its special interest lies, perhaps, in its ability to present visual results, as will be seen by reference to the note on page 765, in which the oscillograph is briefly described for the benefit of those who are not already familiar with its function.

DISTORTION IN WIRELESS TELEPHONY.

Distortion in the reproduction of speech or of music is primarily of two kinds, which we shall term "frequency distortion" and "asymmetric distortion" respectively. Of other kinds of distortion of less frequent occurrence or of a less troublesome nature, the most important we shall term "sound persistence." These various kinds of distortion are dealt with in the article not in order of importance, but as they conveniently follow one another by their nature.

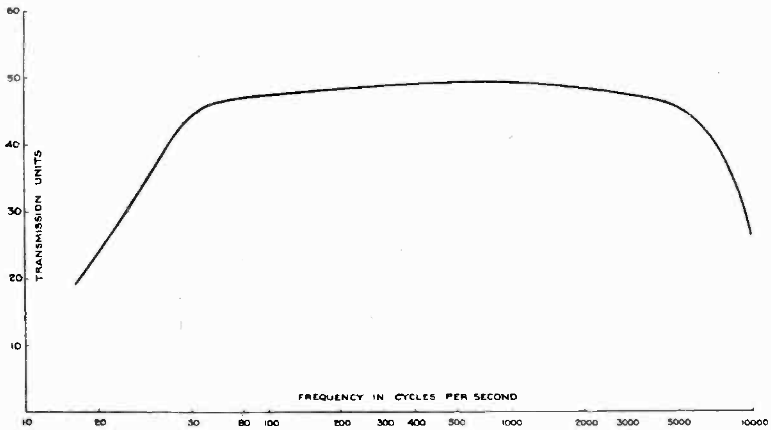


Fig. 1. *Characteristic of amplifier employing tuned transformers.*

Frequency distortion is the name which has been given to the type of distortion in which different frequencies are produced with unequal efficiency. That which has been termed asymmetric distortion occurs when non-linearity of characteristic exists, and results in the production of frequencies which were not present in the original sound wave.

Sound persistence is the effect produced when sounds tend to persist for a longer period in reproduction than when first produced.

Frequency Distortion.

General.—One of the most fruitful sources of this type of distortion is audio-frequency resonance of any kind, whether electrical or mechanical, resulting in the production of some frequencies more efficiently than others. Audio-frequency resonance may occur in the microphone or sound collecting device, or in the loud-speaker or sound reproducing device, as well as in the audio-frequency amplifiers.

Radio frequency resonance—that is the effect of tuning circuits on audio-frequency reproduction—should also be considered under the heading of frequency distortion.

Audio-Frequency Case.—In low frequency amplifiers, distortion is unavoidably caused by the shunt capacity effects introduced by the wiring, and is also aggravated in some cases by the necessary shielding. This effect, which applies both to resistance coupled and to transformer coupled amplifiers, results in a falling off in the amplification at high frequencies (above 5 000 cycles).

In resistance coupled amplifiers, distortion may be caused by the use of condensers for coupling purposes which are too small, with the result that amplification falls off at the low frequencies; to obtain the best results, condensers not less than 1μF should be employed. The value of the low frequencies in the reproduction of speech or music for affording pleasure does not appear to be generally appreciated, although the taste of the public in choosing reproducing apparatus having a low tone is fairly marked. This would seem to be not because the absence of high frequencies is desirable but because hitherto the only apparatus capable of adequately reproducing the low frequencies has unfortunately done so at the expense of the high frequencies.

With transformer coupled amplifiers, as is well known, there may be considerable distortion due to the difficulty of designing and manufacturing a transformer which has equal efficiency at all frequencies in the music range. The science of transformer design is in itself a very large subject, but briefly the chief difficulty experienced is that of securing an adequately large inductance without the attendant self-capacity which a large winding always involves.

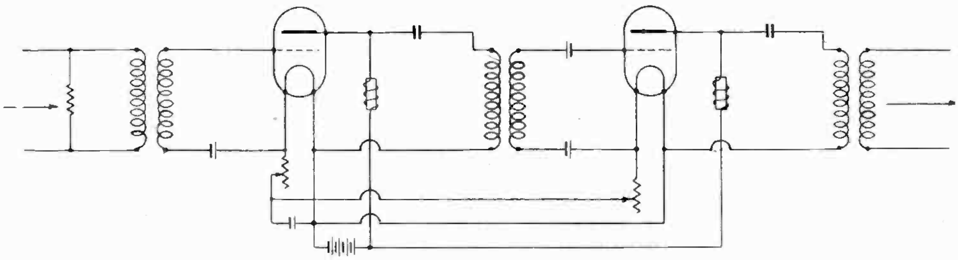


Fig. 1a. *Circuit of amplifier employing tuned transformers.*

For general purposes the music range is usually considered to extend from 30 to 10 000 cycles. Experience has shown however, that from the point of view of æsthetic pleasure, frequencies above 6 000 cycles are of sufficiently small importance to be negligible, and economic considerations usually restrict the reproduced range accordingly.

By means of a very simple system of equalisation, however, it is now possible to build transformer coupled amplifiers whose performance is on the whole preferable to that of resistance coupled amplifiers having regard to the greater efficiency obtainable. A typical curve which has been obtained with the use of a system of equalisation is shown in Fig. 1. The method of equalisation employed to obtain this characteristic is illustrated in Fig. 1a which is extracted from a paper by R.W. King in the *Bell System Technical Journal* for October, 1923. It will be seen that the system involves the use of tuned transformers.

A word of explanation should perhaps be inserted here regarding the " Transmission Unit," in terms of which the above amplification curve is plotted. In view of the fact that the input and output impedances of an amplifier may be different, an expression of actual voltage amplification is misleading and the only true expression of amplification is in terms of power ratio. The Transmission Unit is defined so that two powers (P_s P_r)

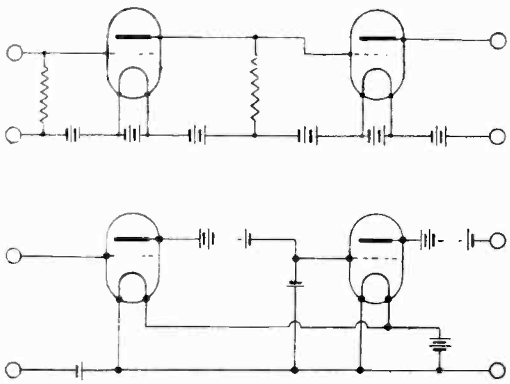


Fig. 2. *Battery coupled amplifiers.*

differ by one Transmission Unit if they are in the ratio $10^{0.1}:1$ so that the gain of an amplifier expressed in T.U.

$$= 10\ Log_{10} \frac{P_s}{P_r}$$

where P_s = the power delivered by the amplifier.

Pr = the power received.

The table gives equivalent power ratio corresponding to different values of amplification expressed in Transmission Units.

T.U.	Power Ratio.	T.U.	Power Ratio.
1	1.26	9	7.94
2	1.59	10	10.0
3	2.00	15	31.6
4	2.51	20	10^2
5	3.16	30	10^3
6	3.96	40	10^4
7	5.01	50	10^5
8	6.31	100	10^{10}

The above table enables any number of T.U. to be expressed directly as a power ratio. For instance, 45 T.U. = 40 + 5 T.U. = 10,000 × 3.16 = 31 600 Power Ratio.

Perhaps mention should not be omitted of the battery coupled amplifier, which represents the acme of distortionless amplification, and for which two circuits are represented in Fig. 2. Such an amplifier is capable of reproducing uniformly all frequencies from very nearly zero frequency up to frequencies above the limit of audibility. It represents practically the earliest type of amplifier and from a performance point of view is undoubtedly the best; from an economic standpoint however it is rather expensive.

Radio Frequency Case.—While in the radio frequency case the effect of shunt capacities is more serious than in the audio frequency case, and while also high frequency transformers transmit different radio frequencies with unequal efficiency, the effects on the audio frequency wave after detection may generally be made so small as to be negligible. The way in which these effects may cause distortion in the audio frequency wave is explained more fully in the case of radio frequency resonance, which we will not consider.

The case of radio frequency resonance, that is the effect of the tuning circuits on the audio frequency reproduction, has been mentioned by many authors, but does not appear to have been investigated very completely in most cases.

The process of modulation of a carrier wave by a series of voice frequency waves gives rise in practice to the production of a large number of audio frequency combination tones, as well as a corresponding number of radio combination frequencies. Also, all the original impressed frequencies and their second harmonics are present. The audio frequency components are suppressed by the tuning of the antenna system, and its natural inefficiency of radiation at such low frequencies. The desired radio frequencies are selected from the unwanted radio frequencies by means of the aerial tuning system and so are radiated. Thus, as indicated in Appendix 1, each voice frequency wave produces two radio frequencies, one greater and one less than the carrier frequency, and which differ from the carrier frequency by the amount of the original audio frequency.

On detection, the two frequencies in the two side bands (or one frequency if only one side band is transmitted) combine with the carrier frequency to form the original voice frequency. Actually, the carrier frequency may be either transmitted with the other radio frequencies formed, or may be supplied by the local receiving station. And provided the relative amplitudes of the side band frequencies after reception are the same as the relative amplitudes of the initial audio frequencies, the audio frequencies on detection will bear the same amplitude relations to one another as they did before modulation.

In practice we know that this ideal condition is not obtained owing to distortion in the tuning circuits both in the transmitter and in the receiving set. Fig. 3 shows three curves which were obtained by one of the authors in conjunction with Mr. E. Swensen. Curve *A*, shows the complete frequency distortion contained in the modulator, sub-modulator and radiation circuits of the Birmingham Broadcasting Station. This curve of course, includes the distortion in the input transformer to the submodulator valve, and in the coupling to the modulator, but it suffices to show how small the tuning distortion actually is. These curves were obtained by receiving on a calibrated wireless receiving set and measuring the received signal strengths at each frequency. Part of the calibration of this set is shown on curve *B* which shows the distortion due to the (single) tuning circuit of this set. The tuning circuit on which this measurement was obtained consisting of a number 50 Igranic coil tuned to 708 000 cycles (425 metres) with a 0.000 5 variable condenser. The distortion is shown as the amplitude of the reproduced voltages at each frequency relative to unity reproduction at 500 cycles. This method of portrayal has the advantage that distortions in successive pieces of apparatus in tandem may be obtained by multiplying corresponding ordinates. For instance curve *C*, in which every ordinate is the square of the corresponding ordinate in curve *B*, shows the distortion which would be introduced by two tuning circuits in tandem.

Reaction.—Reaction at radio frequencies, if not carried to excess, merely serves to modify the impedance of the receiving circuit.

This effect is represented approximately for the case of series resonance in Fig. 4, which is intended to indicate that for equal positive reactance at all frequencies (represented by the vectors (*a*) while the admittance is always increased by a vector of constant relative size, the relative phase in which this vector is added changes as the angle of the admittance changes.

The large vectors *Y* represent the admittance of the receiving circuit without reaction. The small vectors ***a***, *b*, *c* and $d=KY$ represent the increase in admittance due to reaction, where *K* is a constant depending on the value of the reacting E.M.F. If we imagine the receiving circuit to be tuned to the carrier wave-length of some transmitting station and the reaction adjusted so that the phase of the reacting E.M.F. produces a maximum increase in admittance as indicated by the vector $a=KY$, then the reaction will increase the admittance to the upper and lower side bands as indicated by $a=KY_L$ and $a=YC$ respectively.

The net result is that the fineness of tuning is increased. For clearness we have only shown a very small degree of reaction, but

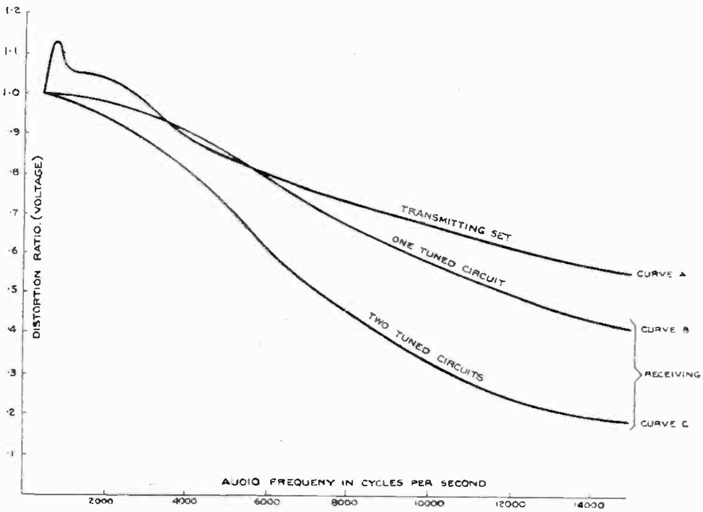
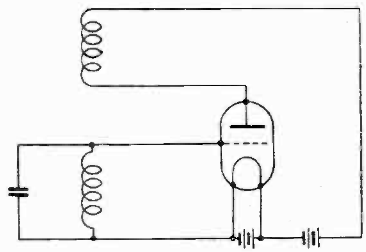


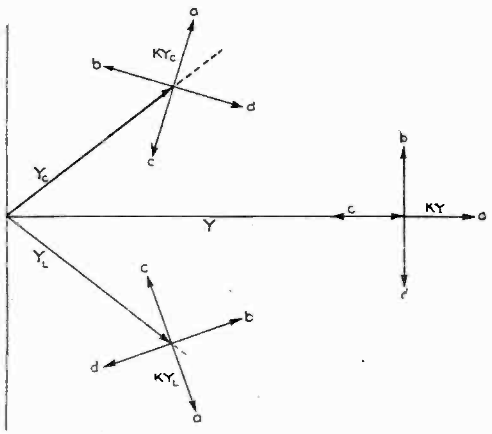
Fig. 3. *Diagram indicating distortion in transmitting and receiving set due to tuning circuits.*

in the limits of reaction this effect is enormously increased. The vectors marked (*c*) represent the case of pure negative reaction, while (*b*) and (*d*) represent the case of 90° lag or lead in the reacting E.M.F. compared with the signal E.M.F. The effect of these is respectively to reduce the capacities and inductive reactance of the circuit.

The reacting forces considered in Fig. 4



SIMPLE REACTION CIRCUIT



Y = ADMITTANCE FOR RESONANCE WAVE LENGTH
Y_C = " WAVE LENGTHS ABOVE RESONANCE
Y_L = " " " BELOW
KY ADDED EFFECTIVE ADMITTANCE DUE TO REACTANCE

VECTOR DIAGRAM OF ADMITTANCES

Fig. 4.

may not only include those intentionally introduced by magnetic coupling, they may also arise from, for instance, valve capacities, leakage and unbalanced wiring capacities, in addition to accidental coil couplings and capacities between coils. In this case, of course, due allowance must be made for any phase shifts which occur owing to the nature of the reaction path.

It is fairly safe to say that whenever audio-frequency reaction occurs, frequency distortion will also result, although this does not necessarily follow. If the reaction were such that the feed back paths had an equal attenuation (or coupling) at all frequencies and such that the phase retardation was independent of frequency, then frequency distortion would not occur; but even so, such reaction would still be highly undesirable, as is explained later. Unintentional audio-frequency reaction may be due to exactly similar causes to those in the radio-frequency case, although not in the same degree. It is usually not until amplifications of the order of one hundred million times (energy ratio) are reached that any serious difficulties are met with under this heading. Provided an amplifier is well shielded, possesses balanced inputs and outputs, and has small capacities between the separate windings of its input and output transformers, little difficulty is likely to be experienced.

Sound Persistence.

Audio-frequency reaction always tends to prolong any oscillation which is applied to the input of the amplifier. The result, to the ear, is a peculiar ringing quality, similar to that obtained from speech or music in a particularly reverberant room. The mechanism of this case is analogous to that of the high frequency case, although the actual effect is, of course, different.

Another cause of sound persistence which is frequently extremely troublesome is due to the acoustic properties of the place where the sound is being initially produced, and it follows, of the place where it is being reproduced after transmission and reception. If insufficient damping is provided in these places, the reflection of the sound from the walls, floor and ceiling of the rooms causes continued echoes which tend to prolong the sound unduly. Reverberation is the term given to the result of continued reflections, which result in a number of sound images being impressed on the microphone or on the ear. Reverberation may be reduced to any required degree by suitably covering the walls of the room with some sound-absorbing textile material, such as felt.

Asymmetric Distortion.

Asymmetric distortion is probably the most objectionable type of distortion with which we have to cope, and it is the least excusable type, since wherever it occurs poor design or careless handling are indicated. Its cause is non-linearity in the output versus input characteristic of any

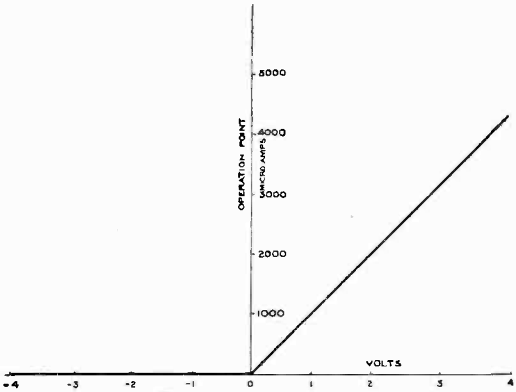


Fig. 5. (a.) *Ideal Rectifier.*

piece of apparatus in the transmission system. This departure from linearity may occur in vacuum tubes due to operation beyond the straight part of the plate current grid-voltage characteristic in transformers due to operation over too great a part of the **B—H** curve (as a result generally of too small a core being used, or of the use of core material for which the lower knee in the **B—H** curve occurs at too low a value of **B**) and in microphones or loud-speakers due to the elastic controlling forces not having a linear displacement-control law.

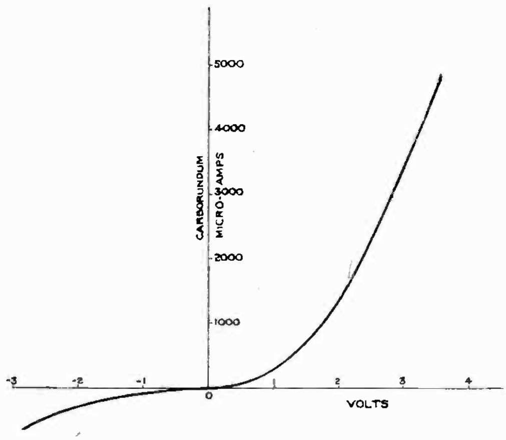


Fig. 5. (b.) *Carborundum Crystal Rectifier.*

It is the limits referred to above which in general define "overloading," considered in the telephone sense, and not questions of heat dissipation. As soon as the amplitude of energy pulses in any piece of apparatus exceeds the limits for which linearity of characteristic holds, then that piece of apparatus is said to be overloaded. Overloading of a valve clearly occurs as soon as the amplitude of the voltage pulses applied to the grid pass beyond the zero of grid-potential, at which point grid-current begins to flow, and the instantaneous impedance of the valve becomes a function of voltage amplitude.

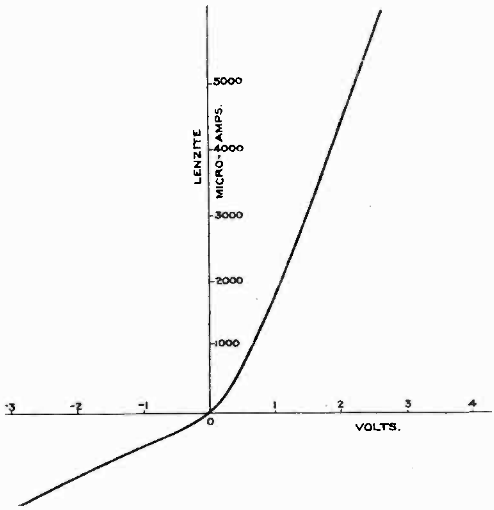


Fig. 5. (c.) *Lenzite Crystal Rectifier.*

Modulation and Detection—If we are to hold rigidly to our definitions of asymmetric distortion we must include under that heading the distortion introduced on normal modulation and detection. Provided we have chosen a proper system of modulation, even if the carrier wave is modulated to a depth of 100 per cent., detection on a straight line rectifier should reproduce the original wave form exactly. In practice it is economically impossible to avoid the peaks of the audio-frequency voltages from rising above the value required for 100 per cent. modulation; this effect (which is termed "over-modulation" and which may really be regarded as an overloading of the modulator) can however, be kept so small that the resulting harmonics are within the limits of tolerance of the ear. If we work with a mean modulation of 10 per cent. then we assume that the peak voltages are not greater than 10 times the mean voltage; this is practically true for normal continued speech but not so for music.

Even if no over-modulation occurs, the use of rectifiers of parabolic output versus input characteristic introduces a number of additional frequencies not present in the original audio-frequency wave, which are sometimes spoken of as frequencies of asymmentry or combination tones.

In Fig. 5 are shown rectification characteristics of two crystal combinations compared with the ideal rectifier characteristic. The curves for these crystals are taken from Morecroft's "Radio Communication." The lenzite crystal rectifier gives a characteristic which approximates very closely to the ideal on the positive side, while the carborundum combination gives a curve more nearly a parabola. It may here be pointed out that a crystal detector when receiving strong signals tends to approximate to a straight line rectifier; this is fairly evident from the curves in Fig. 5.

In detection by valves, one of two methods is employed. In the first, the modulated wave is rectified by apparatus having approximately a parabolic form of characteristic, and the percentage of combination frequencies produced is proportional to the depth of modulation; that is to say, to the ratio of the side-band amplitude to the carrier amplitude.

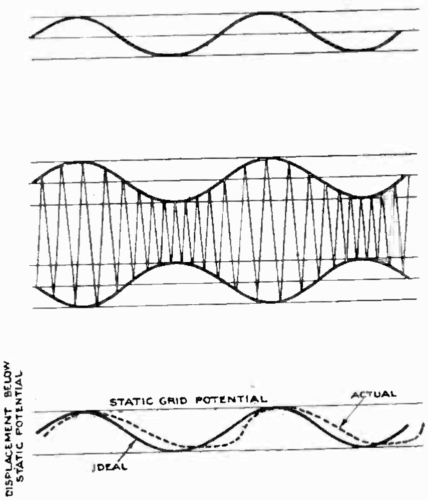


Fig. 6.

The second ordinary method of demodulation—known as grid detection—is of a complex nature. Although it employs apparatus having a linear characteristic, and is not necessarily to be considered as rectification, a certain amount of asymmetry usually occurs. Ideally, grid detection should operate so that the mean value of grid bias displacement, taken over a single high frequency period, should be directly proportional to the mean amplitude of the high frequency wave, sign not being taken into account. (On this basis the mean amplitude of a sine wave over one period is not zero, but $2/\pi$ times the maximum amplitude.) This ideal operation is not actually achieved, since the instantaneous value of the grid bias is controlled by the amplitude of the high frequency oscillation immediately preceding that taking place at any moment; there is thus a time lag.

This is illustrated qualitatively in Fig. 6. Perhaps some may find the process of distortion easier to conceive in terms of the impedance of the grid circuit of the valve. Since the grid assumes a charge of electrons increasing as the amplitude of the applied high frequency increases, the impedance or the grid circuit increases with amplitude, an effect which shows itself in distorting the audio frequency envelope of the high frequency wave. The ideal case is, of course, more nearly approached as the value of the grid leak is reduced—that is to say, as the conductance is increased. Unfortunately, the greater the conductance, the weaker are the signals, so that in practice, a certain amount of asymmetric distortion is always experienced with grid leak detection.

Other Types of Distortion.

As has been already mentioned under the heading of frequency distortion, the use of radio frequency reaction in receiving circuits results in an effective reduction in resistance of the circuit into which the reaction operates, with a consequent reduction of admping. An obvious result of this is that the high frequency oscillations will tend to persist after the actual cessation of the impressed E.M.F. due to the received signal. The wave shape of the audio frequency envelope of the modulated wave is thus changed, and frequencies are introduced into the output of the set which were not initially present. This may be observed on any set possessing reaction, and appears as a harsh grating noise ; it does not appear markedly, however, until the reaction has been increased almost to the point at which the set begins to oscillate.

There are a variety of other considerations, many of which are almost negligible, and some of which are not yet completely understood. Among these may be mentioned : the night effect, which has been observed on cretain wave-lengths, and which results in the preferential transmission of certain frequencies ; also the effect of land configurations and local screening conditions.

The radiation and reception of sound by devices whose dimensions are commensurate with the sound wave-lengths involved is also a problem which some have considered it worth while to investigate.

The question of interference is properly one which should be included under the heading of distortion. The measuring of interference and the assessing of its effect are themselves of so great importance as to constitute almost a separate science. Here we will only touch on two sources of interference considered broadly under the headings of atmospherics and parasitic noises.

Atmospherics are caused by thunderstorms or other sources of natural electric discharges, the nature of some of which has not yet been identified. Parasitic noises may be of two kinds. Those resembling atmospherics may be caused by other stations, by sources of power supply, by electric railways, and a number of other sources ; mercury arc rectifiers are a prolific source of this trouble. The second kind are serious only when small volumes of audio frequency energy are being handled, and may be due to internal leakages in valves, external leakage in the circuit, or in the case of bad handling or workmanship may be due to local action in the high tension battery, or to bad contacts. Microphone noise might also be classed as a parasitic noise, inherent in some degree to all microphones depending on changes of resistance in carbon granules and the like. The modern microphones in use at broadcasting stations, however, entirely remove this source of trouble. The amount of interference tolerated depends naturally on the nature of the transmission as well as on the nature of the interference, and although certain standards of tolerance have been set, no universally applicable figures are yet available.

APPENDIX I.

The Process of Modulation and Detection.

Ideally the process of modulation should consist in making the amplitude of a high frequency carrier wave at any instant such a function of the amplitude of a modulating audio frequency wave that the modulating audio frequency wave may be re-obtained by a process which we may call detection.

The method most commonly employed is illustrated in Fig. 7, where a sinusoidal audiofrequency wave has been made to modulate a sinusoidal high frequency wave producing a resultant wave whose form is revealed by inspection to be—

$$e = E \sin ct + KE \sin vt \sin ct \quad \ldots \quad \ldots \quad (1)$$

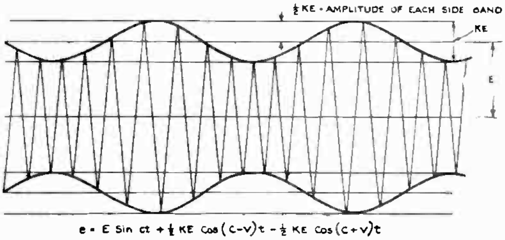


Fig. 7.

In this case $100K$ represents the percentage modulation. By an ordinary trigonometrical transformation this may be written—

$$e = E \sin ct + \frac{KE}{2} \cos (c-v)\, t - \frac{KE}{2} \cos (c+v)\, t \quad (2)$$

(Carrier) *(Lower Side Band)* *(Upper Side Band)*

Thus each initial audio frequency component is represented after modulation by two radio frequencies, one greater than the carrier frequency by the amount of the audio frequency, and the other less than the carrier frequency by this amount. The two spectra of radio frequencies obtained by the modulation of a radio carrier frequency by an audio frequency spectrum are called respectively the upper and the lower side band.

It appears fairly evident that any process of detection must take advantage either of their mutual difference in frequency or else of their difference from the carrier frequency.

Actually, we take advantage of the difference between the carrier frequency and the side band frequency. The ideal method of detection is straight line rectification, which would be intrinsically distortionless ; in practice many available methods of detection involve the use of apparatus whose effective output *versus* input characteristics are curved. If we consider the simplest form of detection, which is by a crystal, this is not necessarily so, but in the case of a valve operating on the curved portion of its plate current-grid voltage characteristic it is evident that a certain amount of distortion peculiar to the method of detection must occur.

The form of the vacuum tube characteristic shown in Fig. 8 is parabolic, of the form—

$$I_B = \mu (V_g + E_R)^2 \qquad (3)$$

If $E_g =$ the grid bias and we superimpose a wave of the form—

$$V_g = e = E \sin ct + \frac{KE}{2} \cos (c-v)t - \frac{KE}{2} \cos (c+v)t \qquad (4)$$

on the grid voltage, then

$$I_B = \mu \left[(E_R - E_g) + E \sin ct + \frac{KE}{2} \cos (c-v)t - \frac{KE}{2} \cos (c+v)t \right]^2$$

$$= \mu \left[(E_R - E_g)^2 + E^2 \sin^2 ct + \frac{K^2 E^2}{4} \cos^2 (c-v)t - \frac{KE}{2} \cos^2 (c+v)t \right.$$

$$+ 2 (E_R - E_g) E \sin ct + 2 (E_R - E_g) \frac{KE}{2} \cos (c-v)t$$

$$- 2 (E_R - E_g) \cos (c+v) t + 2 E \sin ct \frac{KE}{2} \cos (c-v)t$$

$$\left. - 2 E \sin ct \frac{KE}{2} \cos (c+v) t - 2 \frac{K^2 E^2}{4} \cos (c-v)t \cos (c+v)t \right]$$

$$= \mu \left[\text{Direct current} + (2 \times \text{carrier } f) + (2 \times \text{lower side band } f) - (2 \times \text{upper side band } f) \right.$$

$$+ \text{carrier } f + \text{lower side band } f. + \text{upper side band } f.$$

$$+ 2E \sin ct \left\{ \frac{KE}{2} \cos (c-v)t - \frac{KE}{2} \cos (c+v)t \right\}$$

$$\left. - 2 \frac{K^2 E^2}{4} \cos (c-v)t \cos (c+v)t \right] \qquad (5)$$

and neglecting the radio frequency terms which we do not require, we are left with

$$\mu \left[\tfrac{1}{2} KE^2 \left\{ \sin (2c-v)t + \sin vt - \sin (2c+v)t + \sin vt \right\} \right.$$

$$\left. - \tfrac{1}{4} K^2 E^2 (\cos 2ct - \cos 2vt) \right] \qquad (6)$$

$$= \mu \left[\tfrac{1}{2} KE^2 \sin (2c-v)t - \tfrac{1}{2} KE^2 \sin (2c+v)t + \underset{(\text{audio frequency})}{KE^2 \sin vt} \right.$$

$$\left. - \tfrac{1}{4} K^2 E^2 \cos 2ct + \underset{(\text{double audio frequency})}{\tfrac{1}{4} K^2 E^2 \cos 2vt} \right] \qquad (7)$$

We thus arrive at the convenient fact that the percentage of undesired double frequency (of the required audio frequency) is one-quarter of the percentage modulation. A further fact is that the double frequency is caused by inter-modulation between the two side bands. Finally, we see from step 5 to 6 that the audio frequency characteristic may be preserved if only one side band is transmitted.

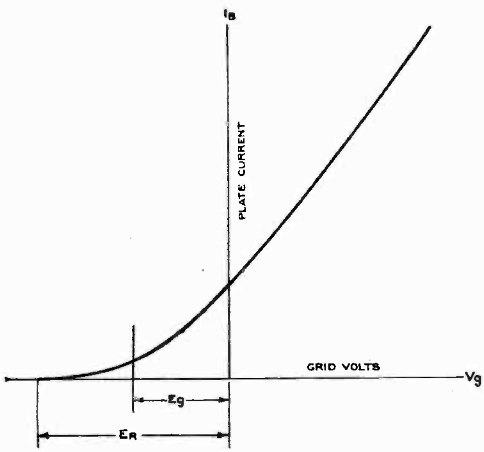


Fig. 8.

A point which is not shown by the above analysis is that there is mutual inter-modulation among the frequencies of one side band. Since the depth of modulation normally employed is less than 20 per cent. these effects are generally negligible as regards the sustained value of the combination tones. Even if over-modulation does not occur, an instantaneous peak voltage which causes 100 per cent. modulation will give rise to a 25 per cent. double frequency term on detection and combination tones dependent on the amplitude of the various component frequencies present. By supplying a carrier locally at the receiving end and so decreasing the effective depth of modulation they may be made as small as required; this method has the disadvantage, however, that since two side bands are generally transmitted, any difference between the local carrier and the original carrier causes differences between the detected audio frequencies contributed by each side band. The application of the superheterodyne or double detection principle may be made to obviate this disadvantage.

A Note on the Cathode Ray Oscillograph. [R388

The essential feature of the cathode ray oscillograph—the use of a beam of electrons as the moving part—is by no means new, as it has for many years been employed in what is known as the Braun tube. This tube was, however, seldom used outside the best equipped research laboratories, because of the very considerable difficulties attendant upon its operation.

Both the Braun tube and the cathode ray oscillograph are operated as follows: the beam of electrons may be deflected in any direction by applying an electric or magnetic field across the beam near its source. Deflection occurs in the same direction as the electric field, and at right angles to the direction of the magnetic field.

If two fields are applied in two directions at right angles, then the path traced by the end of the beam is the curve in rectangular co-ordinates of the relation between the two fields at any time. If the two fields are cyclic and synchronous the beam traces the same pattern repeatedly, so that a stationary curve is in effect obtained. Special arrangements (such as those described in Appendix III.) permit of a stationary figure being obtained when time is one of the variables, provided the other is cyclic.

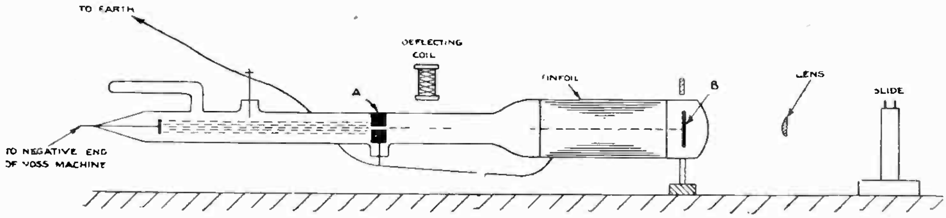


Fig. 9.

With the Braun tube, these principles of function are brought about by the arrangement shown diagrammatically in Fig. 9. The electron beam is derived from a high-voltage gas discharge, from some such electrostatic machine as the Voss or Wimshurst. The tube is a form of the high vacuum type having at one end a cathode from which the cathode beam is projected. Two baffle screens *A* limit the dimensions of the beam, which falls on a screen *B* of fluorescent material. The ray shows as a bright spot on the screen. Deflection of the beam is obtained by placing on either side of the neck of the tube a pair of coils traversed by an electrical oscillatory current. The line of light so produced may be examined by some such device as a rotating mirror. The Braun tube requires a constant voltage from 10 000 to 50 000, so that the operating gear is costly and cumbersome. The focusing of the ray is brought about by the use of "striction" coils, or some other producer of a powerful field.

The cathode ray oscillograph differs from the Braun tube in that the source of electrons is a hot filament. This makes it possible to obtain a sufficiently dense beam, travelling at a convenient velocity, with use of the comparatively low anode potential of 250-400 volts. The sensitiveness of the apparatus is thereby increased and the auxillary gear necessary for the working of the tube is correspondingly simple.

A photograph of the tube, fitted to the bayonet socket made for the purpose, is shown in Fig. 10, and the internal construction is explained more clearly by Fig. 11. In the latter figure, the small internal glass tube contains a length of oxide-coated filament (*f*) heated when in use by a 4 or 6 volt accumulator; from 1.2 to 1.5 amperes are consumed when the beam of electrons is properly adjusted. The small tubular anode (*a*), from which the beam issues, is about 10 mm. long. The current to the anode is about half a milliampere. A shield *S* is inserted between the anode and the filament, and has a small hole in the centre. The end of the filament is bent round to a circular form just larger in diameter than the hole in the screen, so that the back bombardment on to the filament of positive electrons is prevented, and the life of the filament is thereby increased to about 200 hours. The filament is drawn in detail in Fig. 12. Above the anode (*a*) are mounted two pairs of deflecting plates *Px* and *Py*, at right angles; one plate of each pair is connected to the anode. The potentials to be studied are connected between the anode and the other plate of each pair.

The large end of the tube is coated on the inside with a mixture of calcium tungstate and zinc silicate, so that where the beam strikes this screen fluorescence is obtained of such a colour as is bright enough for clear visual examination, and yet contains enough blueness to be fairly active photographically. The brightness of the spot is increased as the anode voltage is raised, but at the expense of course of a certain amount of sensitivity, so that the actual anode voltage employed is best selected according to the requirements of the experiment in hand.

The focusing of the rays upon the fluorescent screen is cleverly brought about by the introduction of a small amount of gas into the tube—a suggestion due to Dr. H. J. van der Bijl, who, with Dr. J. B. Johnson, has been responsible for most of the development work on this tube.

The part which the gas plays depends upon the difference in the mobilities of electrons and positive ions.

Some of the electrons in the stream forming the "cathode ray" in passing along the tube, collide with gas molecules and ionise them. Both the colliding electrons and the secondary electrons leave the beam, but the heavy positive ions receive very little velocity as a result of the impact, and drift out of the beam with only their comparatively low thermal velocity. It therefore happens that an accumulation of positive ions form a field surrounding the "cathode ray" which tends to pull the electrons inwards. Before the beam is focussed however the mutual repulsion between the constituent electrons must be overcome; this would occur when the number of positive ions in the stream equals the number of electrons. Also the original divergence in the beam must be overcome. Assuming this to be one degree from the axis and the electron current to be 2×10^{-5} amp. calculation shows that the radial field required to pull the beam to a focus at a distance equal to the length of the stream in the tube is about 1 volt per cm. This field strength is produced with fields of ordinary intensity if there are four positive ions for each electron in the stream.

When the current is increased, the total positive ionisation of the beam increases, the field around the beam becomes stronger and the electrons are brought to a focus in a shorter distance. The focussing of the beam therefore is brought about merely by adjusting the filament current.

With a 300 volt anode battery, a difference of potential across the deflecting plates of 10 volts causes a deflection of the luminous spot of about 1 cm. If small coils of wire are arranged on opposite sides of the outside of the neck of the tube, in the same plane as one pair of the plates, the deflection due to 1 ampere turn is about 1 mm.

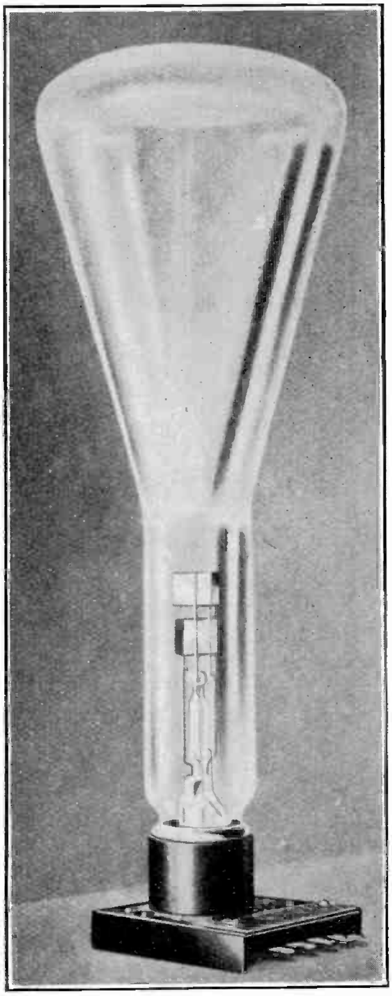


Fig. 10.

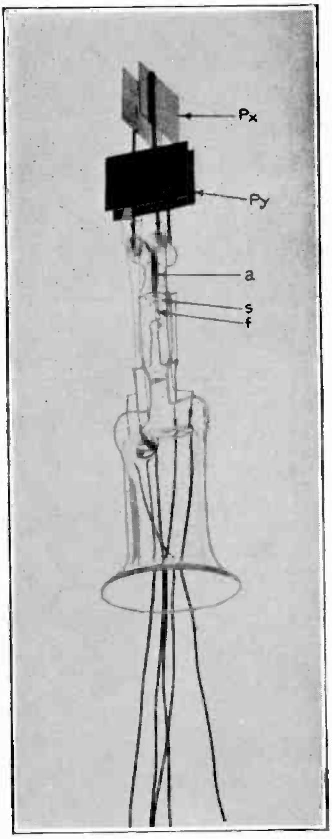


Fig. 11.

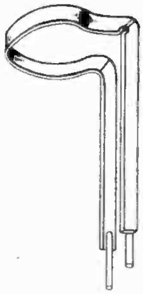


Fig. 12.

(To be concluded.)

Some Notes on 20-Metre Work.

By E. H. Robinson (2VW). **[R545·0124**

WIRELESS experimenters are beginning to take a practical interest in the utilisation of wave-lengths below 40 metres. Wave-lengths round about 20 metres, especially, form a centre of interest, as American amateurs are allowed the use of this wave-length, which is therefore convenient for transoceanic experiments.

Although 20 metres is a very short wave-length compared with those with which we are more familiar, the same general laws hold for the radio frequency circuits involved. The only thing is that the ordinary H.F. effects are greatly exaggerated, and a little extra care is required in connection with certain points. Important things to remember are :—

1. The inductance of a straight wire is quite considerable. The thinner the wire the greater the inductance per unit length. Long connecting leads tend to become H.F. chokes.

2. Incidental stray capacities have a greater effect. The currents sometimes induced in short conductors apparently free at one end appear quite uncanny.

3. Mutual inductive and capacitative coupling between one's H.F. circuits and seemingly well-removed stray conductors in the same room may be quite large.

4. The damping effect of poor dielectrics is pronounced.

5. It is probable that at a frequency corresponding to the wave-length of 20 metres the time of travel of an electron between the electrodes of a thermionic valve is beginning to become comparable with the time of oscillation (1/15,000,000 sec.). If this is the case one would expect to find secondary effects not observable on longer wave-lengths.

Short-Wave Calibration.

The first problem encountered in commencing work on short wave-lengths is to know when one's circuits are tuned to the required wave-length. Some form of wave-meter or calibrated receiver is practically indispensible. A simple heterodyne wave-meter of the Hartley oscillator type has been found very serviceable.

Many experimenters will have hit on the idea of using the harmonics from a local broadcasting station operating on a known wave-length as standard points for calibrating their sets. Since a complete set of exact multiple harmonics is present, carrier-waves will be heard on wave-lengths of exactly $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, $\frac{1}{5}$, etc., of the fundamental wave-length. Harmonics beyond the fifth or sixth, however, become rather weak and are apt to be confused with other transmissions.

If, for instance, we are situated in London,

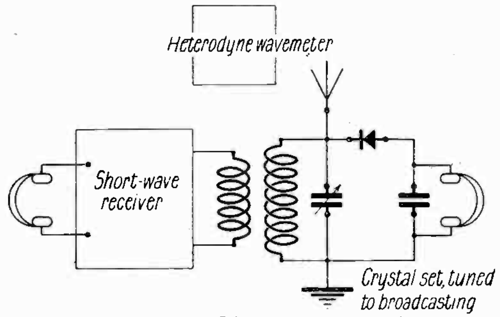


Fig. 1.

and are employing the harmonics of 2LO, whose fundamental is about 365 metres, we shall have to follow the harmonics down to about the eighteenth in order to calibrate a 20-metre receiver. The harmonics here are not only very weak normally, but are close together (about 1.3 metres apart), so that there is a great liability for errors to be made. It has been found, however, that the following simple method allows very strong harmonics to be heard to the practical exclusion of other signals. Fig. 1 shows the scheme.

An ordinary crystal receiver is connected to aerial and earth and is tuned to the local broadcasting station ; the crystal detector is adjusted to give the best rectification as judged by the signal heard in the phones associated with it. Owing to the rectification, and consequent distortion, of the incoming carrier wave, a complete series of exact multiple harmonics are produced in the crystal set, and these may be heard quite strongly in an oscillating short-wave receiver placed within a few inches of the inductance of the crystal set. The reason for the production of these harmonics has been comprehensively treated in a recent article by Mr. Colebrook in this journal.

By means of a short wave receiver with interchangeable coils the harmonics can readily be followed from the fundamental down to the twentieth harmonic. It is necessary to exercise some little care not

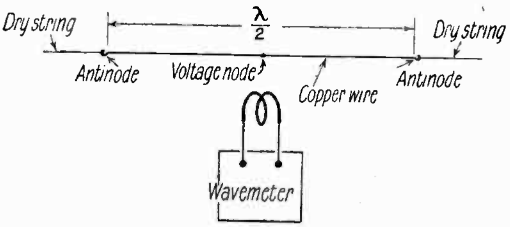


Fig. 2.

to miss a harmonic nor to count the same one twice in changing one's coils when the bottom of the existing range has been reached. It is convenient to use a heterodyne wavemeter to "hold" the wave-length while any change is being effected in the short-wave receiver. In fact, it is a good plan to calibrate the wavemeter in the same sitting. Feeble intermediate notes may be heard due to harmonics in the wavemeter or receiver, but the required harmonics of relative frequencies 1, 2, 3, 4, 5, etc., are comparatively strong and easily distinguished.

Another and more straightforward way of finding one's wave-lengths on these short waves is to employ one of the methods in which stationary waves are set up in straight wires. Wave-lengths are measured directly by a tape-measure or metre rule. The Lecher wire method is the best-known accurate method, but this merits a complete article to itself. In order to obtain an approximate calibration of a wavemeter between 15 and 23 metres, the following method was used; it is extremely simple, takes only a few minutes to fit up and works quite nicely.

A straight length of copper wire is suspended horizontally (see Fig. 2), and is kept taut to avoid sag. The wire is held by lengths of thin, dry string attached to its extremities, the attachment being effected by forming the ends of the wire into the smallest possible hooks. It is best to perform the experiment out in the open as far away from obstacles as possible, and the wire should be at least five feet above the ground. The ideal to aim at as far as possible is a perfectly straight conductor completely isolated in space and out of the influence of other conductors and dielectrics. Under these conditions the velocity of electric waves in the wire is, for approximate purposes, the same as that in free space.

When the wire is responding at its fundamental natural frequency there will be a potential node in the middle and potential antinodes at the ends; the resonant wave-length of the wire will therefore be equal to twice its length. If we wish to obtain a wave-length of 20 metres it is only necessary to measure off a length of wire 10 metres long. It is now only necessary to find when our wave-meter is in resonance with the wire.

With a heterodyne wavemeter having telephones in the anode circuit this is easily enough accomplished by the "double click" method. The oscillating wavemeter is coupled to the middle of the wire by holding it so that the plane of the turns of the wavemeter coil is in the same plane as the wire. This is indicated in the sketch. The dial of the wavemeter is slowly rotated until the passage through resonance is indicated by a double click in the telephones. Often the two clicks are so close together as to sound like only one; if this is the case, so much the better. The wavemeter should be held as far from the wire as is possible without losing the

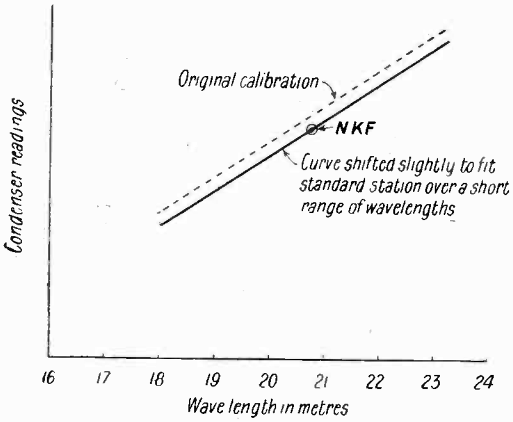


Fig. 3.

indication. Usually it is sufficient to have the wavemeter within a foot or two of the wire. The operator's body, the batteries, telephone leads, etc., should be kept as much in the background as possible.

By repeating the experiment with various lengths of wire it is possible to plot a number of points for the calibration curve of the wavemeter. As to the guage of the wire used, No. 22 S.W.G. seems to answer well.

The calibration curve obtained for the wavemeter may look quite smooth and consistent, but this is no guarantee that it is not as much as half a metre out. There is plenty of room for small errors, and it is up to some of the precise merchants, such as the N.P.L. folk, to give us a hand. The calibration of the writer's own wavemeter does not quite agree with the American naval station NKF, who insists that it is on 20.8 metres. The discrepancy of 50 centimetres is rather difficult to account for, but considering NKF's probable resources for accurate calibration, it ought to be correct, even if it isn't. The curve of the writer's wavemeter has therefore been corrected as illustrated in Fig. 3. The dotted line is the original calibration of the wavemeter as obtained by the straight wire method.

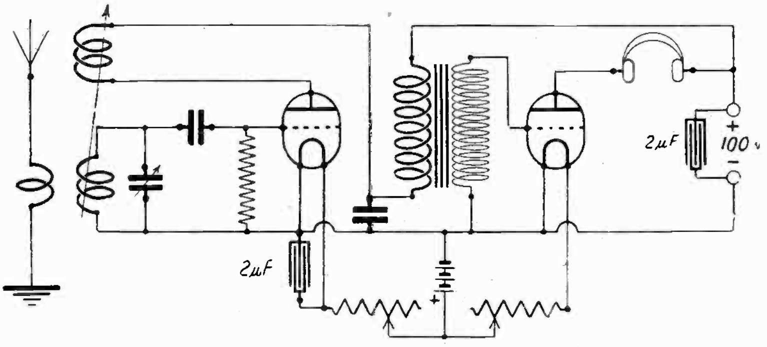


Fig. 4.

As the wavemeter condenser was of the square-law variety and only used over a limited part of its range a very nearly straight line was obtained. The American station NKF was tuned in on a receiver and since the wave-length (20.8 ms.) was known an independent point was plotted on the curve sheet. This fell a little off the original lines, so the thick line was drawn through NKF's point parallel to the dotted line. Provided that NKF is accurate this thick line should furnish a fairly accurate calibration over a short range of wave-lengths.

Reception.

The reception of C.W. signals between 18 and 40 metres does not present any very great difficulty provided that the set is arranged with due respect to the extremely high frequencies involved. This implies keeping all leads carrying H.F. currents as short as possible, using a reasonable minimum of dielectric in the form of coil-holders, valve-holders, etc., and, above all, confining the H.F. currents rigorously to the tuned circuits and detector valve and not allowing them to wander round stray paths such as telephone leads or the L.F. amplifier.

These stray-path effects are often rather surprising and are just as important in causing "dead spots" in tuning and preventing the set from oscillating as the more generally known effects due to dielectric losses. In fact the "low-loss" idea is frequently overworked; it is not necessary in order to receive on 20 metres to build a set which is thoroughly useless on other wave-lengths. The writer finds that a reasonable amount of good quality ebonite, in the form of standard coil-plugs, etc., has no very serious effect. A "Polar" coil-holder has been found satisfactory, the arm with the universal movement allowing a very nice control of the magnetic reaction. Both fixed and movable sockets have been removed from their original base and incorporated with the base of the set.

There is no need to use any unusual circuits for the receiver. H.F. amplification seems to be right out of the question at present, so we have to fall back on the regenerative detector and L.F. amplification. Owing to the confusion of names and circuits occasioned by the popular Press the circuit used by the writer is reproduced in Fig. 4 without apology. An "untuned" aerial is used. The grid circuit of the detector comprises a plug-in coil tuned with a square-law condenser having a maximum capacity of .001μF. This condenser has a vernier plate provided with a long manipulating handle. The capacity may seem rather large for short-wave work, but only the lower 40 degrees of the range are used for 20 metre work.

It is rather convenient to use a large tuning condenser, as the effects of varying stray capacities, such as the operator's body, are reduced, and in addition to this the vernier plate has a very fine tuning effect, enabling C.W. heterodyne notes to be held with comparative ease. The grid tuning inductance is a flat spiral of 5 turns of No. 14 bare copper wire, the diameter of the outside turn being 3 in. and that of the inside turn 1¾in. The coil is fitted to an Igranic plug and is self-supporting. The reaction coil is of a similar type but with one or two more turns. The detector valve and its associated coils are mounted compactly together and well away from the L.F. amplifier. By-pass condensers are placed wherever they may seem necessary.

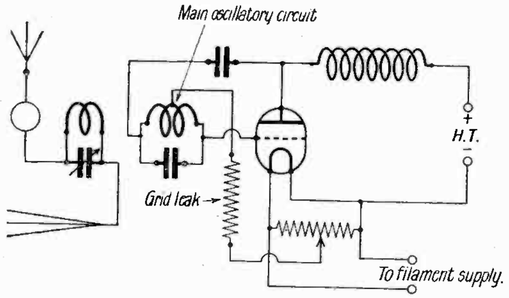


Fig. 5.

Ordinary four-pin valves in reasonably good sockets will oscillate quite well, but it was found a distinct advantage to use a valve of the V-24 type, as the connections to grid and anode can be very much shortened, this enabling the set to oscillate more easily and allowing tighter coupling to the aerial to be used. The connection between the grid and the top of the grid circuit is made by a short copper-foil strip which itself incorporates the grid condenser. This is effected by having the strip in two portions overlapping with mica insulation between them. Connections to the grid and anode of the valve are soldered directly on to the lugs, thus doing away with the clips.

It pays to boil things down like this on 20 metres. In the writer's own experience a stage of L.F. amplification is a very decided advantage, in that it enables signals to be heard which would be inaudible on the detector valve alone. For higher wave-lengths this is a controversial point with some experimenters, but there does not seem to be much doubt about it for ultra-short wave-lengths. The reason may lie in the greater absence of atmospherics and general QRM.

In connection with leaky-grid rectification below 30 metres a very peculiar difficulty is likely to occur. Best detection on ordinary wave-lengths is usually obtained by leaking to the positive end of the filament. If this is attempted on about 20 metres the set may tend to howl when just oscillating. If the reaction is coupled tightly so that the set oscillates furiously the howl disappears; it is just when the set is in the most sensitive condition for picking up faint C.W. signals that this aggravating noise occurs. The trouble can be cured usually by taking the grid-leak to the negative end of the filament, but this may mean a slight sacrifice of signal strength. The effect referred to seems in some way dependent on the very high frequency of the oscillations, the grid current, and to some extent on the presence of the low-frequency amplifier; it never occurs on long wave-lengths. Can anyone explain it? Is it anything to do with the grid-current electrons moving too slowly?

Transmission.

Here we come to the side of the subject which will offer problems to all transmitters and humiliation to many. It is easy enough to make a power valve oscillate on wave-lengths of the order of 20 metres. It is not so easy, however, to obtain a pure, steady C.W. note. Also how are we going to operate a valve efficiently without having an amp of H.F. current or two going through the grid and plate seals?

Dealing first with the power valve, the writer has a strong preference for the low-impedance type of valve for short waves. For one thing they oscillate more readily and require little or no "anode tap" winding. With a high-impedance valve it may be impossible to introduce the optimum amount of anode inductance without raising the wave-length above the desired value; one cannot use much of a closed circuit condenser, with the result that the valve capacity becomes the main closed-circuit condenser with heavy H.F. currents circulating through it. Again, the high-impedance valve must be operated with high D.C. and high H.F. potentials on the anode and therefore the glass is subjected to large dielectric strains. On the other hand a low-impedance valve may be operated in conjunction with a closed oscillatory circuit with a smaller inductance and a reasonably large condenser, through which the main bulk of the high-frequency current flows instead of through the valve.

The simplest form of Hartley circuit seems to be as satisfactory as anything for short-wave transmission—at any rate if a valve of fairly low impedance is used. The arrangement shown in Fig. 5 has been found satisfactory. The H.T. is shunt-fed. It will be seen that the middle point of the Hartley circuit is not anchored to the filament with a condenser but is free except for the grid-leak connection. If the middle of the circuit is anchored at all this must be done at the exact nodal point of the circuit ; but there does not seem to be anything gained by shunting the grid-leak. The aerial circuit is loosely coupled and tuned by a .000 5 variable condenser in parallel with two turns of wire, this working quite well in spite of the fact that that unloaded aerial system has a fundamental wave-length of about 60 metres. No method of keying is shown as the best method has not yet been decided upon.

A few details of the construction of the Hartley circuit may be of interest as showing one way of doing things. This is made up according to the writer's own private ideas about low-loss circuits for short wave-lengths, and comprises four turns of thick copper strip 6 in. diameter spaced half an inch apart. The ends are soldered to two parallel flat copper plates $5\frac{1}{2}$ in. square and about $\frac{1}{4}$ in. apart, forming an air condenser. This is illustrated in Fig. 6. The lower sketch in this figure shows how the spacing between the plates is maintained without introducing any solid dielectric between them. By varying the spacing, adjustments of wave-length may be easily made. The calculated capacity between the two copper plates only amounts to a few micro-microfarads, but this is in proportion to the values of capacity used in valve practice on longer wave-lengths.

Considerable trouble was at first experienced with mechanical vibration due to traffic in the street, etc. This set up relative vibrations between the condenser plates and between the turns of the inductance, with the result that the note had a continual wobble. The turns were bolted to ebonite spacing strips and the whole circuit was fixed firmly to a shelf, but this did no good. Finally the trouble was completely eliminated by hanging the Hartley circuit from the ceiling by a single rubber band. It was then possible to stamp on the floor or bang the walls of the operating room without affecting the note of the transmitter. Connection to the rest of the apparatus is made by means of fine copper wires which do not transmit mechanical shocks to any appreciable extent. It is necessary to avoid draughts, as these blow the Hartley circuit about and cause slight swinging of the wave-length.

It is much harder to obtain a pure C.W. note on ultra-short wave-lengths than on the longer ones, both in the case of D.C. generator supplies and rectified A.C. The difficulty is not insuperable. In the case of rectified A.C. it is usually just a matter of adding more condensers and chokes to the smoothing circuit. If A.C. is used for filament heating the problem is a harder one. Where an absolutely pure C.W. note is required and the filament does not take more than three amps it is best to use batteries. Most American amateurs seem to have solved the problem by not worrying about the note

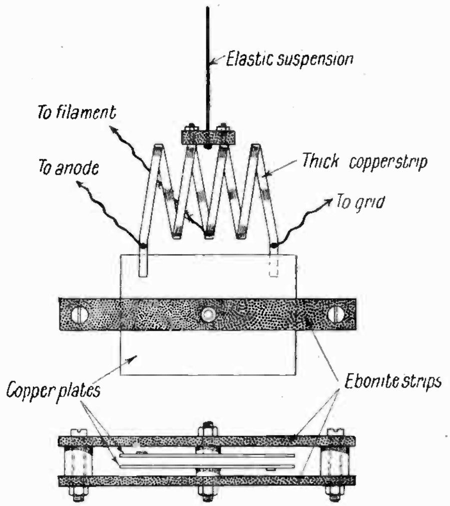


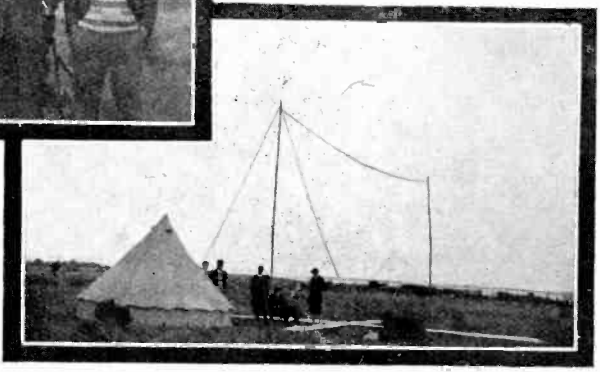
Fig. 6.

at all. This is not altogether a good plan in view of the interference at the receiving end from the ignition systems of passing motor-cars, with which a faint raw A.C. note is likely to become confused.

Wireless Field Work.

Successful experiments at Light 'Plane trials at Lympne.

AT the request of the Royal Aero Club and by the kind permission of the P.M.G., three transmitting and receiving stations were installed by Messrs. N. V. Webber & Co., Ltd., of Vale Road, Oatlands Park, Weybridge, Surrey, on the occasion of the Light Aeroplane Trials held at Lympne recently. By means of these stations, rapid communication between the aerodrome and the two turning points on the course—Postling and Hastingley—was maintained. These turning points were respectively about 4-5 miles from the headquarters station at the aerodrome.



A view of one of the stations, and (above) a group of the operators.

These two out-stations were similar in design, and each consisted of a 2-valve receiver and a single-valve transmitter, equipped both for C.W. and phone. Power was derived from large capacity dry-cell H.T. batteries, about 5 watts being drawn at 220 volts, giving an aerial current of .3 amps between 150 and 200 metres. Both transmitter and receiver were combined in one instrument.

Tents were erected in which the apparatus was installed, and two bamboo poles, 15 ft. in length, were tied together and used for aerial masts. This gave a height of about 25 ft., and a single-wire aerial, 75 ft. long, was employed. A single-wire counterpoise, immediately under the aerial and 3 ft. from the ground, was used instead of an earth system, an earth pin being used for the receivers.

At the headquarters station two aerials at right-angles were used—one for transmission and the other for reception. Two receivers were connected in series—one tuned to Hastingley (6ZB) and the other to Postling (6ZC). By this means reports from both out-stations were received simultaneously and without difficulty; and as the two out-station receivers were tuned to headquarters, orders could be transmitted to them as desired.

Conditions during the trials were by no means ideal; heavy rain was experienced while the apparatus was being installed, and severe thunderstorms occurred on the Saturday. Moreover, the Hastingley station had to be moved a distance of some $1\frac{3}{4}$ miles, owing to an alteration in the course for one of the day's trials.

However, in spite of these drawbacks, everything was carried out according to schedule, phone being worked nearly all the time, with C.W. as a stand-by when static and oscillations from curious local B.C.L.s made phone reception unreliable.

Communication was constantly maintained between out-stations and headquarters at the aerodrome, and there was great satisfaction at the efficient way in which the arrangements worked; reports being rendered to the Royal Aero Club officials, not only of the progress and position of the competing machines, but also of the safety of the pilots and passengers when forced landings had to be made. Removal of the aeroplane, when these occurred, was also greatly expedited.

Finally, mention must be made of two definite conclusions which emerged. Firstly, all field stations using portable aerials *must* have loose-coupled aerial circuits—both on transmitters and receivers; and secondly, aerial and counterpoise leads-in *must* be taken in at the top and bottom of the tent respectively and firmly staked to prevent swaying—great difficulty being experienced during the preliminary tests in keeping the wave-lengths constant.

Long-Distance Work.

By Hugh N. Ryan (5BV). **[R545·009·2**

SINCE its inception DX work has passed through a number of phases. As far as this country is concerned they were firstly, transmission between different parts of Britain; secondly, work with France, Holland, Denmark, etc.; thirdly, work with the United States; fourthly, the world-wide communication of to-day. In the earlier days of the work, one sometimes heard the question "What will happen when we can transmit all over the world?" To-day that question actually arises, and with it we enter another phase of the work—the time when mere distance is not our aim, and a station will only be credited with the use which he makes of his results and observations, and not with the results themselves.

This doubtless should always have been the case, but it is common knowledge that many of our best stations were aiming solely at "distance," and lists of large numbers of stations worked, without worrying much about the technical interpretation of their results. Far be it from me to decry their work, which has brought about the very desirable state of "world QSO" that now obtains. But that stage of the work is over, although I still receive reports for these columns, saying that a station has worked, say "25 Yanks in one night." This may be a diverting way of spending a night, but one wonders whether anything useful was done in conjunction with any of the twenty-five?

All of which is a prelude to saying that I propose altering slightly the scope of these notes, to make them more useful under the new conditions. Briefly, I propose devoting less space to the doings of the well-known, high-power stations, except when they accomplish something of special technical interest, and dealing more with low-power and definitely experimental work. To this end I want particularly to ask for reports from the many lower-powered stations, who are known to be doing a lot of work, but who perhaps, have been afraid that their reports would look insignificant beside those of the "super DX-merchants."

Since all European stations may now be regarded as "local," I hope to include (at the request of a number of Continental readers) the work of Continental stations in these notes, wherefore I ask for reports from foreign readers.

Now for the reporting. The month has been one of steady work on the 45-metre wave, with practically nothing doing on 90 metres, and not very much on 23.

2NM (900 watts) is always fairly weak at 5BV (10 miles), his phone being at times quite hard to follow on one valve. At Newcastle he is stronger than this normally, but at about midnight his signals suddenly disappear completely, or become so weak as to be unreadable. Two hours later he suddenly comes back, at about double strength. During the time he is inaudible at Newcastle he is very strong in America.

2VX (only a few watts) is of tremendous strength, a genuine R9, at 5BV (about 400 miles) late in the evening, and suddenly disappears at about 2245 G.M.T. His time of reappearance has not yet been noted.

Dutch PC7 is very strong at 5BV in the forenoon, and suddenly disappears at about 1145 G.M.T. These examples will serve to indicate the sort of phenomena experienced. In addition to this effect, it seems that a station at a short distance (100 or 200 miles) can be of widely different strengths at two other stations situated close together. For example, 2IH (Yorks) is of very different strength at 5LF and 5BV at the same time, all possibility of difference in receiver sensitiveness being eliminated. I should welcome other observations on these effects.

As to the more remote stations, the Americans are strong from before midnight until some hours after sunrise, the 1st, 2nd, 3rd, 4th and 8th districts being very easily worked on 50 watts.

The New Zealanders and Australians are to be heard between 4 and 8 a.m. G.M.T. approximately, and are also fairly readily worked, the only bar to every station above, say, 50 watts working them almost daily being that there are not enough of them to go round.

Other countries now regularly heard on 40 metres, or thereabouts, are Mexico, Brazil and Chile, and we hear the Philippine intermediate (pi) in calls from Chilian stations, but have yet to hear it coming back the other way.

The Post Office have entered the select company of "DX night-birds" with their station 5DH. He is notable for his propensity for CQ calls of enormous length, and for the worst note ever heard in London. He seems, however, a useful DX station, having been heard a great deal in America, and by South African A4Z.

A number of other Londoners are in regular operation. 6LJ recently worked z2AC and twelve Americans in one morning and has heard several stations in Chile, Brazil, Argentine and Java.

6QB heard NRRL (F. H. Schnell on the U.S.S. "Seattle") when he was in Melbourne Harbour. His own transmitter, the aerial current of which he is unable to measure, continues to be heard occasionally in U.S.A.

2GO recently worked 4SA (Porto Rico) for 25 minutes with 12 watts input.

5BV's mast, which for some time has been trying to resolve itself into a very complicated Fourier series, has proceeded to the limit and is now a "discontinuous function." The aerial is slung up temporarily, part being below the counterpoise, but the only difference (on 45 metres) is that some of the Americans report stronger signals!

2XV is even more unfortunate with masts. Mine did stay up for two years, whereas 2XV has just put up his fourth this year. He is working with 3 watts input, and with this he covers Europe as far as Germany.

5SI, who in the past has performed wonders with very low powers on 90 metres, is now working on 45, with less power than ever. Tests (on different days) with u1PL and u1CMX have resulted in communication with ¾ watt input. He contemplates a QRO to 5 watts for New Zealand!

6JV's work during the past month has been mostly on the reception side. He has followed the ARRL 20 and 40 metre tests, noting variations of strength of the stations at different times of the night. On the transmitting side, he is attempting to get as pure a note on 45 metres as he does on the longer waves. Like many others, he has not yet entirely succeeded. An H.T. accumulator is on the way.

2VR (Bristol) is a "dry cell" station using 3 watts, and has worked many parts of Europe on 100 metres. 5FS, also of Bristol, is still on 90 metres at the time of writing, but is about to start on 45.

6VP has just completed his first month as a transmitter, and (believing in starting from the beginning) he systematically covered the British Isles with 2½ watts before increasing to 10 watts.

2IH is in the curious position of working regularly with Brazil, while he had not yet succeeded in working with the United States. Another Yorkshire station, 2VO, has worked BSM (Palestine) and 1DH (Mosul) with 3 to 4 watts, 1DH reporting him as the best British station heard (100 watters, please note).

6TD is regularly to be heard on 45 metres, where he is conducting a great deal of useful DX work, being the most active Welsh station at the moment. 5OC is another very active Welsh station, who has worked chiefly on the longer waves, but hopes soon to be on 45 metres. He has worked nearly every country in Europe and several American stations.

5NJ, of Belfast, is now in regular operation though only, as yet, on dry cells. During his first month of operation he has worked most of the nearer European countries on 7 watts. He will be using higher power, with a generator, in October.

The only foreign report to hand is that of Danish 7EC. He worked stations in five American and two Canadian districts on 90 metres before descending to 40. On the latter wave he has worked Americans up to 6 000 miles, having a nightly schedule with u4SA. He has an automatic key for testing and sending CQ, which accounts for the varying "fist" of his station.

Readers will probably be interested to hear that the following schedules have been fixed by the British section of the I.A.R.U. for the exchange of messages between British stations. 0000 to 0015, daily, on 90 metres; 0015 to 0030, and 0730 to 0800, daily, on 45 metres—all times B.S.T. It is hoped that all stations will keep these periods clear for "inter British" work.

Every Sunday morning, at 0030, B.S.T., 5MO (I.A.R.U. British secretary) will send, on 45 metres, a report of I.A.R.U. work.

Please let me have next month's reports by 10th September.

Investigation on Fading of Signals.

By S. R. Chapman, M.Sc.

[R113·1

THIS investigation was undertaken by the Radio Research Board under the Department of Scientific and Industrial Research in the early part of last year. In the issue of the *Wireless World*, 12th May, 1923, an article was published inviting, through the Radio Society of Great Britain, the co-operation of amateurs in investigating the occurrence of this phenomenon during the reception of broadcasting and signals from other transmitting stations.

Pads of forms were issued to over 380 observers who were willing to assist in recording their observations and of these 118 have taken part.

A further article was published in the issue of 7th November, 1923, as an aid to observers when filling up these forms.

The following article is an analysis and report on the observations made during the period of July, 1923, to July, 1924, but before going into the details, it is necessary to make some general remarks on the records and to refer back to the system and method adopted in recording these observations.

In the first place, the 118 amateurs who have taken part are fairly widely scattered with regard to the British Broadcasting Company's stations, the majority being in England, a dozen or so each in Scotland and Wales, two in Ireland, four in the Channel Isles and one in Spain.

The majority of the observations have been taken on the B.B.C. stations, only a few observers having watched other transmitters, such as ship and shore stations, and thus all programmes of watches that have been specially arranged have been on the B.B.C. transmissions. A few observers have watched the U.S.A. broadcasting, and a note concerning their reports appears later in this article. A few have watched Ecole Supérieure and other Paris and Continental stations, but in these cases there has been no chance of comparing reports as no two observations have coincided in point of time.

All observers were asked to watch for periods of ten minutes or more, as shorter periods are hardly of any value in showing the general behaviour of the station, and to note the strengths on the forms, say, every fifteen seconds, using the figures "0" to "9" to denote various strengths. The gradation of the figures "0" to "9" and the type of form used for recording observations can be referred to in the issue of the *Wireless World* for 12th May, 1923.

As mentioned in previous articles, the greatest difficulty met with in this method of recording observations is in the programmes of the transmitting stations themselves. Most of the programmes are musical, and it is extremely difficult to decide whether a real "fade" has occurred or whether the diminution in intensity of the received signal is merely due to a pianissimo passage in the music, especially if the piece being played is unknown to the observer. Observers were asked to make notes as to whether they knew the piece or not, but very few have done so, making the analysis of the records still more difficult. This also applies if the transmission is a song; and in the case of speeches, observed change in intensity might be due to the raising or lowering of the voice, or any change in the relative position of the speaker to the microphone. Consequently, it should be stated here what has been considered for the purposes of this report as a definite "fade" when analysing the records.

In analysing an observer's report, the author has first noted what the normal strength of any transmitter is at his station. For example, say the signal strength has been designated by him as "7" or "8" during periods when the transmission has been steady with no "fading." In a subsequent watch it may be frequently recorded as dropping from the normal to "5" or occasionally "3," but it has been considered this may easily be due to pianissimo passages, or in orchestral performances a solo instrument for a few bars, and has not been reckoned as a "fade." When, however, the signal is recorded as dropping to "1" or "0," this may safely be taken as a definite "fade."

Still more care has been taken in deciding what are "fades" when the normal strength is recorded as only "5" or "6" strength. It was found impossible to make any hard and fast rules to cover all the records owing to the variety of receivers used by the many observers.

One of the general statements that can be made with regard to all districts is that they all do experience fades at one time or another. There is no district of which it can be said no "fades" exist there. A few isolated cases have sent in records with no "fades" at all, but these observers have only watched one transmitter, and then perhaps only on a couple of evenings in one month. What has happened during the other twelve months of the period under report is not known, and so no inference can be drawn as to the behaviour of other transmitters at their receiver.

Another thing which is common to all receivers is that on reception from stations which can be heard before sunset, no fades are recorded until "sunset period." Many have recorded that a little before and during sunset a "mushiness" and unstable condition is noted, and then after this transition period from day to night the signal settles down.

This is very similar to the experience we have had as to the behaviour of the bearings of transmitters on neighbouring wave-lengths working under similar conditions, *i.e.*, over land, when direction finding, and further investigations are being undertaken to see if "fading" is always accompanied by a change of bearing or *vice versa*.

There is a difference, except at short distances when it is probably existent but inappreciable, in intensity between the strength of signal received during day and night from the same transmitter at any one station, the former being weaker. This has been the experience of the observers in their reports on the B.B.C. transmitters, and as mentioned in a previous paragraph, they find some stations are inaudible to them during the day. Distance is one of the main factors in this phenomenon, and the general experience is that transmitters situated 200 miles or more from the receiver are inaudible until after sunset. It has not been found possible when analysing the reports to discover any definite distance at which this effect occurs, but it can be stated to be somewhere between 160 and 200 miles, the former being audible. However, this general statement must be qualified by stating that not only is distance a big factor in inaudibility, but the amplifier used plays an important part. The apparatus used by the majority of observers agrees with the general statement, but if a highly efficient and selective amplifier is used, combined with directional reception, it is possible to hear a B.B.C. Main Station transmitter over 400 miles distant during daylight, although, of course, the intensity is extremely weak compared with the night strength obtained with such an amplifier.

It cannot be said in any single case that the signal strength of any one transmitter will be constant from night to night for a lengthy period at the same receiver; the strength may easily be below normal one night and perhaps the next or a few nights after, considerably above. However, there is no analogy between these changes of normal strength and "fading." For instance, an observer when watching one night may find that the best he can get from a transmitter after the most careful adjustment of his receiver is below its normal strength; he cannot assume that because of this he will experience very erratic signals and marked "fading." The opposite is just as likely to occur and the signal remain constant. Similarly he cannot assume the absence of "fading" should the strength be well above normal. Consequently there is no general principle to be laid down as to the relative change of normal strength of a transmitter from night to night.

One general consideration of interest is the comparison of the number of "fades" experienced with the bearing of the transmitter observed. Briefly, it may be stated that from the analysis of the reports received it can be shown that there is no particular compass direction in which there is a preponderance in the number of "fades" recorded.

Another general consideration to be taken into account is comparison of the number of "fades" with distances between transmitter and receiver. Again there appears to be no general rule governing this, excepting that no "fades" as defined in this paper, *i.e.*, audible changes in intensity, have been recorded over shorter distances than 50 miles, transmitters situated nearer to the observer than this can be reckoned as "non-faders." Examples could be given of signals "fading" from a transmitter at a certain observer's station and yet another observer situated at a greater distance from the same transmitter records less "fading" or none. In this case, it can probably be shown to be due no doubt to the geographical features of the space intervening between the transmitter and receiver and that this plays the more important part.

One more general remark to be made on this analysis before proceeding with the more detailed part of the report, is that there seems to be no definite periodicity of the time intervals between each occurrence of "fading." During long watches no definite recurrence of fades at constant equal time intervals were observed, and from night to night, or even on the same night, fades may occur at both short and long intervals having no relation to one another. To give a better idea of these time intervals, an example can be cited where a group of fades occurred with a time interval between the maxima and the respective minima intensities of only a few seconds—*e.g.*, one record showed a group of four or five fades from "8" to "0" in times varying from 6 to 15 seconds—then the next real fade might be one minute from this group and the next say three minutes and so on. Also over long watches such as two or more hours no recurring periods could be traced with these groups of fades, the interval between them being unequal, sometimes two close together followed almost immediately by a fade to "0" perhaps lasting two minutes or more.

The analysis of these observations over this period of 13 months shows the fades to be very erratic in occurrence and type and to follow no general law, and to be independent of bearing of transmitter from receiver.

Now to consider the details obtained by the analysis of records sent in. At the beginning of the report it was mentioned that only 118 amateurs took part out of the 380 odd who requested that they might be supplied with observation forms. Of these 118 records, unfortunately, many had to be discarded as being useless. The reason for this in a few cases was that observers had watched stations, but according to their records never for more than five or six minutes at a time. Such records as these were discarded as the general behaviour of a transmitter cannot be judged from such little information, which frequently was limited to a record of the signal strength only at the beginning and end of the five minutes. Another reason for discarding some records was that they lacked any information other than that a fade occurred, and contained no note as to the moment it happened, or how frequently. Sometimes the record even omitted to mention the strength to which the signal faded, a remark only being made that the signal "Faded badly," or that there was a "Gradual fade."

Table I. (see next page) shows an analysis of the records throughout the period under review. By means of this table it is possible to trace any seasonal effect on the number of fades recorded, *i.e.*, whether they are more prevalent during the winter months than the summer. This table must be considered in conjunction with Table II., because it is obvious from Table I. that there were many more fades recorded during November and December, 1923, and January, 1924. However, at that time many more observers were working, and consequently more periods observed, although it will be seen from Table II. that the percentage is more or less of the same order.

ERRATA.

A few printer's errors occurred in our August issue, and we shall be glad if readers will note the corrections, given herewith.

(1) On p. 685, line 2, in Mr. R. M. Wilmotte's article "A Variable Resistance for Radio Frequencies" the word "nickel" should be "nickelin."

(2) The Dewey index number for Mr. Mines' article on p. 687 was given as R555.5, instead of R355.5.

(3) On p. 711, at the end of the description of Messrs. S. G. Brown's hand microphone and telephone transformer, we state that the price of the outfit is "rather high" and £11. We regret that we were misinformed, since the correct price is £7 7s.

(4) Our attention has been called to the fact that the address of the manufacturers of the "Harlie" detector—described on p. 712—has been changed to: Harlie Bros., 36, Wilton Road, Dalston, E.8.

(5) Finally, in the Appendix (p. 719) to Mr. Barton Chapple's article on the self-capacity of inductance coils, the formula for parallel circuits was given as :—

$$\frac{1}{(R + j\omega L)} = \frac{j\omega C_s + 1}{(R_0 + j\omega L_0)}$$

This should have been

$$\frac{1}{R + j\omega L} = j\omega C_s + \frac{1}{(R_0 + j\omega L_0)}$$

Further remarks which should be made with regard to Table I. are that of the 118 observers who took part, no less than 44 reports were rejected as useless under the two headings mentioned above. Also it should be borne in mind that this table does not represent the total number of *fades* recorded throughout the 13 months. It will be seen that the total number of actual *periods observed* (column 1) is 2 022, and since frequently more than a dozen fades were recorded in one period, many thousands of fades are omitted as occurring in periods shorter than ten minutes in duration. It will be seen that periods are divided into those of 10, 30 and 60 minutes' duration. Here, again, many periods have been of, say, twenty minutes, *i.e.*, intermediate between 10 and 30 minutes. In these cases only the numbers of fades occurring in the first 10 minutes are considered, as this is the only way of showing fair comparison from month to month. Also, each period of over an hour's duration has fades shown in the two previous columns of 30 and 10 minutes, for it is possible that one period of an hour's duration may only show two fades, which might have occurred in the first 10 minutes of the watch. Consequently this figure 2 will occur in the total of each of the columns for 10, 30 and 60 minute periods.

Table II. shows the total number of periods observed, together with the percentage of those in which "no fades" and "fades" were recorded. From this table there does not appear to be any definite change in the percentages throughout the year excepting perhaps in the last three months. This may probably be accounted for by the fewer hours of darkness in which the B.B.C. stations were working.

It is obviously possible to represent graphically every single record received, but this has only been done in the case where any two observations have coincided in point of time. In the earlier months these coincidences were matters of chance, but during the last three months a definite programme of watches was arranged for each night. The number of such graphs which it was possible to draw on this basis as a result of each month's observations is shown in the right-hand column of Table I. It will be seen that the number is far too few to allow any but the most general conclusions to be drawn. These may be summarised as follows :—

TABLE I.

Month.	Total No. of Periods Observed making no Allowances.	Nos. of Observers.			Records used in this analysis.		Totals of Periods in which "No FADES" recorded.			Totals of Periods recording "FADES," with No. of Fades recorded.						Total No. of Graphs possible.
		Total No. of Obsrs. recording.	No. of Obsrs. whose records are "useless."	No. of Obsrs. whose records are always under 10′.	Total No. of Observers.	Total No. of records over 10′.	Of 10′ duration.	Of 30′ duration.	Of 60′ duration.	Up to 10′		Up to 30′		Up to 60′		
										Periods Obsd.	No. of Fades.	Periods Obsd.	No. of Fades.	Periods Obsd.	No. of Fades.	
1923																
July ..	254	42	20	9	13	38	14	3	1	24	29	2	8	1	3	2
August ..	127	29	11	7	11	25	14	1	—	11	21	3	6	1	2	2
September	209	34	12	6	16	44	27	11	4	17	36	7	23	5	17	6
October	127	24	9	4	11	38	24	9	4	14	28	6	13	5	8	4
November	249	50	8	6	36	130	69	17	11	61	151	27	121	12	63	6
December	249	48	4	2	42	146	70	29	9	76	195	37	177	19	176	18
1924																
January	254	44	6	2	36	150	84	48	20	66	169	32	144	19	151	19
February	164	29	4	4	21	53	36	13	6	17	34	3	9	2	8	11
March ..	110	24	1	3	20	75	46	11	2	29	46	11	32	3	7	6
April ..	70	17	3	4	10	36	23	9	2	13	20	4	21	—	—	0
May ..	110	20	3	1	16	75	60	26	7	15	23	10	34	2	2	8
June ..	64	12	2	4	6	32	27	14	5	5	10	4	17	3	29	2
July ..	35	11	3	1	7	25	20	14	10	5	6	3	3	3	7	3
Whole Period	2,022	118	35	9	74	867	514	205	81	353	768	149	608	75	477	87

(i) Confirmation of the fact mentioned in the early part of the paper, that no fades recorded before sunset on any B.B.C. station.

(ii) There was absolutely no similarity between any of the graphs of different observers. When two or more observers watched the same transmitter, they did not record fades at the same time, even if their receivers were situated less than a mile apart.

Comparisons were made between observers situated equi-distant from the transmitter but in different directions. Still again, on superimposing the graph of one record on that of the other, no similarity could be traced.

There are some other interesting observations bearing on the effect of the intervening country which can be made from comparison between records from different observers on the same transmitter. A remarkable example is the case of Cradiff (5 WA) observed by one amateur in the north of Wales and another in the Fen district. On comparing the results of these two records, it was found that in North Wales, Cardiff was always recorded as steady and no fading, whereas in the Fen district this station invariably showed fading. Since the two observers were approximately equidistant from Cardiff, one is forced to consider the intervening country. In the case of North Wales the signal passes over the Welsh mountain ranges, whereas its passage to the Fens is over comparatively flat country. On studying the features more closely, it is seen that the great circle from Cardiff to the Fen station passes up the mouth of the river Severn and closely follows and grazes its northern coastline and then along the river; these together may be responsible for the fades in the Fen district.

Another comparison is to be made between signals received only over land and over land and sea. For example, Holywood in Co. Down, Ulster, never recorded fading on Glasgow, the intervening distance being broken land and sea, but there is practically no "grazing" effect as the waves pass over the various coastlines almost at right angles. Also London is mostly steady at Holywood, whereas Manchester is extremely erratic, yet London and Manchester lie approximately on the same great circle through Holywood, the signal from Manchester passing mostly over sea. Many other examples could be cited, and one is led to the conclusion that fading has a great deal of "local" effect when comparing fading on the same transmitter in different districts, but that in a district itself where observers are only short distances apart, the "local" effect applies only to general behaviour, *i.e.*, a given transmitter fades or not in that district, but not instantaneously at receivers within short distances of each other.

One last remark should be made with regard to some very excellent records made in Queenstown, Co. Cork. During November and December, 1923, and January, 1924, many records were compiled on both U.S.A. and B.B.C. transmitters. The general behaviour of both was similar. Sometimes incessant and rapid fades were recorded and at other times the signals remained perfectly steady. Lengthy periods have been recorded on U.S.A. when no fades were recorded, WGY being steady for one hour at Queenstown and on another occasion, Grimsby recorded 25 minutes with no fades.

In conclusion thanks are due to the Radio Society of Great Britain for their assistance in introducing this investigation to the notice of their members, and to the amateurs for the time they have voluntarily given up in its pursuit.

TABLE II.

Month.	Obsns. of 10′ duration.			Obsns. of 30′ duration.			Obsns. of 60′ duration.			Average No. of Fades per			Total No. of Obsns. recording
	No. of Periods.	% N.F.	% F.	No. of Periods.	% N.F.	% F.	No. of Periods.	% N.F.	% F.	10′ Obsn.	30′ Obsn.	60′ Obsn.	
1923													
July ..	38	36.8	63.2	5	60.0	40.0	2	50.0	50.0	0.763	1.6	1.5	13
August ..	25	56.0	44.0	4	25.0	75.0	1	0.0	100.0	0.84	1.5	2.0	11
September	44	61.3	38.7	18	61.0	39.0	9	44.4	55.6	0.82	1.275	1.8	16
October ..	38	63.1	36.9	15	60.0	40.0	9	44.4	55.6	0.737	0.867	0.8	11
November	130	53.2	46.8	44	38.6	61.4	23	47.8	52.2	1.16	2.75	2.74	36
December	146	48.0	52.0	66	44.0	56.0	28	32.2	67.8	1.335	2.68	6.285	42
1924													
January ..	150	56.0	44.0	80	60.0	40.0	39	51.25	48.75	1.125	1.8	3.88	36
February	53	68.0	32.0	16	81.25	18.75	8	75.0	25.0	0.642	0.562	1.0	21
March ..	75	61.4	38.6	22	50.0	50.0	5	40.0	60.0	0.613	1.45	1.4	20
April ..	36	64.0	36.0	13	69.2	30.8	2	100.0	0.0	0.556	1.615	0.0	10
May ..	75	80.0	20.0	36	72.2	27.8	9	77.8	22.2	0.307	0.945	0.2	16
June ..	32	84.4	15.6	18	77.7	22.3	8	62.5	37.5	0.313	0.945	3.625	6
July ..	25	80.0	20.0	17	82.35	17.65	13	77.0	23.0	0.24	0.1765	0.528	7
Whole Period	867	59.25	40.75	354	58.0	42.0	156	52.0	48.0	0.385	1.718	3.6	74

Rectifiers for High-Tension Supply.

Part II: Electrolytic Rectifiers.

By R. Mines, B.Sc. **[R355·5**

Theory and practice in electrolytic rectification are dealt with in this part, and some notes, both on the choice of materials and the construction of cells, are given.

Electrolytic Conduction.

THE distinguishing feature of the conduction of electricity through electrolytes is the chemical reaction that accompanies the passage of the current. Now an electrolyte is essentially a *solution* of some substance in a solvent, most commonly water; and the characteristic of a conducting solution that concerns us here is the *partial dissociation* or chemical decomposition of the dissolved substance when it is in solution. In general the molecule of the dissolved substance is split into two component parts, the "acid radicle" and the "basic radicle"; the former of these is found to possess a negative electric charge, and the latter a positive charge.

Thus when a unidirectional P.D. is applied between two electrodes dipping in such a solution (see Fig. 1), a "migration" sets in; the acid radicles tend to collect at the positive electrode, and the basic radicles at the negative electrode. On reaching the surface of the electrode each radicle is either precipitated, or reacts with the solvent or with the electrode material, depending on their chemical affinities; in doing this, its charge is delivered to the electrode, and it is the passing along of charges in this manner that constitutes the current flow in the electrolyte.

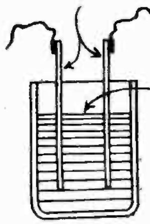


Fig. 1.

The accumulation of the products of this reaction leads to a condition of asymmetry in the cell, and gives rise to a "back E.M.F." opposing the original flow of current. Thus in the simple case of the electrolysis of impure water using platinum electrodes (or other material that is chemically inactive towards the electrolyte and the products of its decomposition), as soon as there is a sufficient layer of bubbles of Hydrogen and Oxygen adhering to the respective electrode surfaces, a back E.M.F. of about 1.7 volts comes into action, and if the P.D. applied to the cell from the external supply is less than this critical value, called the "Polarisation E.M.F.", current will practically cease to flow.

In passing it may be noted that if the supply is disconnected and the electrolytic cell is short-circuited through a galvanometer, a momentary current flows, due to the back E.M.F., in the reverse direction through the cell, which thus acts as a "gas" battery of limited capacity; the layers of bubbles disappear and the cell reverts to a symmetrical state, chemically speaking. The commercial utilisation of this principle with solid products of electrolysis is seen in the Secondary Battery—the original Planté cell consisted of two plain lead electrodes dipping in dilute sulphuric acid. Similarly if a "chemical asymmetry" is deliberately introduced into a cell by suitable choice of materials, current may be generated spontaneously on closing the external circuit, without any previous "charging"—this is the Primary Battery.

One would expect to be able to use some of these conditions of asymmetry for the purpose of rectification, since a rectifier is only an asymmetric conductor. Actually however this is not practicable; because if the electrical asymmetry of the cell is rendered independent of current flowing through it, by choosing suitable materials, it becomes, as we have seen, a battery, capable in itself of supplying the unidirectional power required. In any case, since with no known combination of materials does the back E.M.F. obtainable exceed about 2½ volts, the number of cells it would be necessary to connect in series becomes excessive for the high-tension supply even of a receiving set.

Electrolytic Valve Action.

Nevertheless, with some combinations a true "valve action" is obtainable. Usually this occurs when one of the products of the chemical reaction is a bad conductor, and is deposited as a coherent film on one of the electrodes and partially insulates it from the electrolyte (so that the resistance of the cell increases). The P.D. applied to the cell may be increased considerably (to a hundred volts or so)—there is no definite value at which the cell will "break down."

If the P.D. is reversed, the slight leakage current (now also reversed) causes decomposition of the badly-conducting film till it disappears and the cell resumes its original conducting condition. By choosing suitable electrodes the action may be limited to one direction only of the current flow, and a cell thus constituted should act as a good rectifier; but there is this limitation, that a considerable quantity of electricity is required to form the insulating film, and with normal current density this takes a considerable time to flow. So the arrangement is of no use for our purpose after all, since usually it is required to rectify an alternating current with, for example, a frequency of a public supply.

Electrolytic Rectification.

The phenomenon described above is called "ionic" valve action, because it depends on the behaviour of the charged radicles, which are commonly called electrolytic "ions."

With certain combinations of materials, however, a phenomenon called "electronic" valve action is obtained, and we shall discover that with its aid rectification is in some cases possible at frequencies approaching a million cycles per second.

It is evident that the valve action in this case cannot be due to the insulating property of the film, since such film (whether solid or not) has to be formed and destroyed for each cycle of the alternating current. Nevertheless the presence of such a film on the anode is still necessary before rectification can take place—for a new anode, or one which has been standing idle, must always be "formed" before use. But according to the latest theory, this solid film is porous, and in the pores are formed bubbles of gas—these bubbles are next to the anode surface, the remainder of each pore being filled with electrolyte (see Fig. 2). This condition of a porous film holding gas in its pores is permanent so far as concerns the cycles of the alternating current; and it is necessary to look to some inherent

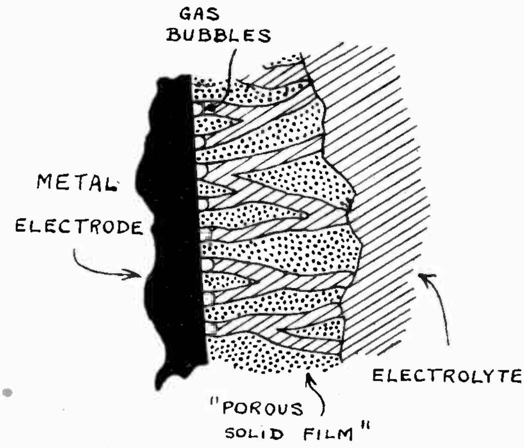


Fig. 2.

property of the combination for an explanation of the valve action.

Although the resistance of the threads of electrolyte in the pores of the film will be higher than that of the bulk of the electrolyte in the cell, it bears no comparison with that of the gas layer; in fact, the solid parts of the film and the gas bubbles together form a complete insulating jacket for the anode, and no appreciable current is able to pass through the cell with normal P.Ds. Note however that this insulating jacket (the effective thickness of which may be under a millionth of a millimetre) takes practically the whole potential drop; and if this is raised too far, the potential gradient becomes such that the gas exhibits first a glow discharge, then a spark discharge (sparks can be seen at the electrode surface of a rectifier cell that is being operated near its limit of P.D.), and finally its resistance breaks down in known manner.

On the face of it one would have expected that (subject to this P.D. limitation) the gas layer would preserve the insulation of the electrode with the P.D. in either direction. But here we must anticipate a little our consideration of gaseous conduction, and take into account the fact that it is an asymmetric process, unlike conduction through an electrolyte described above. As with an electrolyte, both positively-charged and negatively-charged, carriers may take part in the conduction process; but with a gas it is not necessary for an exact balance to exist between the numbers of the two kinds of carriers; and further, the negative carriers may be, (and in fact most commonly are,) plain electrons, whereas the positive ones are of necessity particles of matter of some kind or other. Therefore, in the case of a thin film of gas, conduction will take place quite readily if electrons are available, if their "mean free path" is greater than the film thickness. On the other hand, if positive carriers only are available the conduction cannot take place so readily—a very much greater force is required to make them traverse the gas film, since though they carry only the same charge (in magnitude) they have a mass thousands of times as great as the electrons. The effect of this asymmetry is that such a film "breaks down" to the passage of electrons very much more readily than to the passage of material carriers.

In the particular case of an electrolytic valve, the gas film is bounded by electrolyte on one side of it and by a metal electrode on the other. The electrolyte can offer only charged "radicles," *i.e.*, particles of matter; whereas the metal, being a conductor of electricity, contains free electrons. When an E.M.F. is applied to the cell in the correct direction (making this electrode *anode*) some of these electrons will traverse the film; thus the cell conducts current: but with the P.D. in the reverse direction, as long as it is below the critical value, "nothing happens," because there is not force enough available to drive any appreciable number of heavy material particles across the film.

This explanation of the action is supported by the following experiment: if a metal plate is brought up quite close to the active electrode and held there by an insulating handle, the cell resistance falls, rectification ceases, and sparks pass between the plate and the electrode. In effect the plate makes available a supply of electrons on the second side of the gas film.

Practical Application.

One of the most important factors in the choice of a suitable electrolyte is its sensitivity to temperature. Primarily, both it and the electrode material should be chosen so that the solid film formed shall not be decomposed under a reasonable rise of temperature. The condition is helped by choosing an electrolyte which keeps sufficiently cool—but it is not necessarily best to use the most *efficient* electrolyte, *i.e.*, one which will have minimum losses at the commencement of a run; for it may have a positive temperature coefficient, and this means that any rise in temperature that occurs causes an increase in the resistance, and hence in the heat generated in the cell. It is easily possible for the rate of heat generation to increase faster with temperature than the rate at which heat can escape from the cell; under these conditions the temperature is unstable, and rises rapidly until the rectifying property of the cell is destroyed.

Much labour has been expended in determining what materials will support the rectifying action and at the same time will maintain satisfactory operation over a period of time. Among others *Codd*[1] gives some interesting results; so also does *Nodon*.[2] Modern practice shows that *Ammonium Phosphate* (a strong aqueous solution) is favoured above others by many experimenters; *Sulphuric Acid* (dilute) is also being used in some commercial rectifiers.

The acid electrolytes have the higher conductivity and so give rise to less heating than the others, which is a useful advantage; but in general the breakdown P.D. of the cell is lower, necessitating a larger number of cells for a given supply P.D.

For the electrodes the choice of suitable material seems to have been made more readily. The active electrode must be one that yields the required porous film under the electrolytic action; and, as already stated, the film should be stable under rising temperature.

Aluminium fulfils these conditions—it oxidises readily even in ordinary air, and the oxide forms a tenacious film; its compounds usually require a high temperature for their decomposition. Further, it is cheap

[1] *Elec. Review.* Vol. 93, p. 324, 2nd Mar., 1923.
[2] See Jolley's *Alternating Current Rectification*, p. 301.

and easy to work, and is easily procurable in forms to fit any type or rectifier cell. It has in fact become the most popular material with the radio experimenter.

E. H. Robinson,[3] who has done useful pioneer work in adapting this kind of rectifier for high-tension supplies, used aluminium and worked it at a current density of about 5mA/cm.[2] [4] (for a 50 cycle supply). Thus a strip 1 cm. wide and with 5 cm. of its length immersed in the electrolyte (ammonium phosphate was used) the total area is 10 cm.[2] and the cell will deliver about 50mA of rectified current.

This combination has the further advantage of withstanding a high back P.D.—when in good condition 120 to 140 volts may be allowed for each cell; thus for a D.C. output of 1 000 volts, 10 cells were connected in series to form each "rectifier group," giving a substantial margin for deterioration of the cells.

Tantalum is being used by an American firm in the "Balkite" Battery Charger.[5] Here the electrolyte is sulphuric acid as used in accumulators. The current density of the active electrode (which is a thin sheet) is 0.5 amp/cm.[2]—a hundred times as great as the figure mentioned above for aluminium. The high cost of the electrode metal does not therefore weigh so much because of the small size required. This combination is not, however, suitable for high-tension supplies because the maximum back P.D. allowable across the cell is only 27 volts.

Tungsten has been tried successfully by L. H. Walter[6] as an anode with different electrolytes. In one cell the tungsten filament from a 60-watt lamp and a lead cathode were immersed in sulphuric acid (sp. gr. 1.2); a rectified current of 0.5 amp was obtained, giving a current density of about 4 amp/cm.[2], which is eight times the value quoted for tantalum.

It has also been proposed recently[7] to use a colloidal suspension for one or both of the electrodes of an electrolytic rectifier, a porous membrane being used to separate the colloid from the electrolyte. Judging, however, from some experiments published in a French radio journal on their use of colloids for wireless detection and amplification (using immersed electrodes analogous to those of the thermionic valve), it would appear that such a colloid would not be sufficiently stable under the influence of an electrostatic field.

The *inactive electrode* is primarily a means of making electrical connection to the electrolyte, and for this function to be unimpaired there should be no chemical action between the two when the cell is working (or when idle). *Iron* and *Graphite* have been frequently used, but *Lead* has been found the most convenient for experimental work.

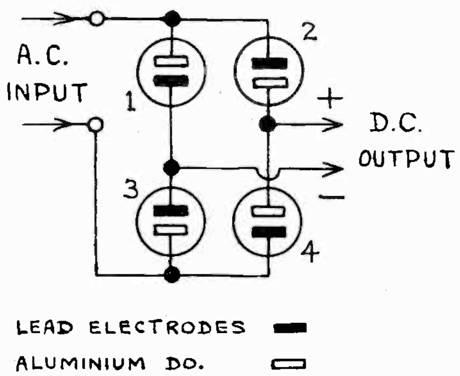


Fig. 3.

Rectifier Circuits.

We have seen that the fundamental form of chemical rectifier cell has two electrodes constituting its two poles, each having a terminal for connection to the external circuit; no "auxiliary supplies" are required, as, for example, there are with a valve. Thus in the rectification circuits given in a previous article[8] the cell may be connected directly in circuit at the points marked R_1, R_2, etc.

In some instances, however, a simplification is possible, in so far as two units may be combined into one. This is done by putting the four electrodes (belonging to the two cells) in one pot, with the same electrolyte; then the two of like kind which are normally connected together externally are replaced by a single one. Obviously it is not possible to combine into one electrode two of a different kind, since their functions are different. Thus in Fig. 3,

[3] E.W. & W.E., Vol. I., p. 154, December, 1923.
[4] This figure appears rather low.
[5] Described in E.W. & W.E., p. 429, April, 1925. See also Abridgment of Patent No. 235 658 in *Patents Journal* of 12th August, 1925.
[6] *J.I.E.E.*, Vol. 43, p. 547, 1909.
[7] See Abridgment No. 224 871, *Patents Journal*, 14th January, 1925.
[8] E.W. & W.E., Vol. I., p. 580, July, 1924.

it is impossible to combine the pairs of cells R_1 and R_2, or the pair R_3 and R_4.

There is also a second limitation, as to which kind of electrode may be made common. For it must be remembered that in such a combination cell there are three electrodes, one of one kind, and two of the

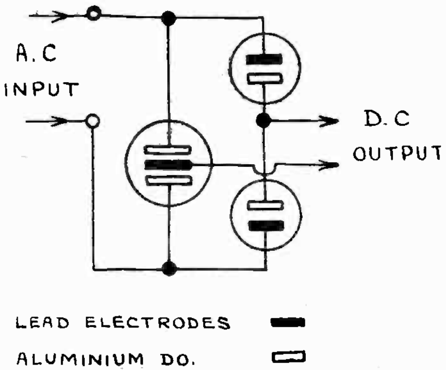


Fig. 4.

other kind. If, for example, two lead electrodes and one aluminium one were used (*e.g.*, replacing the pair of cells R_2 and R_4 in Fig. 3), the immediate result would be a short-circuit of the alternating supply, since the lead electrodes, whose sole function is to make connection with the electrolyte, are in effect connected together. It is possible, however, to use two aluminium electrodes with a common lead one (*e.g.*, replacing the pair R_1 and R_3 in Fig. 3), because when these are formed as described above they are capable of withstanding the full P.D. in one direction; and since they are connected to opposite poles of the alternating supply, with the potential of the electrolyte at an intermediate value, only one of them at a time will be passing current. The rectifier action is thus preserved. (See Fig. 4.)

Similarly when a two- or three-phase supply is being used, it is possible to use a single cell for all the phases, provided the connections are such as to require a separate aluminium electrode for each phase and a common lead one.

The Capacity Effect.

When in action, the active electrode is insulated from the electrolyte by a composite layer; the total thickness of this depends mainly upon the time the rectifier has been in use and the P.D. applied to it —it may reach a millionth of a millimetre. But the "effective thickness of insulation" is the spacing between electrode surface and electrolyte maintained by the gas in the film; and this is a much smaller quantity.

Hence even though we assume that the "gas film" has unity dielectric constant, the two conductors (electrode and electrolyte) in such close proximity from a condenser with a very high capacity relative to the area of its plates; in fact, capacities of over 100μF. per square centimetre may be attained.

This property has been used for some time past in the "electrolytic condenser"; one of these units of 30μF. occupies about the same space as a 2μF. paper condenser. The device may be used as a reservoir condenser on a single rectifier circuit (see Fig. 5), where the output P.D. does not exceed the safe limit for a single cell. Here the D.C. output P.D. supplies the unidirectional polarising P.D. which is necessary to keep the condenser electrodes "formed."

Obviously when arranged as shown the two cells may be coalesced into a single one with a common lead cathode, in the manner stated above. This arrangement (as devised by Messrs. Siemens for battery charging) is shown in Fig. 6. To provide an adequate value of the smoothing capacity the "condenser" electrode is made up to sixteen times the area of the "rectifier" electrode.

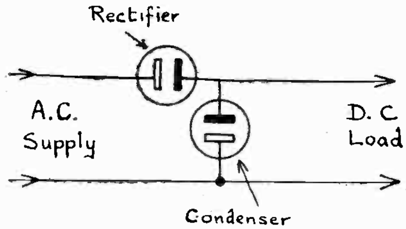


Fig. 5. *Use of Electrolytic Condenser.*

Use of Higher Frequencies.

The effect of this capacity on the rectifier is that a heavy charging current is taken when the applied P.D. passes zero and builds up in the direction for which the cell is an insulator. Similarly when the P.D. falls from its maximum value to zero again a corresponding discharge current flows (this is followed during the remaining half cycle by the load current in the same direction but containing no capacity current). The charging current wave is thus far from being a "sine wave leading by 90° on the P.D. wave"; but it is seen to contain such a wave as its fundamental component, and its effect is similar to that of a condenser connected across the rectifier cell.

If a rectifier normally designed for a power frequency is used on a supply of, say, 10 times the frequency, it will take a capacity current 10 times as great. This will in many cases be equivalent to a short-circuit on the alternator or transformer supplying the power, and obviously no rectified output will be obtainable. The first consideration, then, in endeavouring to work on higher frequencies is to reduce this capacity effect; this can be done only by reducing appropriately the area of the active electrode exposed to the electrolyte. This point and other considerations have been dealt with by E. H. Robinson.[9]

It must be borne in mind also that to use a *smaller cell* is not sufficient, for probably the losses will be a larger proportion of the input at the higher frequencies, and the cell must be capable of dissipating these as heat without too great a rise in temperature. Actually, the higher the frequency, the higher is the current density that must be used on the active electrode.

[9] E.W. & W.E., Vol. I., p. 672, August, 1924.

Robinson (*loc. cit.*) uses a current density of 0.25 amp/cm.[2] at 500 cycles, being 50 times his value for 50 cycles, with aluminium

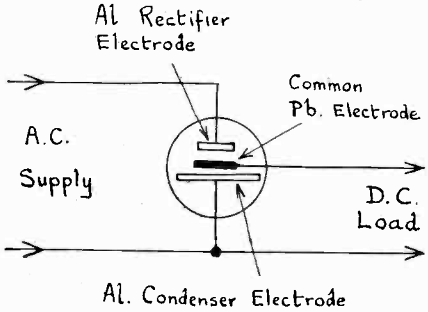


Fig. 6. *Messrs. Siemens' Connection.*

electrode. Thus with electrodes of tantalum or tungsten it will be increasingly difficult to produce a satisfactory high-frequency rectifier.

An alternative method of reducing the capacity effect that has been proposed is to use the electrolytic salt in a molten state instead of in aqueous solution; with fused potassium nitrate, rectification has been successfully accomplished at a frequency of 300 000 cycles per second.[10]

[10] See also Correspondence in E.W. & W.E., Vol. I., p. 746, September, 1924.

A Variable Coupling Unit.

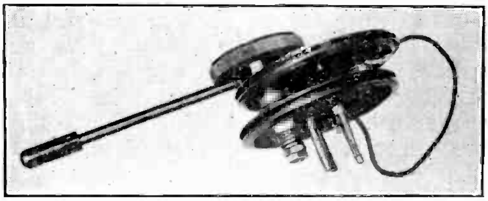
A VARIABLE coupling sent us recently by Midland Radiotelephone Manufacturers, Ltd., Brettell Lane Works, Stourbridge, has been designed to take the place of plug-in anode and reaction coils.

Our photograph shows the construction of the unit, and it will be seen that the two coils are wound between circular ebonite discs. The under disc of the fixed coil is fitted with four split pins arranged to fit into an ordinary valve-holder. The second coil is capable of rotation about a pivot which is screwed through the fixed coil. The ends of the two coils are connected to the four pins. Control is obtained either by the knob shown or by an extension handle.

The finish is exceptional; all the brass parts are well lacquered, and the ebonite is highly polished.

We measured the inductances of the coils of the unit sent us (range: 250-650 metres) and found the fixed coil to have an inductance of 209μH. That of the moving coil was 199μH.

These results show that the coils of the unit correspond approximately to standard plug-in coils of 75 turns. The maximum coupling coefficient was found to be 28 per cent. The minimum was very low, but never became negative.



The Mellowtone Reaction Unit.

The component is made in four sizes, to cover four wave-length bands, with a reasonable overlap: 80-250, 256-650, 600-1 650 and 1 500-3 000 metres, priced at 5s. 6d., 5s. 6d., 7s. 6d. and 10s. 6d. respectively.

For the Esperantists.

A GLIMPSE AT ESPERANTO.

The Alphabet.

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

No Q, W, X, or Y.

Pronunciation.

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

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

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

Accent always on the second last syllable. Phonetic spelling. **-O** is the ending of the **NOUN. ADJECTIVES** end in **-A.**

Nouns and adjectives form the **PLURAL** by adding **-J.**

The simple **VERB** endings :—

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

N marks the **ACCUSATIVE** (direct object). **ADVERBS** end in **E. NO IRREGULARITIES. NO EXCEPTIONS.**

Distordado. [R800

Serio de artikoloj verkitaj de teknika spertulo por montri la kaŭzon de la nebona tonkvalito de nuntempaj aparatoj, kaj kiumaniere oni povas ĝin eviti.

Parto II.

KIEL UZI LA LASTAN VALVON.

La antaŭa parto pritraktis nur unu punkton, la neceson utiligi valvon kapablan porti sufiĉan potencon. Ni montris, ke la malfacileco okazas nur je la lasta ŝtupo de aparato por hejma laŭtparolila funkciado, kaj ni faris komentarion pri nuntempaj valvoj taŭgaj por tiu ĉi celo.

En la nuna parto ni intencas doni konsilojn pri la *uzado* de la valvo.

Ni jam diris, ke la unua estas valvo, kies karakterizo estas rekta trans amplekso de kradtensio almenaŭ egala al tiu de la "svingiĝo" naskita de la envenanta signalo, t.e., ĉirkaŭ 15 voltoj por la lasta valvo en aparato, kiu emisias bonan laŭtparolilan fortecon en mezgranda ĉambro. Ne malfacile estus pruvi tiun ĉi neceson, sed por ŝpari tempon ni denove diros, ke ja estas necese funkciigi je la "rekta" parto de la kurvo se ni deziras eviti distordon.

La longeco de la "rekta" parto varias laŭ la filamenta tensio, kiel oni vidas per Fig. 1. Tial, la unua konsilo al la uzanto estas :—

SUFIĈE VARMIGU LA FILAMENTON.

Jen kelkeda proponitaj tensioj minimumaj por diversaj tipoj, kalkulante 15-voltan svingiĝon. Ili estas, kompreneble, nur proksimumaj. Poste ni montros kiel fari definitivan indikon :—

Tipo.	Taksitaj Voltoj.	Minimumaj Voltoj.
L.S.5	4.5	3.25
625	5.5—6	5
435	4	3.5
606	6	5.5
312	3	3
240	1.8—2	2

Due, supozante ke la "rekta" parto estas sufiĉe longa, estas alia punkto. Eĉ je la momento, kiam ĝi estas plej pozitiva, la krado devas ĉiam esti negativa rilate al la filamento. Ni klarigu alimaniere; se estas svingiĝo 15-volta, kaj estas konstante —5 voltoj ĉe la krado, tial la svingiĝo estos de $-12\frac{1}{2}$ voltoj ĝis $+2\frac{1}{2}$ voltoj, sed tio estas malĝusta. Ni devus plialtigi la kradtension ĝis almenaŭ $7\frac{1}{2}$ voltoj, kiam la svingiĝo devos esti de —15 ĝis 0. Estas efektive pli sendanĝere uzi 8 aŭ 9 voltan kradtension, tiel ke la plej pozitiva loko de la svingiĝo estos —1 aŭ —2 voltoj. Sekve de tio, ni recevas nian duan konsilon :—

ĈIAM UZU KRADTENSION DE PLI OL DUONO DE LA SVINGIĜO.

Oni notas, ke unu, aŭ eble du piloj, sufiĉos por ĉiu escepte la lasta valvo, por hejma funkciado.

LA NECESO POR MILIAMPERMETRO.

La lasta punkto decidota estas pri la altatensia voltkvanto; tion jam fiksis definitive la antaŭaj konsideraĵoj. Konsiderante, ekzemple, la kurvon CD de Fig. 2, estas bone sciite, ke la efekto de ŝanĝo de la a.t. voltkvanto estas fari kurvon samformatan sed movitan dekstren aŭ maldekstren, kiel, ekzemple, la punktita kurvo por 200 voltoj. Se ni deziras kaŭzi la kradon svingiĝi de C ĝis D, t.e., 22-volta svingiĝo, oni povas facile vidi, ke la *konstanta* krada tensio devas interrespondi kun punkto mezvoje inter ili, t.e., la punkto G. Tie ĉi la kurento estas 14 miliamperoj, kaj tial ni devas nur almeti variantajn anodtensiojn ĝis, kun la kradtensio je 12 voltoj, la anoda kurento estas 14 miliamperoj.

Ĉe tiu ĉi valvo kaj filamenta varmeco, nia norma svingiĝo de 15 voltoj varias de C ĝis H (−22 ĝis −7). La interrespondanta meza punkto estas K, 11 miliamperoj, kaj tio estas havigenda per 8 voltoj kradaj La voltkvanton altatensian bezonatan ne montras la kurvo, sed ĝi estas proksimume 190.

Kaj jen, nunokaze, niaj legantoj certe ekkrios pro konsterno aŭ eĉ moko. "Ho ne, tute senutile! Ni ne havas miliampermetron, kaj iuokaze la fabrikistoj ordonas, 'Uzu 100 voltojn,' kaj ni havas nur unu baterion."

Al tio ni respondas, "Se vi *ja* posedus miliampermetron, vi baldaŭ uzus 190 voltojn, kaj tiam vi eble ĝuus bonan ricevadon." La miliampermetro senpere anoncas, ĉu ekzistas distordo pro la valvoj.

Jen la kialo. Se la valvoj ne funkcias ĉe la rekta parto de siaj kurvoj, ili, plimalpli, rektifos. Tio signifas, ke pligrandiĝo ĉe la malaltfrekvenca enmeto produktos definitivan ŝanĝon de la kontinukurenta anoda kurento, kaj la miliampermetro, kiu estas kontinukurenta instrumento, ekmoviĝos je ĉiu laŭta tono. Se ne ekzistas distordo valva ĝi restos tute konstanta.

Oni rimarku, ke la metro ne devas esti absolute preciza—ne gravas se ĝi montras 8 miliamperojn kiam estas nur 7.5; ĉar ĝia ĉefa funkcio estas proksimume indiki la kurenton fluantan, kaj samtempe, per ekmoviĝo, montri ian *ŝanĝon*.

Tia metro estas aĉetabla je tre malkara prezo, kaj devus esti enkorpigita en ĉiun bonkvalitan aparaton laŭtparolilan. Per ioma manipulo, oni povas aranĝi, ke ĝi indiku ankaŭ la filamentajn tensiojn kiam bezonataj, tiel ke la uzanto faris ĉion necesan por liberigi sian aparaton kontraŭ valva distordo.

FUNKCIADO SEN KURVO.

Ĝi estas ankaŭ uzebla por "elekti" valvtensiojn sen kurvo karakteriza laŭjene: Funkciigu la aparaton kun la metro enmetita en unu aŭ alia altatensia konduktoro, kaj kun la ĝusta kradtensio ĉe la valvo. Alkonduku la taksitan filamentan tension, kaj observu la metron dum vi atingas la elmetan fortecon bezonatan, la alta tensio estante, ekzemple, 120 voltoj. Se ĉiu laŭta signalo *pligrandigas* la altatensian kurenton, altigadu la altatensiajn voltojn ĝis tio jam ne okazas. Se vi troŝarĝas, ĉiu laŭta signalo *malpli-*

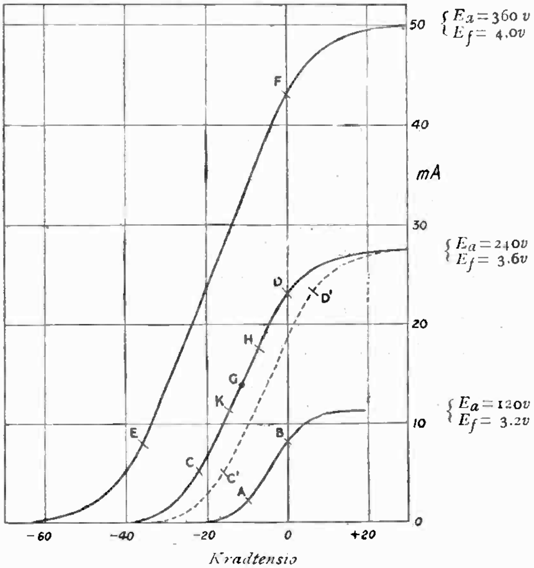


Fig. 1.

grandigos. Se, je unu kvanto de alta tensio, la montrilo vibras nedifinite, jen pligrandigante, jen malpli-grandigante, tio estas signo, ke la filamenta varmeco ne sufiĉas. Oni ĝin plivarmigu, kaj faru novan provon. Se ne estas eble aranĝi, ke la montrilo restu konstanta, kun la plena taksita tensio ĉe la filamento, uzu pli potencan valvon.

Efektive, por praktika uzado, ne ĉiam estas absolute necese, ke la metro restadu precize konstanta. Oni devas memori, ke la inĝenieroj ĉe senda stacio ŝanĝas la modulon, por ke ĝi tenu sufiĉe bonan fortecon aŭ por parolado aŭ por granda orkestro. Estas tamen diversaj subitaj bruoj, kiel ekzemple, la bato de tamburo—kiuj kreas tre grandan svingiĝon, kaj per transformatore-kuplita amplifikatoro, oni povas permesi, ke tiaj bruoj estu iomete distorditaj, sen grava perdo de kvalito. Ankaŭ, la metodo aludita permesas, ke oni vidu distordon plibone ol ĝin aŭdi. Oni trovos, ke malmulta ekmovigo de la montrilo indikos distordon ne rimarkitan de la ordinara orelo.

Se oni insistus, ke eĉ la plej laŭta malofta sono ne ekmovigu la montrilon, oni devus kalkuli por svingiĝo, de ĉirkaŭ 30 ĝis 40 voltoj, kiu bezonus tre grandajn kradtension, altan tension, kaj anodan kurenton.

La verkanto trovas, ordinare, ke kradtensio de 6 ĝis 8 voltoj, kun 120-150 voltoj altatensiaj, kaj anoda kurento de 5-7 milamperoj ĉe la lasta valvo, funkcias tute bone ĉe la plimulto de la altpotencaj valvoj cititaj. Estas ja videbla ekmoviĝo de la metra montrilo okaze de laŭta muziko, sed la distordo estas nerimarkebla al iu ajn, escepte treege lerta muzika kritikisto; kaj la plimalaltaj tensioj kaj anodaj kurentoj nature multe ŝparas altatensiajn bateriojn. Sed oni ne tro kompromisu.

FINO.

Estas kaŭzoj kial ŝoke- aŭ rezistance-kuplitaj amplifikatoroj estas pli sensitivaj tiurilate, kaj oni devas tre zorgi pri ili. Punkto citinda pri tio, estas, ke la altatensiaj voltkvantoj pritraktitaj en ĉi tiu artikolo estas tiuj, *ĉe la valvo mem*. Se estas rezistanco en la anoda cirkvito, la *bateria* tensio devas esti pligrandigita. Tio ne koncernos nin, se ni juĝos per la anoda kurento montrita de la metro, nur altigante la voltojn bateriajn ĝis la kurento estas ĝusta.

Resumi—Por eviti distordon pro la valvoj—

1. Uzu valvon kun sufiĉa elmeta povo: por hejma funkciado en tre granda ĉambro; L.S.5; granda ĉambro, tipon 625 aŭ 435; mezgranda ĉambro, tipon 606 aŭ 312; malgranda ĉambro, tipon 245. Oni povas uzi ian tipon por ĉambro *plimalgranda* ol tiu, por kiu ĝi estas rekomendita. Tio estas por la lasta ŝtupo. Por antaŭaj ŝtupoj, uzu ian ajn valvon,

2. Donu al la lasta valvo kradtension plimalpli laŭjene: Tre granda ĉambro, 20 voltoj; granda ĉambro, 10 voltoj; mezgranda ĉambro, 6 ĝis 8 voltoj; malgranda ĉambro, 4 ĝis 6 voltoj. Kompreneble tiuj tensioj estas nur proksimumaj; oni devus kontroli ilin per provoj. La antaŭaj valvoj ordinare ne bezonos pli ol $1\frac{1}{2}$ aŭ 3 voltojn.

3. *Enmetu miliampermetron en la anodan cirkviton*, kaj alĝustigu la altan tension ĝis oni vidos nenian ekmoviĝon ĉe la metro dum laŭtaj sonoj. Tio kredeble bezonos treege plimulte de alta tensio ol ordinare uzata, sed ne timu. La rezulto meritos ĝin.

La ĉi-supraj instrukcioj bone pritraktas tion, kio, laŭ la opinio de la verkanto, estas la plej ofta kaŭzo de distordo ĉe hodiaŭaj aparatoj—la tipo de valvo uzenda, kaj kiel ĝin uzi.

A Novel Combined Rheostat and Potentiometer.

THE Igranic Electric Co., Ltd., of 149, Queen Victoria Street, E.C., have recently produced some novel components, including their standard filament rheostats, combined with either a standard 300 ohm potentiometer, a high resistance potentiometer (30 000Ω), or a variable grid leak (0-5 MΩ). The low resistance rheostat is of the usual wire-wound type, while both the H.R. potentiometer and the grid leak are of the graphite type.

The Igranic component described herewith.

A base of moulded material is provided with a circular, raised portion, over which a graphite rod, mounted as a spring plunger, rotates. Thus it not only makes contact, but replenishes the supply of graphite on the raised portion, which forms the resistance element. In the case of the grid leak, the raised portion of the moulded base is smooth, but that of the potentiometer is made with a number of concentric circular grooves, which hold more graphite, and thus give a lower resistance than in the case of the grid leak.

In each case the two resistances are controlled by two concentric knobs. The components are fitted with the requisite terminals, one being common in each case.

These components are very neat in construction, and take up no more room on the panel than does the filament rheostat alone.

The prices are: rheostat and low resistance potentiometer, 9s.; rheostat and H. R. potentiometer, 8s.; rheostat and grid leak, 8s.; The rheostat can be supplied with resistances of 4, 6, 8 or 10 ohms.

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.

Proposed Institute of Radio Engineers.

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

SIR,—I think it has been quite clear in all the correspondence that the above Society was proposed because there did not appear to be any body in existence in this country which catered sufficiently for the growing number of wireless engineers.

I am very pleased to say that by invitation of the Committee of the Wireless Section of the Institution of Electrical Engineers, I was present at a meeting of the Committee which took place on Friday, 24th July. Matters were discussed very fully and I must thank the Committee for the businesslike manner in which they dealt with the subject. For the present it is sufficient for me to state that I am satisfied that entrance into the I.E.E. by those professionally engaged in wireless matters is not as difficult as I had imagined, and that it is realised by the Institution that radio matters are of great and growing importance.

I would like all those who have written supporting the proposed Society to feel that they have done a great deal of good in demonstrating the need of more activity in wireless matters.

Further criticisms on the position after perusing any statement the Council of the I.E.E. may make in the Technical Press can be sent to Mr. Y. W. P. Evans, 66, Oxford Road, Manchester. All our friends may rest assured that their interests will be well looked after.

J. NELSON.

7, High Street,
Prescot.

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

SIR,—You will probably have read an announcement in the electrical journals to the effect that the question of a new Wireless Society was discussed at a recent Committee meeting of the I.E.E., at which Mr. Nelson was present by invitation. The statement goes on to say that "The definite conclusion has been arrived at that there is no need for a new body." As Hon. Secretary of the proposed Association I have been asked to state that the definite conclusion arrived at is only definite in so far that it should be augmented by the words "should it be proved conclusively that the Radio Engineering Section of this country is fully catered for by the Wireless Section of the I.E.E."

I am to add that before this can be proved, the statement which is shortly being issued by the Committee of the I.E.E. will have to be studied and commented upon by those engaged in the Radio profession.

Y. W. P. EVANS,
Hon. Sec. Temp. Proposed Radio Institute.

66, Oxford Road,
Manchester.

Strength of Atmospherics.

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

SIR,—The following account of some rough measurements taken of the strength of atmospherics at different wave-lengths may be of interest.

The receiver used for these tests was an aperiodic aerial arrangement with two L.F. valves of the D.E.5 type. A V.24 was used in the detector side, and 60 volts H.T. was put on all valves. A Silvertown galvanometer with a 90° scale was connected in series with a pair of 2 000 ohm phones, and when no signals or atmospherics were being received the needle stood at zero. During the tests, a thunderstorm was going on, about ten miles away, and on listening on 400 metres with the set just on the oscillating point, static was so strong that at times the needle flicked round to 90° (full scale) and remained most of the time between 70° and 90°. We will say this wave-length gave an average reading of 80°.

Next the set was tuned to 200 metres, where a marked decrease in atmospherics was at once noticed. Here the needle read 30° as an average, while at 120 metres 20° was the average reading. Forty metres was the next wave-length measured, and here the needle stood at 10° most of the time, and never flickered above 15°. Again, on 20 metres, only a very slight movement of the needle occurred, about 5° at the most, while at 15 metres atmospherics were practically nil, making only a slight sound in the 'phones, and the needle stood at zero.

A return was then made to 400 metres and the whole process gone through again in order to check the former readings. Although these measurements are only rough they serve to show how immune the lower waves are from the greatest enemy of wireless —static.

One other interesting point: some few weeks ago I was working G.2MX on a Sunday night, atmospherics at this end being nil, not even a distant crash was heard. Greatly to my surprise 2MX asked for a report, and reported static as "terrific" at his end! Considering the distance between 2MX and myself is only about 35 miles, air-line, I think the above is very strange. That static conditions can be local is something new to me, for some text books tell us that a lot of the Xs we hear originate in Africa !

F. WALKER.
(5 AX).

Crowmarsh,
Wallingford.

A Standard Report-Card.

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

SIR,—I note in the current issue of E.W. & W.E. Mr. Coode's article "A Standard Report-Card." With the idea of standardisation in view I have lately had produced a batch of cards, a sample of which I enclose. It was compiled after con-

61 BURLINGTON GARDENS, BAYSWATER, W.2.

To Radio.................. Sig Rcd .... G.M.T.................. Calling / Working } ....

QRK .... QSB.............. QRH.............. QSS.............. QRB..............miles

QRN.................. QRM.................. Modulation..................

REMARKS :—

TRANSMITTER.	T&R RSGB IARU	RECEIVER.
Type..................	LONDON	
QRH.......Rad..........	G2GO	Type..................
Input..................	ENGLAND	..........V..........

Aerial.................. Earth.................. CPSE..................

Times of Working	QRH	PSED to QSO Pse. QSL Best 73's O M. Date.................. ....Operator 2GO

The specimen standard card referred to below.

sultation with several brother amateurs, and produced in its present form as most nearly filling the requirements of a standard card.

The production price, as matters now stand, is, of course, comparatively high, but if the cards were produced in large quantities, they would, I think, work out very cheaply.

The ideal aimed at was to produce a card which not only would furnish the receiver with all the information necessary, without being overloaded, but also in layout and colour would be sufficiently distinctive to differentiate it from advertisement cards, order cards, etc.

Moreover the card would lend itself well to index, a means of reference I see Mr. Coode suggests.

The idea of duplicate report-cards has the disadvantage, I think, of involving the use of blue leaf on the card to be sent. Everyone knows how difficult this usually is to read.

If, with your kind help, I could get some idea of how this card meets the requirements of the amateur fraternity as a whole, I should be very pleased.

I hope Mr. Coode will forgive me criticising his layout in general, but I think that popular feeling would be for something more distinctive.

I have enclosed a standard specimen card and also a blank card ready for blocking in.

E. H. APPLEBY (Member T. & R. Section).

The Croft,
Wimbledon, N.W.10.

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

SIR,—With reference to Mr. M. T. Coode's article on "A Standard Report-Card" in last month's issue of E.W. & W.E. I wish to correct one or two points and to offer criticism.

In the first place it is stated that there exists in America a standard report-card. Although I have received over 700 cards from America I can find only four cases where the design of the card is used by another station, and these four designs are entirely different. The greatest number of cards I have of one design is three. This is the nearest approach to a standard I have seen. Individuality in report-cards will always exist, but there are certain generalisations that have been made. For instance, how often do we see a card of the vertical type ? I received ten of them in two years !

The horizontal type may be set out in a much neater fashion. Instead of the report on the transmission given in Mr. Coode's card : signal strength ——λ——.——fading, QRM——, ——X's ; on two lines—we may have QRK——QRH——QSB——QSS——QRM——QRN——on one line ; another line for a description of the receiver, one for the aerial, one for the counterpoise, and one, or perhaps two, for a list of the best DX stations logged, in order that the transmitter to whom the card is sent may form an idea of the efficiency of the receiver. In conclusion we have two lines for remarks.

S. K. LEWER (6LJ).

32, Gascony Avenue,
West Hampstead,
London, N.W.6.

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

SIR,—With reference to the article, "A Standard Report-Card" by M. T. Coode, I have a suggestion to make on the subject of transmissions and the identification of reports thereon.

It is that the particulars of transmissions be recorded in a book having numbered pages, a separate page being used for each transmission, which would take, as a reference, the number of the page on which it was recorded. The number would be signalled (*e.g.*, "Test No. 10") and reports asked for on that particular test. Reports when received could at once be associated with their respective transmissions, and clock uncertainties avoided.

It is thought that this would particularly assist stations having foreign range ; time and date calculations being ruled out.

H. BISHOP (6QS).

56, Upper Valley Road,
Sheffield.

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

SIR,—As a non-transmitter I have read your article on Standard Report-Cards with much interest. I have three suggestions to offer, viz. :—

(*a*) "Calling" to be bracketed with "working" (an obvious difference).

(*b*) G.M.T. to be bracketed with B.S.T. (British Summer Time) and

(*c*) The inclusion of QRH.

I think the inclusion of QRB is quite good and if a standard report-card could be published it would lead certainly to a much greater number of reports being recorded.

H. PORTEOUS KING.

107, Elgin Road,
Seven Kings, Essex.

Methods of Coupling.

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

SIR,—It has been common practice since the "low-loss" tuner came into being to use a one-turn coil in the aerial circuit loosely coupled to the secondary circuit to put the received voltage variations on the grid. This system works extremely well on the wave-band of about 80-120 metres simply because the aerial circuit was then tuned to a wave in or near this band, and the transference of energy to the secondary coil tuned to any wave in that region was perfectly satisfactory.

Now, if the aerial circuit is allowed to remain like this while the secondary is tuned to a much lower wave, say 40 or 20 metres, the signals on these lower waves are weak. This is because the aerial circuit is tuned to a wave much higher than the working wave, and there is little transference of energy. To reduce the wave-length of the aerial circuit we may, of course, introduce a small series condenser. This is fairly satisfactory, but much better signals may be obtained with the grid circuit. The aerial is simply tapped on to the grid coil a few turns above the filament lead, which is earthed, while the grid lead (from the condenser) is tapped on higher up. The position of the grid tap determines the wave-length, and the position of the aerial tap determines the coupling. The number of turns in the aerial portion is about a quarter of the number of grid turns for all waves.

At my station, by changing from the one-turn aerial coil to the grid-tap circuit, the strength of signals on the low waves (below 50 metres) was increased enormously. It is now possible for me to cut out the L.F. amplifier and hear just as many stations as with the one-turn aerial coil and the amplifier. The tuning of the grid-tap circuit is quite as simple as the old method.

S. K. LEWER.

32, Gascony Avenue,
West Hampstead,
London, N.W.6.

DX Records.

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

SIR,—I have read with interest the letter published in your correspondence page of the issue of E.W. & W.E. for August, 1925, from Mr. J. A. Partridge.

I think he is labouring under a slight misapprehension regarding the details of my letter which was published, I believe, in your previous issue. As far as I can see, the details which Mr. Partridge publishes of the working of his own station 2KF, and also 5LF, have no bearing whatever upon the transmission which I made, and which, in spite of what he says, still remains the shortest wave-length used for such long distance transmission; also it was the first transmission on ultra-short waves in daylight to be made to Australia; of course, by this I do not mean two-way working. At the same time it might prove of interest to Mr. Partridge to know that my own station was working on the very short wave-lengths for quite a considerable period before his first two-way working with NFK.

No doubt you have another odd space in your correspondence page wherein to publish this letter, and if this is available I should be pleased if you would do so, for the information of those who are not in possession of the facts of some of these transmissions.

J. H. D. RIDLEY (G5NN).

"Studley,"
106, Woodside Green,
S. Norwood, S.E.25.

Station News.

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

SIR,—Will you kindly publish in your next issue that the call letters of the Manchester Wireless Society are G6MX and that the permits covered by 2FZ, 5MT, and 5MS have been returned to the General Post Office, since when they have been re-issued. Perhaps the present holders of these three permits will notify listeners of their whereabouts through the medium of your columns. All communications for the Manchester Wireless Society and referring to tests of G6MX should be addressed to the Hon. Secretary, 66, Oxford Road, Manchester.

Station G5MB is worked by the Hon. Treasurer of the above Society from 808, Stockport Road, Longsight, Manchester.

GEO. P. EVANS, Hon. Secretary, Manchester Wireless Society.

66, Oxford Road,
Manchester.

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

SIR,—Will you kindly note that I hope to be transmitting on 45 and 90 metres in the near future, in addition to the 150-200 metre band. Maximum power 10 watts, though I generally use much less. All cards will be acknowledged.

F. M. COOPER, B.Sc. (G6PF).

22, Guest Road,
Endcliffe,
Sheffield.

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

SIR,—U2BW is now operating on 39 metres every day at 12 m. G.M.T. until 0300 G.M.T. I wish to Q.S.O. G's on 45-47 metres and 30-37 metres power input here 204 watts "S" rectified 60 cycles A.C.

U2BW will exchange a photo of station for reports on reception of signals that check with log.

I am a reader of your magazine and have not missed a copy in 3 years. Your paper is what we call a real good live wireless magazine. The technical end is very well presented and, I think, better than any we have here in the U.S.A.

Dr. A. L. WALSH (U2BW).

319, 33rd Street,
Woodcliffe on Hudson, N.J.

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

Sir,—This station is now working on 150-200 metres C.W. and phone. All Q.S.L. cards are answered and are very welcome.

With good wishes for your excellent paper,

F. Illidge (5HG).

Main Street,
Frodsham,
nr. Warrington.

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

Sir,—This Society will be greatly appreciative if you will give publicity to the fact that the Society's call sign is 2FZ and reports of reception should be sent to E. Butterworth, Esq., B.Sc., A.Inst.P.. 102 Grenville Street, Stockport.

Jas. Hudson (Publicity Secretary),

Radio Experimental Society of Manchester.
1, Dalton Street,
Hulme, Manchester.

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

Sir,—It may be of interest to you that the P.M.G. has granted me a transmitting licence. My call letters are 6CT, power 10 watts, wave 150-200 metres.

I hope to be on the ether very shortly and will welcome all reports.

G. S. Aitchison.

" Glenshee,"
58, Mildred Avenue,
Watford, Herts.

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

Sir,—The call sign 2WK now replaces my old call sign 1XM and I will be glad to have reports of my transmissions.

Power, 10 watts: wave-lengths, 8, 90 and 150 metres.

W. A. Hayes.

" Moyallon,"
Portadown,
Ulster.

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

Sir,—We beg to inform you that the call sign 5VR has been allotted to this company. Experimental transmission will shortly commence on wave-lengths of 23, 45 and 90 metres. Reports of the reception will be greatly appreciated and acknowledged and times of special tests will be sent to anyone on request.

We should esteem it a favour if you would insert a note to this effect in your journal.

H. Ruband.

The Edison Swan Electric Co., Ltd.,
123-5, Queen Victoria Street,
London, E.C.4.

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

Sir,—Please note that I have a licence for an artificial aerial transmitter at the address below, call sign 2BBQ.

E. H. Capel.

32, College Road,
Harrow.

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

Sir,—The following may be of interest to some of your readers.

The call sign 6IZ has now been allotted to me. Input up to 10 watts; wave-length 90 metres. Reports on transmissions will be very welcome and all Q.S.L. cards answered by return.

Edward G. Ingram.

18, Victoria Street,
Aberdeen.

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

Sir,—I should be pleased if you would publish the fact that the call sign 6YC has been allotted to me.

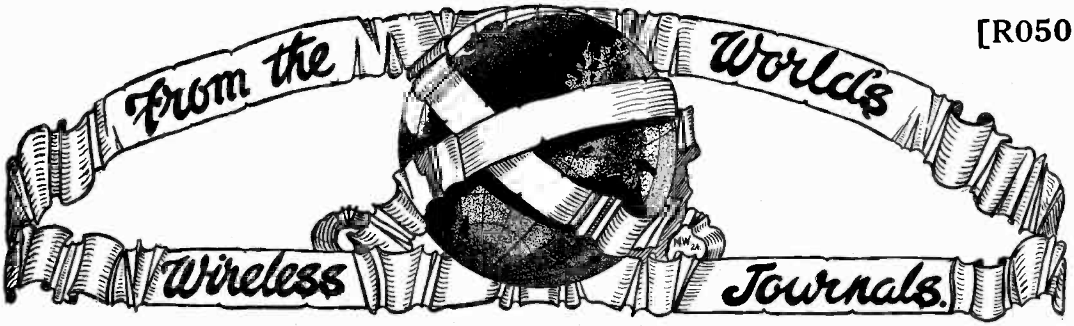
The power employed is 10 watts, C.W., on wave-lengths of 150-200, 90, 45 and 23 metres. Reports will be welcomed, and Q.S.L's. acknowledged.

Wishing your excellent journal every success.

J. Roberts.

Fern Bank,
Endcliffe Rise Road,
Sheffield.

[R050



R100.—GENERAL PRINCIPLES AND THEORY.

R113.4.—Radio Propagation.—G. W. de Tunzelman (*Electn.*, 17th July, 1925).

Eccles showed mathematically in 1912 that the presence of ions in the upper atmosphere would tend to bend horizontal waves downwards. Larmor has elaborated this theory recently. Practical observations suggest a greater complexity than that indicated by Larmor's theory. It is suggested that the ions exert a selective action on waves corresponding to various frequencies. If a simple periodic force be exerted upon an ion it will execute a free oscillation together with a forced oscillation. The component velocities become very large at a certain frequency which is a given function of the earth's magnetic field, the electric charge and mass of the ion and the velocity of wave propagation. By actual insertion of known values for these quantities a value for this critical frequency obtained corresponding to a wave-length of about 214. Practical experience shows that wave-lengths between 200 and 300 metres are about the worst for establishing long distance communication. Rays entering an ionised medium are resolved into two component rays which may travel at different velocities, have their planes of polarisation rotated to different extents and are bent to different extents.

R133.—Génération d'Oscillations Polyphasées au moyen de Tubes Electroniques.—Prof. R. Mesny (*Onde Elec., June*, 1925).

By connecting n triodes in an arrangement having both geometrical and electrical symmetry it is possible to generate polyphase oscillations of n phases. The particular arrangement shown in Prof. Mesny's article comprises three identical triodes whose filaments are in parallel and whose anode circuits each have similar inductances connected in " star " formation. The grid circuits are also connected in " star " and are each coupled to their respective anode circuits. Three tuning condensers may be connected "in delta" between the extremities of the anode or grid " star " accordingly as anode or grid tuning may be required. That such a circuit is capable of generating three-phase oscillations is fairly obvious and in actual practice it has been found to do so with stability. A short analysis of the emission of a three-phase field is given and the important property has been found that with a frame aerial receiver the effect of a three-phase transmission can in general only be cut out at one orientation of the frame instead of at two as is usual. Various uses for high-frequency rotating fields suggest themselves. For instance it would enable a small rotating mirror to be rotated at very high speeds in a vacuum. A method is described of using a rotating H.F. field to measure phase relations in ordinary oscillatory systems such as amplifiers, etc.

R200.—MEASUREMENTS AND STANDARDS.

R248.—A Variable Resistance for Radio Frequencies.—R. M. Wilmotte, B.A. (*Exp. W.*, Aug., 1925).

An account of the construction of a continuously variable resistance of the order of one ohm, having constant inductance, capacity and geometrical form over its range.

R300.—APPARATUS AND EQUIPMENT.

R334.—Les Phénomènes de Résistance Négative dans les Lampes a Deux Grilles.—P. Amye (*Onde. Elec.*, July, 1925).

This article deals with the use of thermionic valves having two grids. One of the earliest of such valves was the pliodynatron of Hull, which had one grid very close to the filament and another very close to the plate, a positive potential being applied to the outer grid as well as to the plate. By this means it is possible to obtain a " negative resistance" characteristic which allows oscillations to be sustained in a tuned circuit connected in the outer grid circuit. The inner grid may be used to modulate the oscillations so produced. More recently double grid valves have been used in a somewhat different manner, the inner grid being given a positive bias to reduce the " space charge " effect while the outer grid and anode are used in the usual ways for regenerative detection, etc. Some dynatron characteristics of a certain French make of double grid valve are given. Some dynatron receiving circuits are described. Owing to the space-charge grid it appears that quite low anode voltages suffice. Most of the diagrams indicate an anode voltage of about 8. It is stated that distant stations can be received on such arrangements through atmospherics which would render their reception on ordinary valves impossible. No doubt this is due to some limiter action owing to the small anode voltage, but the author has not enlarged upon this point.

R342.—MORE ABOUT THE REFLEX.—P. K. Turner (*Exp. W.*, Aug., 1925).

Concluding portion of series of articles dealing exhaustively with the principles underlying the operation of wireless receiving sets.

R376.3.—RECENT ADVANCEMENT IN LOUD SPEAKER REPRODUCTION.—Dr. J. P. Minton (*W. Age*, July, 1925).

Continuation of a series of articles on the problems of distortionless loud-speaker reproduction of broadcasting. Horn limitations in particular are dealt with. It is stated that the range of response of the average loud speaker horn is very limited, not covering more than about three octaves. The metallic sound of loud speakers in general is not due to the horn being made of metal, but to insufficient reproduction of the lower tones. A serious source of distortion is constituted by the resonant frequency peaks, inherent in practically all horns, which give undue prominence to impressed fundamental tones or harmonics of these frequencies. A striking instance is given of an experiment in which a pure sine wave current of 270 cycles was supplied to a loud speaker. A sound output oscillogram was obtained showing copious distortion, the amplitude of the second harmonic being over five times that of the fundamental and the amplitude of the fourth harmonic being nearly one and a half times that of the fundamental. As a result of experiments with horns the relatively long exponential type is preferred. Very satisfactory results have been obtained by combining two or three horns of different sizes in order to cover a large frequency range. The largest horn may have a total acoustical length of 7½ ft., while the smaller horns are of more familiar dimensions. It is said that by this means the range of reproduction has been increased to about six octaves or from 90 to 5 000 cycles.

Experiments were also made with a view to ascertaining to what extent a loud-speaker horn may be curved round for the sake of compactness without sacrificing quality. It was found that even a smooth curvature of large radius gives rise to a certain amount of reflection back towards the apex of the horn. Sharp right-angle bends are ruled out altogether.

R382.1.—THE SELF-CAPACITY OF INDUCTANCE COILS.—H. J. Barton Chapple, B.Sc. (*Exp. W.*, Aug., 1925).

Description of the results of exhaustive tests made with both commercial and experimental coils.

R384.—HENRYMÈTRES, CAPACIMÈTRES, TELLUROHMMÈTRES.—R. Barthélmy (*Onde Elec.*, June, 1925).

A description is given of some ingeniously designed instruments capable of giving direct scale readings in henries, microfarads or ohms accordingly as the instrument is designed to measure inductance, capacity or resistance. Taking the henrymeter first, this contains a small hand-driven magneto-alternator giving a few volts at 150 cycles. Across the output of this alternator is a fixed inductance of high value in series with the unknown inductance to be measured. The alternating potentials set up across the latter are rectified by a synchronous commutating rectifier on the shaft of the generator, the rectified potentials being applied to a sensitive moving-coil D.C. voltmeter. The voltmeter reading is directly proportional to the unknown inductance. If this inductance possesses ohmic resistance as well there will be an ohmic potential drop across it in addition to the reactive drop. It is shown, however, that the change of phase due to the presence of resistance upsets the synchronism at the commutating rectifier in such a manner as exactly to compensate for this resistance effect. Hence the scale deflection always indicates the inductance of the coil under measurement and is independent of its resistance. The readings are independent of the frequency but the voltage delivered by the hand-generator must be maintained at the right value. This implies turning the handle at the right speed, and in order to do this a button on the instrument is pressed and the generator handle turned at such a speed as to bring the pointer of the voltmeter to a specified mark on the scale; the button is then released on the rate of turning is maintained at the same value.

Capacity meters are constructed on very similar lines, condensers being employed in the place of the inductances in the circuit mentioned above. Here again the instrument reads the true capacity of the condenser under measurement no matter whether the dielectric is good or leaky.

Finally, a special form of ohmmeter is described. This again employs a hand-driven A.C. generator, which, however, is not directly connected to the measuring circuits but to the primary of a step-down transformer. Across the secondary of this transformer a fixed resistance and the unknown resistance are connected in series. Across the unknown resistance is shunted the rectifying commutator in series with a large fixed inductance. This commutator works off the generator shaft as in the other instruments and the rectified output operates a D.C voltmeter. The voltmeter reading is a function of the unknown resistance and may be calibrated accordingly. An advantage in this form of ohmmeter is that it may be used to measure the resistance of circuits already carrying D.C. currents or A.C. currents of a different frequency from that produced by the instrument generator. Such currents will not affect the meter reading.

R386.—FILTERS.—P. K. Turner (*Exp. W.*, August, 1925).

An account of the design of electric frequency filters. Filters may be designed to pass all currents above a certain frequency, to stop all currents above a certain frequency, to pass frequencies only within a specified limited band or to stop frequencies within a limited band. A method of calculating the requisite values of inductance and capacity for the various components of a filter to have specified electrical properties is developed. Stress is laid upon the importance of taking the actual working output load into account in designing any filter.

Some Recent Patents

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

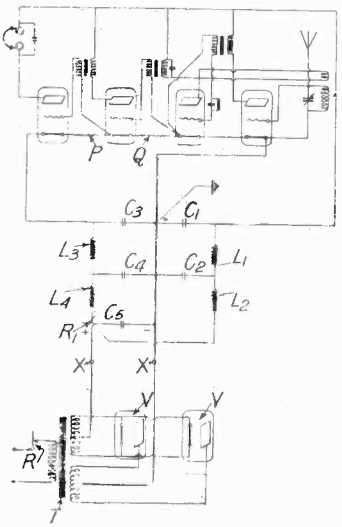
[R008

AN ALTERNATING CURRENT RECEIVER.

(*Convention date, France, 15th March, 1924. No.* 230,854.)

Yet another system for utilising alternating current for broadcast receivers is disclosed in the above British Patent, which is granted to the Société Française Radio-Electrique. The system is rather ingenious, and is one of the best which we have met, as it is adapted to be used with ordinary valves.

The alternating current supply is introduced to a transformer *T*, the primary of which is provided with a regulating rheostat *R*. The secondary consists of two centre tap windings. The low voltage winding is connected to the filaments of two rectifying valves *V*, while the high voltage winding is connected to the anodes of the rectifying valves.



The output is taken, of course, across points *XX*, *i.e.*, the centre tappings of the two windings. The output is led through a double filter consisting of two series of chokes and condensers, *L*1 *C*1, *L*2 *C*2, and *L*3 *C*3, *L*4 *C*4, *C*5. The first system is an ordinary smoothing device for the high tension supply, while the second system is for the filament supply, which is further controlled by a variable resistance *R*1. This second filter system contains enough resistance to lower the voltage to a suitable value for the filaments. The filaments, of course, are connected in series.

Additional grid bias is obtained for the last stages by the inclusion of extra resistances *P* and *Q* in the filament leads. Valves suitable for use with this circuit are, of course, of the 60 milliamp type on account of the small current delivered from the rectifier valves. Readers will probably find that experiments on these lines will prove very successful and probably afford one of the best solutions to the problem of broadcast from the experimenter's point of view.

RESISTANCE CONSTRUCTION.

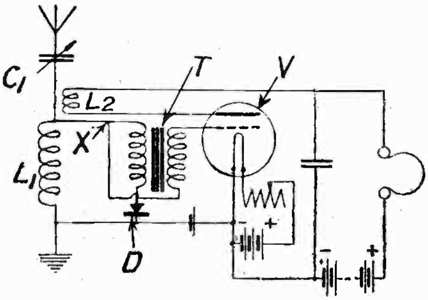
(*Convention date, Switzerland, 14th March,* 1923. *No.* 212,912.)

A rather interesting method of constructing resistances which might be suitable for use in anode circuits is described in the above British Patent by E. Hediger. A quantity of powdered carborundum is mixed with a certain amount of retort graphite, the mixture being arranged to give a suitable resistance coefficient. This mixture, to which aluminium in powdered form may be added if desired, is pressed into shape with the addition of an oxide such as quartz or lime, and heated in an oven to a temperature of 1 800 degrees C., together with an air supply as an oxidising agent. This hardening produces a recrystallisation, so that a hard mass is produced which is not brittle. The resulting mass may then be heated to red heat, so as to temper it, which renders it somewhat softer, and more conductive, and also results in a uniform resistance throughout the mass. It appears that resistances built on these lines may be exceedingly useful for amateur purposes.

A DOUBTFUL INVENTION.

(*Application date, 30th April,* 1924. *No.* 234,965.)

A rather interesting, but probably doubtful invention is described by G. W. Hale and the Radio Engineering Company, Limited, in the above British Patent. The circuit shown in the accompanying illustration is said to be a modification of an ordinary dual amplification scheme. It will be noticed that an ordinary aerial circuit *L*1 *C*1 is provided, and it is stated that first of all the valve *V* acts as a high frequency amplifier, a radio frequency potential set up across the inductance *L*1 being conveyed to the grid by means of the self capacity between the windings of an iron cored low frequency transformer *T*. It is also stated that the amplified high frequency potentials in the anode circuit of the valve are introduced into the aerial circuit by virtue of the H.F. coupling between the coil *L*2, which is untuned, and the aerial inductance *L*1. It is further stated that these amplified potentials are rectified by a crystal detector *D*, which is in series with the primary of the low frequency transformer. The secondary of this transformer is connected between the grid and the upper end of the aerial inductance, and it is stated that the valve functions as an ordinary low frequency amplifier. It is perfectly obvious that the scheme functions, and no doubt functions very well, but

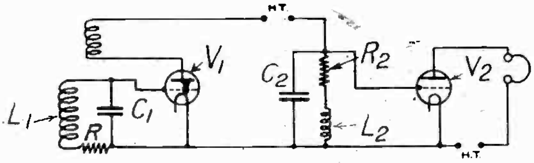


we ourselves do not consider that the above explanation is correct, the more probable explanation being as follows. The reader should notice particularly the connection of the lower end of the secondary winding of the transformer. This is shown connected at a point *X*, which happens to be the upper end of the aerial coil. It seems highly probable that the received oscillations are rectified in the first place by means of the crystal detector *D*, which is in series with the primary of the transformer, and these rectified oscillations are simply applied to the grid of the valve in the ordinary way, and the valve acts as an ordinary low frequency amplifier. So far as low frequency amplification is concerned, the connection at *X* might just as well be made to the earth in the usual manner. The fact that connection is made to the upper end of the aerial coil instead of the lower end does not affect the transformer to any extent as part of a low frequency amplifier scheme. In a modification of the system, the scheme indicated is shown preceded by an ordinary radio frequency amplifier.

NEUTRALISING DISTORTION.

(*Application date*, *6th February*, 1924. *No.* 233,417.)

A very interesting scheme, which is represented more or less diagrammatically by the accompanying illustration, is described in British Patent No. 233,417 by P. W. Willans. It is pointed out that if reaction is used to an almost unlimited extent in broadcast receivers, the sharpening of the tuning gives unequal amplification over the entire range of side bands, and results in distortion. Obviously there is a greater reduction in the amplitude of

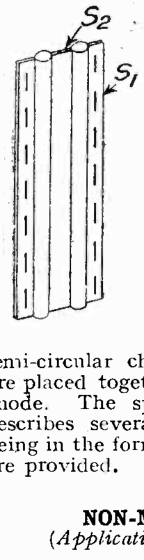


the higher side tones than in those of the lower side tones. Accordingly means are employed in the audio frequency stages which will increase the amplitude of the higher side tones, the amplitude of which has been decreased by radio frequency more than those of the lower side tones, which are comparatively unaffected by reaction. Referring to the accompanying illustration it will be seen that V_1 is a regenerative valve in which the resistance of the input circuit L_1 C_1 is represented as *R*. In the anode circuit of the regenerative valve, and across the grid filament circuit of the valve V_2, is connected a resistance R_2, and an inductance L_2, which are shunted by a by-pass condenser C_2, the impedance of which to low frequency currents can be considered as very large compared with the impedance of $R_2 L_2$. The required correction is obtained by making the ratio of R_2 to L_2 half that of the effective resistance of the circuit L_1 C_1. It is stated that the value of the inductance L_2 may be of the order of 0.2 henries, while the resistance R_2 may be of the order of 3 000 ohms for use in conjunction with a regenerative valve having an internal resistance of about 100 000 ohms. The scheme is undoubtedly very ingenious, and should prove of considerable interest to amateur experimenters.

A MULTIPLE ELECTRODE VALVE.

(*Application date*, *30th April*, 1924. *No.* 234,966.)

A form of multiple electrode construction for valves is described by E. Y. Robinson, E. J. E. Hubbard, and The Metropolitan-Vickers Electrical Company, Limited, in the above British Patent. Readers will notice the multiple electrode valve described in these columns, (see page 798) and devised by the Mullard Radio Valve Company, Limited, and S. R. Mullard, in which separate ribs of anodes and grids were placed round separate filament limbs. A very similar scheme is described in the present patent, application for which, it will be noticed, was made several months later. The accompanying illustration represents one method of constructing an anode. Two exactly similar sheets of metal S_1 and S_2 of rectangular formation are provided with two longitudinal, semi-circular channels, so that when the plates are placed together as shown, they form a double anode. The specification is very detailed, and describes several modifications, one modification being in the form of a cross, in which four channels are provided.



NON-METALLIC FILAMENTS.

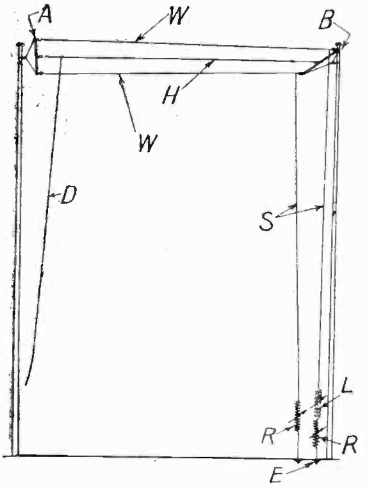
(*Application date*, *12th November*, 1923. *No.* 223,487.)

A system of non-metallic filament construction is described by W. R. Bullimore in the above British Patent. According to the invention oxides of alkalis and alkaline earth metals are mixed with an agglutinant material such as uncarbonised cellulose, which is squirted through dies, after which the resulting filament is sintered by raising it to a high temperature in an inert atmosphere. An alternative method is to heat it in a packing of graphite or magnesite, so as to exclude air and prevent injury to the filament during heating. It is stated that the advantage of this system is that the metal oxides cannot peel off the wire, and there is far less tendency for volatilisation or disintegration to occur.

INTERFERENCE FROM ELECTRIC SUPPLY.

(*Application date, 6th February*, 1924. *No.* 233,416.)

Broadcast listeners and amateur experimenters are frequently inconvenienced by interference arising from the proximity of public supply systems, or motors or lifts in action in the neighbouring buildings. A method of eliminating this trouble is claimed in British Patent No. 233,416 by T. G. Threlkeld and W. W. Butterfield. The invention is illustrated by the accompanying diagram, from which it will be seen that the scheme is associated with the actual aerial system. An ordinary aerial consisting of a horizontal portion *H* and a down lead *D* is provided in the usual manner. In close proximity to the horizontal portion of the aerial are a number of wires *W*, which are insulated at the ends *A* and *B*. The down-leads *S* from these wires are connected to earth at *E* through resistances *R* and *L*, which act as damping devices. It is stated that the normal receiving aerial has to be connected to a gauze or other earth mat, or alternatively, to counterpoises. No definite explanation is given, but it would appear that the wires *W* and down-leads *S* simply form an ordinary screen which is affected by an inductance. The object of the damping system appears to be merely to render the screening aperiodic so as not to affect the normal tuning system to any appreciable extent.



A TWISTED FILAMENT.

(*Application date*, 15*th January*, 1924. *No.* 232,320.)

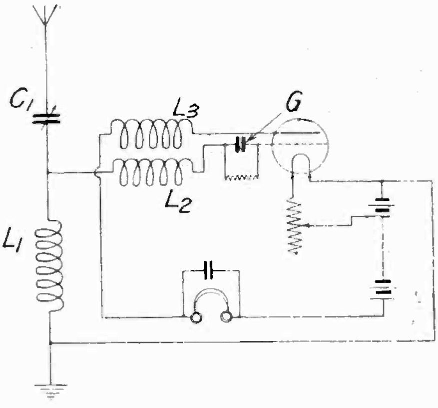
C. Seymour and H. R. Cantelo describe in the above British Patent a method of constructing a filament which consists essentially of plaited or woven wires. In the case of thick filaments, designed to give a very large emission, as is needed in high power transmission, considerable difficulty is frequently experienced in adequately supporting and keeping in tension a normally thick wire. A thick filament is somewhat liable to fracture, and is unsuitable on this account. Accordingly the filament is constructed on the lines of a cable or rope made of thin tungsten or similar material woven or braided together to form a cable. It is said that a cable of this description has greater tensile strength and has a much larger surface area than a single wire filament of the same overall diameter. We should imagine that the system would be very successful.

A REVERSE REACTION CIRCUIT.

(*Application date*, 12*th February*, 1924. *No.* 232,363.)

A rather peculiar reverse reaction circuit is described in the above British Patent by H. J. Warner and H. Tyler in British Patent No. 232,363.

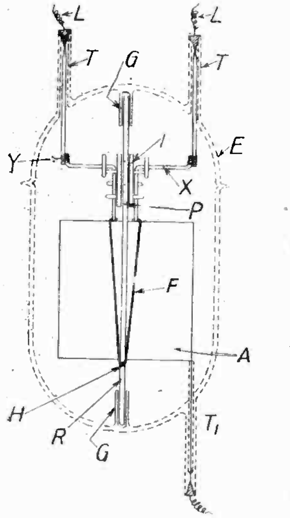
Referring to the accompanying illustration it will be seen that an ordinary tuned aerial circuit L_1 C_1 is provided, and between the grid connection (which includes a grid condenser *G* and leak, since that valve is functioning as a rectifier), and the output of the aerial inductance another inductance L_2 is included, while a third inductance L_3 in the anode circuit is coupled to the inductance L_2. It is stated that electrostatic reaction is obtained almost to the point of oscillation essentially by virtue of the capacity which exists between the electrodes of the valve. By making the grid condenser *G* of very small value the electrostatic reaction will not vary to any considerable extent if the coils L_3 and L_2 are moved. The coil L_3 is arranged so that reverse electromagnetic reaction is obtained. It is stated that by adopting this circuit very much louder and purer signals are obtained, but we do not see why this should be the case. The amount of regenerative amplification obtained with any given valve is determined by the amount of positive reaction which exists in the circuit, and since we have here a balance between positive electrostatic reaction and negative electromagnetic reaction, we fail to see why the arrangement should give better results. It appears that it might be due to the fact that the circuit is better balanced, and that there is no tendency for sustained oscillations to occur until the maximum amount of positive reaction has been introduced; in other words, the tendency for overlap exists. The circuit, however, should prove of considerable interest to experimenters.



SUPPORTING THE FILAMENT.

(*Application date, 1st January,* 1924. *No.* 231,580.)

A method of supporting the filament is described by C. Seymour and H. G. Hughes. Essentially the invention consists in keeping the filament taut by supporting it on a metal rod extending throughout the end of the valve. The accompanying illustration shows the invention as applied to a two-electrode rectifier valve suitable for high-power work. The envelope *E* may be of silica and is provided at each end with two guide tubes *G*, which hold the supporting rod in position. The rod is provided with a metal hole or slot *H*, to which a hairpin filament *F* is attached. The rod also carries a special form of insulator *I*, which is pinned to the rod at *P*. The ends of the filament are attached to end-pieces *X*, which are bound at *Y* to the filament leads *L*, which are sealed into tubes *T*. The anode is shown at *A*, and the lead is taken through another tube *T*1, which is sealed in in the normal manner.



PROTECTING COATED FILAMENTS.

(*Application date, 7th March,* 1924. *No.* 234,565.)

A very interesting method of protecting coated filaments is described by E. Y. Robinson and Metropolitan-Vickers Electrical Company, Limited, in the above British Patent. It is stated that although a coated filament is comparatively robust and can be handled without special care, it is liable to deteriorate owing to exposure to the atmosphere. The well-known oxide coating combines readily with water or carbon dioxide to form hydroxides and carbonates which are liable to become detached from the filament and ruin the coating. Accordingly coated filaments have previously been kept away from the atmosphere, and the process of assembling and initial exhaustion has to be carried out very quickly. This difficulty is obviated by covering the coated filament with an impervious protecting medium such as an organic gum. One method is to dip the coated filament into a solution of nitro-cellulose in amyl acetate. When the protected filament is sealed into the valve the coating can be flashed off in the usual way. We should imagine that the scheme would be quite successful in practice.

A MULLARD MULTIPLE ELECTRODE VALVE.

(*Application date, 15th January,* 1924. *No.* 232,318.)

A rather interesting form of multiple electrode valve is described by the Mullard Radio Valve Company, Limited, and S. R. Mullard, M.B.E., M.I.R.E., in the above British Patent. The invention relates particularly to valves employing looped or hairpin type filaments, and consists essentially in providing each filament with its own group of associated electrodes. The simplest embodiment of the invention is illustrated by accompanying diagram, in which the valve shown employs a hairpin type of filament. It will be seen that the electrodes are mounted on a frame which consists of two insulating cross bars *X*, and two uprights *U*, which also support the filament at *Y*. The cross members *X* carry the two grids *G* and the two anodes *A*. The leads from the electrodes are taken out in the usual way through a foot *F*, and the valve is provided with the usual base and plugs. A similar construction is used for a valve containing three or four sets of electrodes. It is stated that the advantage of a construction of this type is that the electrode path between each limb of the cathode and its respective anode is shortened as much as possible, and has a much larger cross section than valves having a looped filament and a single anode enclosing the whole of it. It is stated that for this reason the amplification factor and the electrical characteristics of the valve are very considerably improved. The valve is certainly extremely novel, and it would be very interesting to test one not only on signals, but to measure its various inter-electrode capacities.